Watershed Ecosystems Project | Community Report

Assessing Critical Linkages and Interactions in the sqʷʔa (Peachland Creek) Community Watershed

October 28, 2025

This report provides an interim update on the ongoing research in the sqʷʔa (Peachland Creek) Community Watershed being conducted through a partnership between UBC Okanagan, syilx community representatives and the District of Peachland.

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Contents

Acknowledgements

We respectfully acknowledge the syilx Okanagan Nation and their peoples, in whose traditional, ancestral, unceded territory the sqʷʔa (Peachland Creek) watershed and this research are situated.

We respectfully acknowledge, and extend our gratitude to, syilx traditional knowledge keepers and community representatives, and the District of Peachland operations staff and municipal council along with community members and organizations for their continued partnership and support. Thank you for your guidance, expertise and investment in this initiative!

Our team is grateful for the financial support from UBC Okanagan's Eminence Fund program, the UBC Community-University Engagement Support Fund, the UBC Okanagan Watershed Enhancement Fund, Barry Silver and Ethel Johnston, and financial and in-kind contributions from the District of Peachland, syilx community partners and the UBC Okanagan Department of Earth and Environmental Sciences and Irving K. Barber Faculty of Science. We also thank Laura Brandes at the University of Victoria's Centre for Global Studies, POLIS Water Sustainability Project for her thoughtful review of the initial draft of this report.

The sqʷʔa (Peachland Creek) watershed community has been so welcoming and supportive – thank you for your ongoing pivotal contributions to this initiative, and for setting a strong foundation from which we can continue to grow and advance watershed ecosystem science! Our goal is for this research to be of value to the community, and ultimately, to help inform policy. We look forward to continuing to engage with the community as we co-create our next steps together.

Introduction

The Watershed Ecosystems Project

Who Are We?

The Watershed Ecosystems Project (WEP) is an interdisciplinary, community-engaged research initiative assessing critical linkages and interactions in the sqʷʔa (Peachland Creek) watershed to develop and advance watershed ecosystem-based science and governance knowledge. This work centers around the concept of watershed ecosystem science, extending beyond the inclusion of just surface and groundwater considerations to include recognition of the interconnectedness of all critical ecological and social processes in water research and management paradigms. Indigenous syilx rights, knowledge, and water law are integral to this place-based research.

This initiative is led by a team of researchers at UBC Okanagan (UBCO) in partnership with syilx communities and the District of Peachland. The WEP team includes hydrologists (UBCO and the Ministry of Forests), syilx researchers, ecologists, engineers, and social scientists. Our goal is to develop and advance watershed ecosystem-based science and governance knowledge through interdisciplinary and community-engaged research.

Our values:

- We respect Indigenous syilx rights, knowledge, and water law. We acknowledge syilx knowledge as empirical, evidence-based, verifiable and modern science. We are committed to working in a manner that reflects the 5Rs of Indigenous-engaged research: Relevance, Respect, Reciprocity, Relationships, and Responsibility.
- We conduct our research on a scale that is relevant to watershed systems and processes. Recognizing the critical linkages within an ecosystem, and the many complexities that communities face under siloed frameworks for watershed management, we conduct our research at a watershed ecosystem scale.
- Community engagement is central to our work as we strive to better understand these complexities and develop research programs to address the community interests, concerns and needs.

Our research seeks to:

- Understand community and ecological values to inform better decision making and to find solutions to these challenges.
- Advance the field of watershed ecosystem science.

What is a Watershed Ecosystem Approach?

A watershed ecosystem approach manages interactions among critical processes and values (e.g., biodiversity, Indigenous values, aquatic functions, water, timber) under a changing environment in a watershed. Understanding these processes and their linkages can inform sound management decisions and approaches to governance.

The WEP's focus is to test the watershed ecosystem approach for assessing and managing interactions among critical watershed processes and values, including topics such as forest disturbance and cumulative effects, trade-offs and resilience, inclusion of Indigenous values in watershed governance and climate change adaptation.

Testing the watershed ecosystems approach:

- **Assess** cumulative effects of forest disturbance and climate change on water resources, sediments and nutrients.
- **Quantify** the risks of cumulative effects to downstream community water supply and environmental hazards, fish habitat/population, and Indigenous values.
- **Integrate** these key processes and linkages to assess the trade-offs from various management and climate change scenarios with an integrated model.
- **Explore** a new watershed governance model addressing critical processes and their interactions with explicit consideration of Indigenous values.

Research Themes, Activities and Progress

Research Themes

The WEP's research activities encompass the following six distinct, but very interconnected, themes:

- **Hydrology:** An exploration of the cumulative effects of forest disturbance, land use, and climate change on water quantity and quality.
- **Urban Water:** Risk assessment of the cumulative effects and other stressors on downstream community (water supply and environmental hazards).
- **Fish:** Risk assessment of the cumulative effects and other stressors to fish habitat and population.
- **Syilx Knowledge:** Risk assessment of the cumulative effects and other stressors on Indigenous Okanagan Syilx values.
- **Integrated Modeling**: Integrated modelling on all above interactions under a changing environment.
- **Governance:** Development of a locally inclusive, socio-ecological watershed governance model and assessment of the enabling conditions for its practical implementation.

Research Activities by Theme

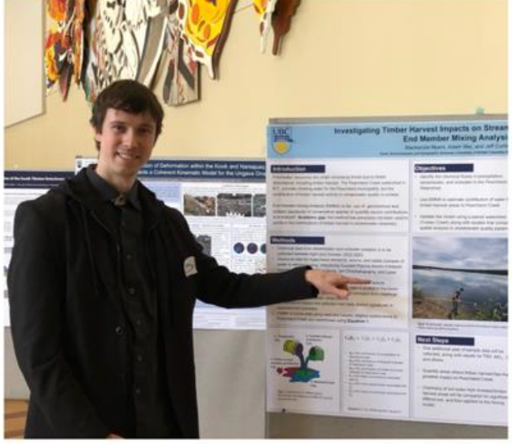
Hydrology	**Research Activity 1:** Impacts of Timber Harvest on Hydrological Processes.
	Research Activity 2: Interacting Effects of Forest Disturbance and Climate Variability on Peak and Low Flows.
Urban Water	**Research Activity 3:** Urban Water: Risk Assessment Framework for the Downstream Community.
Fish	**Research Activity 4:** Predicting the Effects of Climate Change on Spawn Start Time.
Syilx Knowledge	**Research Activity 5:** Risk Assessment of the Cumulative Effects and Other Stressors on Indigenous Okanagan Syilx Values.
Integrated Modeling	**Research Activity 6:** Integrated Modelling: Integrated, Whole-of-Ecosystem Approaches to Understanding Impacts of Cumulative Effects.
Governance	**Research Activity 7:** Developing a Watershed Co-Governance Model for sqʷʔa (Peachland Creek).

Research Progress

This report summarizes the key findings to date for each research activity, including:

- An introduction to the researchers;
- A list of the main themes and objectives;
- Key findings to date;
- The research timeline and status;
- Next Steps; and
- Comments on any gaps in understanding.

At the end of October 2025, the WEP will have completed its first phase of operation. While some research teams have presented their final results, others are working with longer timeframes and are still in development. We will continue to provide updates over time.



Theme 1: Hydrology

An exploration of the cumulative effects of forest disturbance, land use and climate change on water quantity and quality.

Hydrological processes involve studying the quantity, quality, and movement of water on the surface, atmosphere, and subsurface of the earth. Water and forests are invariably linked, and shape ecosystems at both large and small scales, including the biodiversity of terrestrial and aquatic life, climate, and water availability.

Understanding the movement of water in the environment can inform responsible and sustainable land use planning and provide information about potential risks to the environment (and ultimately to humans!) that coincide with anthropogenic and natural forest disturbances such as development, wildfires, and timber harvest.

The cumulative effects on water quantity and quality under current and future conditions will be quantified using a hydrological model capable of simulating the quality and quantity of surface and groundwater and predicting the environmental impact of land use, land management practices, and climate change. Results will support other research themes.

Meet the Hydrology Research Team

Dr. Adam Wei – Watershed Ecosystems Project Team Lead

Adam Wei, Watershed Ecosystems Project Team Lead, is a professor of forest hydrology and watershed management in the Department of Earth and Environmental Sciences. He is also coordinator of the IUFRO (International Union of Forest Research Organization) Task Force on Forests and Water Interactions in a Changing Environment, and associate editor of Ecohydrology. His major research interests include forest disturbance and hydrological responses in large watersheds and landscapes, watershed ecosystem analysis, and climate change impact assessment. He has published about 200 scientific papers in peer-reviewed journals including Science, Nature Communications etc.

Jinyu Hui

Before starting her PhD program at UBC Okanagan in May 2021, Jinyu graduated from Xi'an Jiaotong University in China in 2020 with an MSc and in 2016 with a BSc.
Her research interest is how climate and forest cumulatively affect hydrological processes. She has benefited from the wide gamut of XJTU's syllabi content in her undergraduate studies, which helped her gain comprehensive knowledge in the core area of environmental science. Her masters focused on eco-hydrological processes.

For her PhD study, she will try to analyze the relative contributions of climate and forest to hydrological extremes. She is skilled at using eco-hydrological models as well as processing multi-source data (e.g., remote sensing, model outputs, NetCDF file, etc.) by using multiple scientific tools, such as R, C++, SPSS, and ArcGIS.

Mackenzie Myers

Mackenzie is a Masters student in the Department of Earth and Environmental Sciences. Mackenzie was born and raised in Kelowna, BC. Having graduated with a BSc in Earth and Environmental Sciences at UBC Okanagan, he has returned for his MSc program. His research focuses on watershed hydrological processes. Supervised by Dr. Adam Wei and Dr. Jeff Curtis, Mackenzie is using isotopes and geochemistry to understand flow paths, residence time, and interactions between surface *siwɬkʷ* (water) and groundwater in the *sqʷʔa* (Peachland Creek) watershed. An improved understanding of *sqʷʔa* watershed's hydrological processes can support integrated watershed modelling and other water-related assessments.

Research Activity 1: Impacts of Timber Harvest on Hydrological Processes

Researchers: Dr. Adam Wei and Mackenzie Myers

Main Themes and Objectives

The main objectives of this research were to:

- Investigate forest disturbance impacts and watershed properties such as slope, area, and elevation on hydrological processes including flow pathways, mean transit times, and young water fraction in the sqʷʔa (Peachland Creek) Community Watershed.
- Understand what factors lead to differences in hydrological response at the detailed sub-watershed scale.

This project involved the sampling of stream water across various sub-basins in the sqʷʔa (Peachland Creek) watershed (Figure 1.) and analyzing the chemical and isotopic (different molecular weights) content of water towards assessing the flow pathways water takes, and how quickly water is flowing from watershed entry to the stream. Studying these aspects provides a practical way of understanding hydrological information without direct measurements of discharge, which is useful in areas that are difficult to access and monitor (Figure 2).

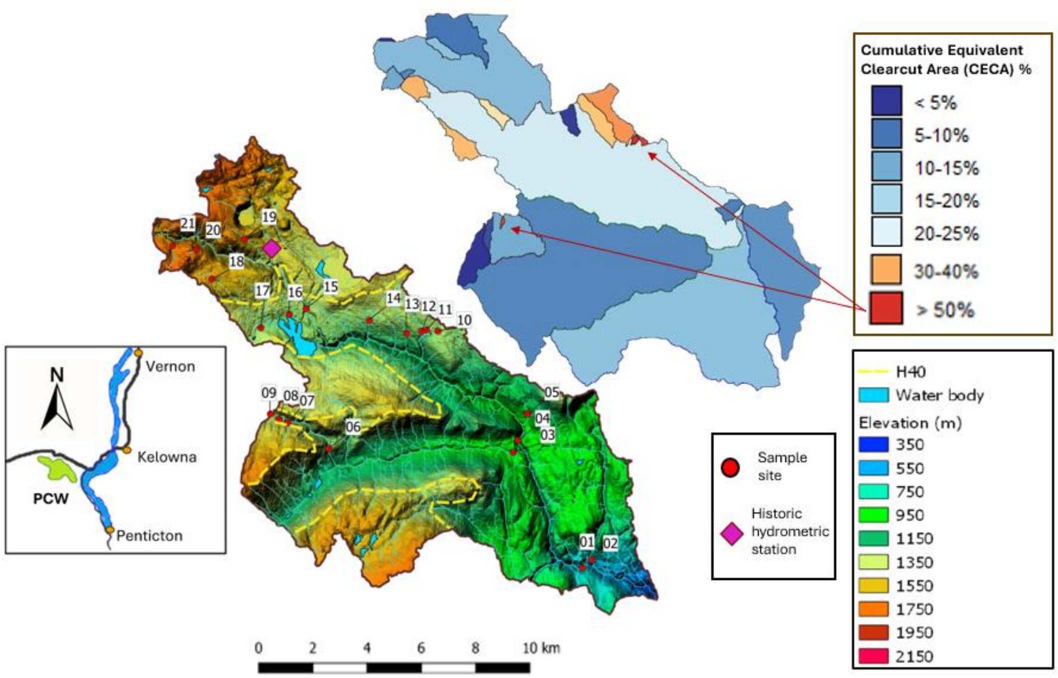


Figure 1. Map of sqʷʔa (Peachland Creek) Watershed and the sampled sub-basins.

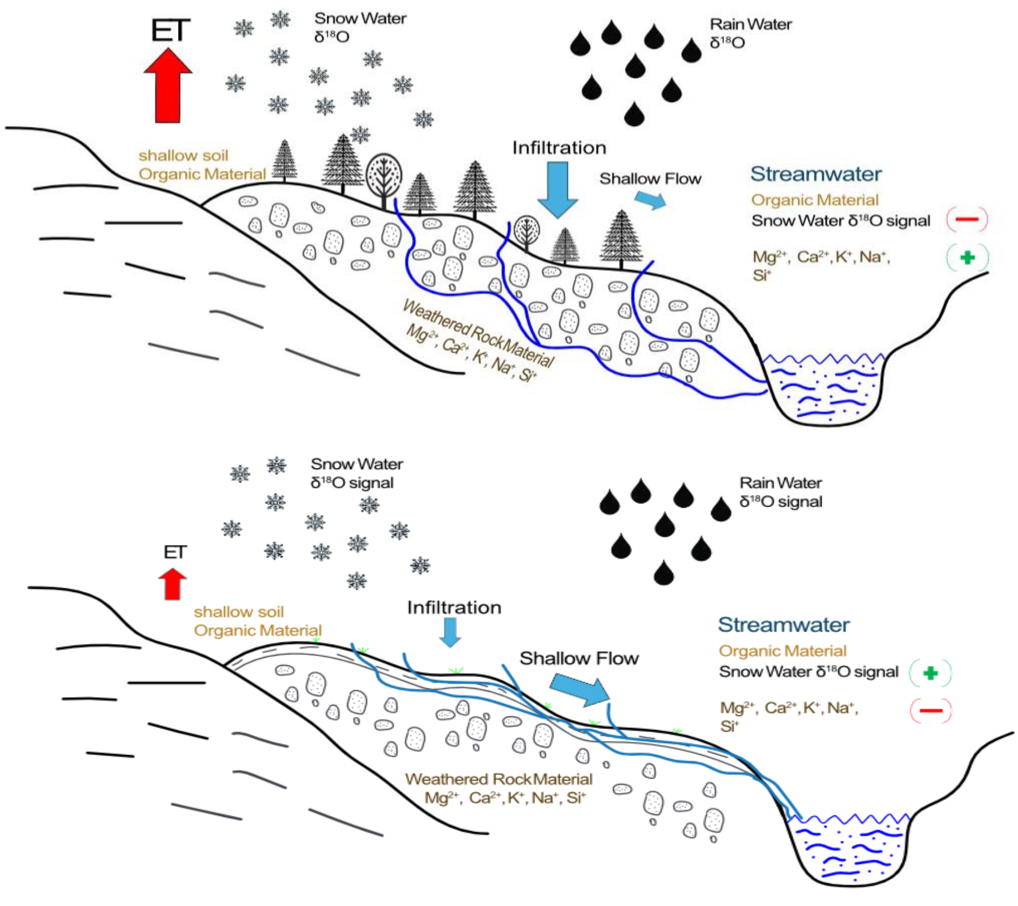


Figure 2. Hypothetical geochemical responses under conditions of longer mean transit time, lower young water fraction, and a greater proportion of subsurface flow (top) vs shorter mean transit time, increased young water fraction, and shallower flow pathways (bottom). ET refers to evapotranspiration, while (+) and (-) symbols refer to relative abundance of ions present in streamwater, or water isotope enrichment or depletion respectively.

Key Findings

This study has provided quantification of different water source components based on the conservative properties of ions including magnesium, sodium, calcium, and potassium content of streamwater. A model was created that assigned different water components including shallow flow and subsurface flow based on the ion quantities. The results demonstrate a slight trend of snowmelt (shallow flow) component increase as disturbance intensifies, and more variability in ion concentrations in sub-watersheds of relatively less disturbance, possibly due to the variety of flow pathways and speeds that water may travel when disturbance is limited. This implies a promotion of shallow preferential flow as disturbance intensifies, though this trend varies depending on local watershed properties such as elevation, slope, and soil drainage. A comparison of mean transit time, young water fraction, and model-derived snow water proportions across different forest disturbance intensities are provided in Figure 3.

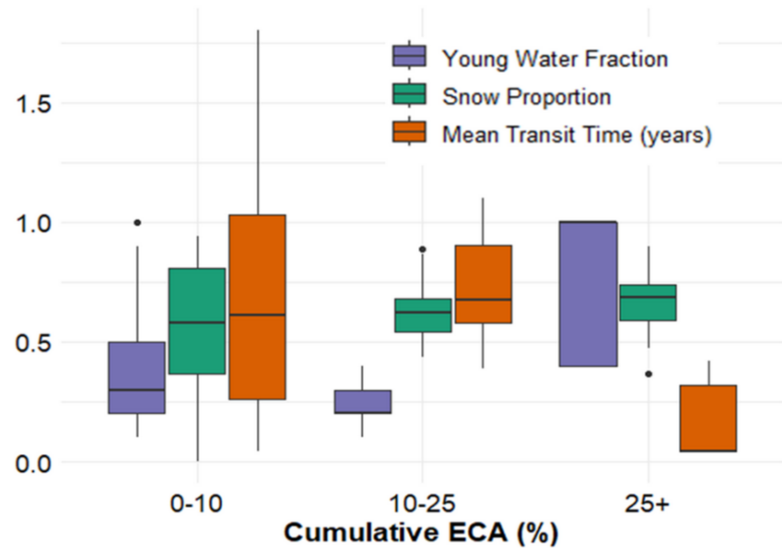


Figure 3. Boxplot of hydrological process changes for different ranges of Cumulative Equivalent Clearcut Area (ECA), which is a metric of forest disturbance accounting for hydrological recovery as the forest regrows after disturbance events.

Steeper slopes and well-drained soils were also found to strongly influence how quickly water moves through the watershed. Sub-watersheds with steeper slopes tended to have longer mean transit times (slower water movement) and a smaller proportion of young water fraction (older water). Similarly, areas with better soil drainage also showed a lower young-water fraction. Together, these results suggest that steep and well-drained areas may store more water and release it more gradually, leading to slower, less "flashy" flow.

The current state of analysis suggests chemical heterogeneity between some sub-watersheds, which implies that assumptions about the conservative (time invariance and non-reacting) nature of chemical tracers cannot be applied to all sub-watersheds in the sqʷʔa (Peachland Creek) watershed. This study challenges common research assumptions that assume watershed-scale homogeneity, providing evidence that detailed sub-watershed-scale studies are necessary towards understanding watershed-scale processes.

Further research may explore how these changes impact ecosystems specific to the watershed.

Research Timeline and Next Steps

- Mackenzie Myers' M.Sc. thesis is available on the UBC thesis database for public viewing: Assessing impacts of forest disturbance on hydrological processes in Peachland Creek Community Watershed using geochemical approaches.
- Mackenzie intends to pursue the publication of a research paper in the coming months.

Anticipated Gaps in Understanding

- This study compares watershed sub-basins post-harvest. It does not apply tests to the watershed before timber harvest treatment, and therefore statistical capabilities of this project are limited.

Research Activity 2: Interacting Effects of Forest Disturbance and Climate Variability on Peak and Low Flows

Researchers: Dr. Adam Wei and Jinyu Hui

Main Themes and Objectives

The main objectives of this research are to:

- Investigate the effects of historical climate variability and forest disturbance on peak flows and low flows; and
- Predict hydrological responses under future combined climate-forest change scenarios.

Key Findings

Climate change and forest disturbance, such as logging, fire, and mountain pine beetle infestation (MPB), are regarded as two major drivers affecting streamflow in forested watersheds. Peak and low flows are closely linked to the occurrence of floods and droughts, which can pose significant risks to water supply, environmental stability, aquatic habitats, local economies, and Indigenous values. When extreme hydrological events such as major floods or droughts occur, whether climate or human disturbance (i.e., timber harvesting) should be responsible or blamed for is often debated. Consequently, quantitatively determining the impacts of these two factors to peak and low flows is important for effective watershed management. Moreover, assessing hydrological responses under a variety of possible future scenarios is essential for developing adaptive management strategies.

1. Watershed characteristics and historic forest disturbance in the sqʷʔa (Peachland Creek) watershed

The sqʷʔa (Peachland Creek) watershed covers an area of 147.57 km² with an average elevation of 1,221 m, ranging from 254 m to 1,836 m. Over the historical period from 1984 to 2024, the long-term average annual precipitation in the sqʷʔa (Peachland Creek) watershed was 617 mm, with a mean annual temperature of 4.8°C. According to recorded data (1971–1982), the multi-year average annual streamflow depth was 87.2 mm, while the mean maximum daily streamflow depth was 1.7 mm, with peak flows driven by snowmelt typically occurring in May.

In this study, we used the cumulative equivalent clear-cut area (CECA) to indicate dynamics of forest disturbance, which incorporates all types of disturbances and vegetation recovery across both spatial and temporal scales (Winkler & Boon, 2017). The sqʷʔa (Peachland Creek) watershed has experienced multiple types of forest disturbance (Table 1 and Figure 1). Since 1970, logging has been the primary disturbance, with the highest recorded CECA reaching 18.1%. A wildfire in 2023 resulted in an additional CECA of 9.2%. Since 2000, the watershed has suffered Mountain Pine Beetle (MPB) outbreaks. However, due to the relatively high survival rate of affected trees, the CECA attributed to MPB infestations was limited to 2.5%.

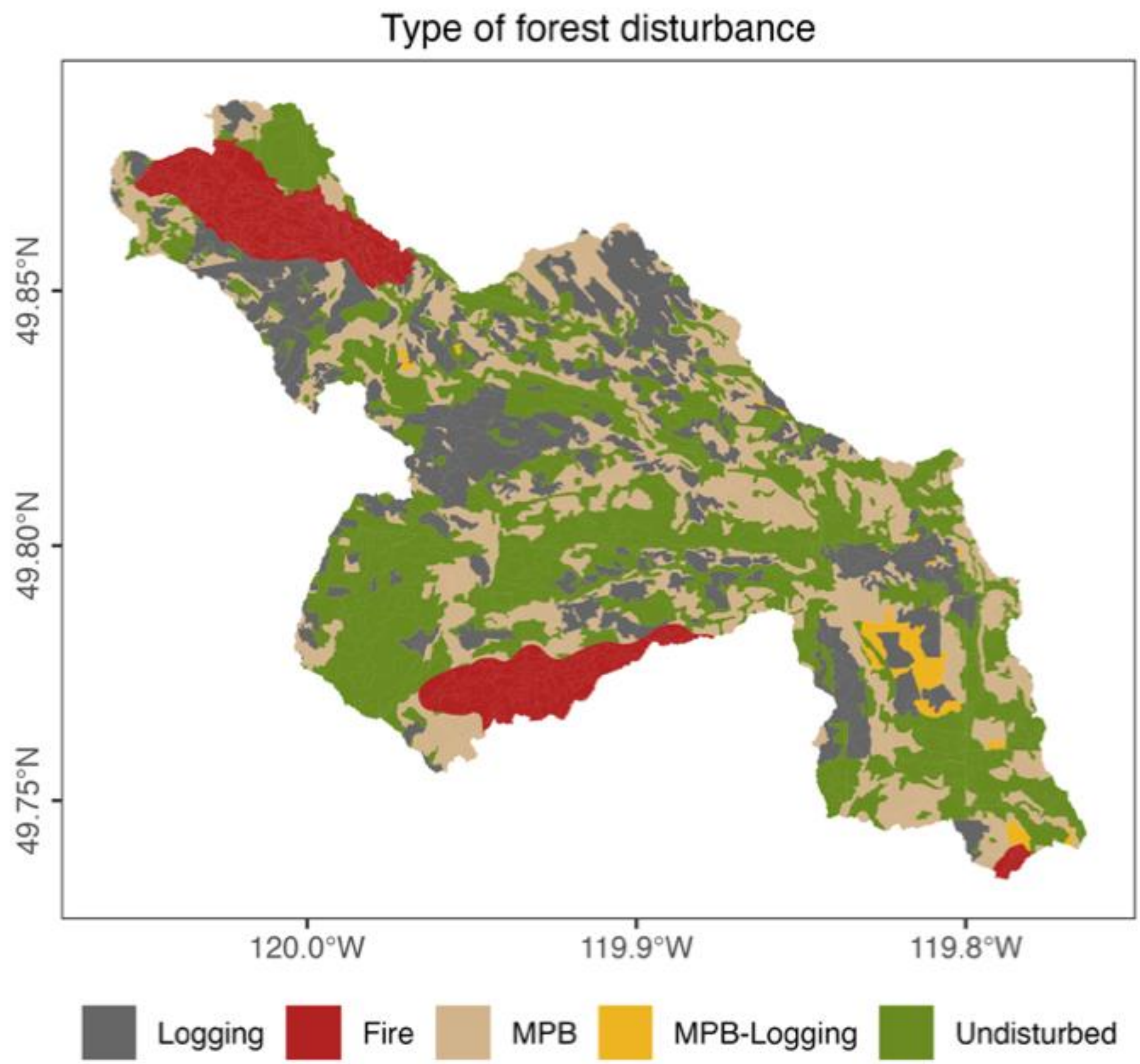


Figure 1 Spatial distribution of forest disturbances in the sqʷʔa (Peachland Creek) watershed

Period	CECA (%)				
	Logging	Fire	MPB	MPB-Logging	Total CECA
1970s	2.63	0	0	0	2.63
1980s	2.70	0	0	0	2.70
1990s	9.86	0	0	0	9.88
2000s	9.86	0	0.55	0.04	10.03
2010s	18.21	0.21	2.18	0.26	20.87
2020s	18.09	9.16	2.50	0.25	28.81

Table 1 Annual cumulative equivalent clear-cut area (CECA) due to multiple forest disturbance types across time periods in the sqʷʔa (Peachland Creek) watershed

2. Historical hydrological responses – relative contributions of climate and forest disturbance to peak and low flows

In this project, we focus on key peak- and low-flow variables, including annual maximum daily snowmelt streamflow (Qmax) and its corresponding timing (Qmaxdate), as well as the monthly streamflow from April to September. We use the multi-year average of each streamflow metric as the baseline, with any yearly variations from this average reflecting how the total combined effects of both drivers on the selected monthly streamflow.

Due to the limited hydrological data in the sqʷʔa (Peachland Creek) watershed, the hydrological responses are based on extrapolations from the results of three neighboring watersheds, including 241 Creek in Upper Penticton watershed, Camp Creek, and Trepanier Creek (Table 2). There are some similarities in terms of climate, topography and vegetation between the sqʷʔa (Peachland Creek) watershed and the three neighboring watersheds. We used an explainable artificial intelligence approach to assess how streamflow in these three watersheds responds to climate change and forest disturbances. Then, we applied a weighted algorithm based on the proportion of area at different elevations to calculate the estimated hydrological responses of the sqʷʔa (Peachland Creek) watershed. Because the intensities of forest disturbances (represented by CECA) are different across the watersheds, we only considered significant impacts and then estimated hydrological responses per unit change in forest disturbance.

Based on the above-mentioned analyses and extrapolation, we derived the following major results in the sqʷʔa (Peachland Creek) watershed (also shown in Figure 2):

- Climate-related factors were the primary drivers of peak flows: increased magnitude and advanced snowmelt timing (during April and May);
- Forest disturbance had limited impacts on peak lows, but it significantly increased monthly summer low flows (July to September), and
- Amplifying effects are detected on peak-flow timing, with increased temperature and forest disturbance jointly advancing it.

Watersheds	Slope (°)	Area (km^2)	Elevation-mean (m)	Elevation-min (m)	Elevation-max (m)	CECA (%)	CECA Range (%)
241	10.10	5.14	1757.68	1601.00	2023.00	33.97	48.94
Camp	13.52	35.75	1437.89	976.13	1925.29	36.75	13.26
Trepanier	14.10	183.52	1322.62	588.73	1908.05	4.78	12.78
Peachland	12.07	147.46	1220.57	354.00	1836.00	13.89	20.09

Table 2 Topography and forest disturbance in the sqʷʔa (Peachland Creek) watershed and its neighboring watersheds

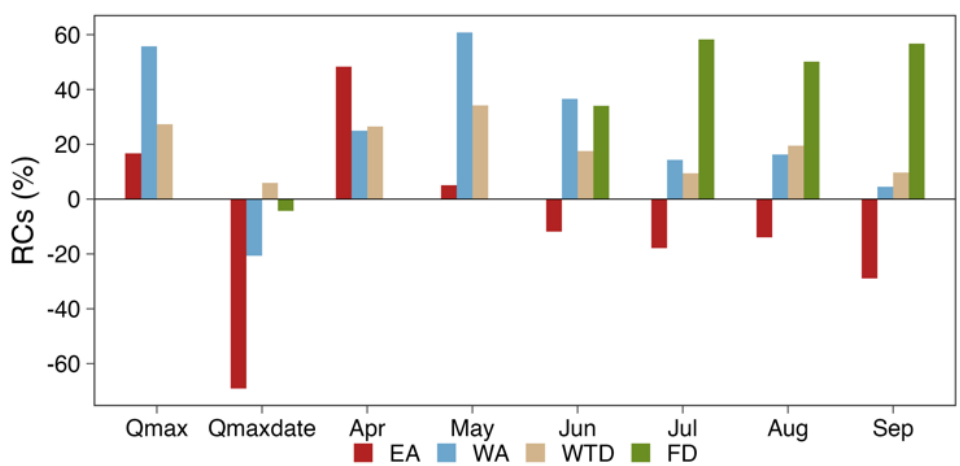


Figure 2 Relative contributions (RCs%) of climate features and forest disturbance during historical period. Note: EA is energy amount, WA is water amount, WTD is temporal distribution of water, and FD refers to forest disturbance. A positive value indicates the driver increases magnitude or delays Qmaxdate timing, and vice versa.

3. Future predictions on hydrological responses under climate change and forest disturbance scenarios

Based on historical data, the climate-forest disturbance-streamflow relationships were established and interpreted by explainable Artificial Intelligence, and these relationships were then used to predict the hydrological responses with various future climate change and forest disturbance scenarios. For forest disturbance scenarios, we selected 0%, 25%, 50% and 75%. While 50% and 75% of CECA represent severe forest disturbance levels, 0% and 25% reflect either low-level disturbance or forest recovery. To define climate change scenarios, we incorporated widely used future climate datasets which are presented below.

3.1 Future trends of temperature and precipitation

Before making future predictions, we assessed temperature and precipitation trends in the sqʷʔa (Peachland Creek) watershed at both annual and seasonal scales until the end of the century (2100) (Figure 3). The results indicate a consistent rise in temperatures across all emission pathways, with the most pronounced warming occurring during summer. Alongside this warming trend, annual precipitation levels are projected to increase, particularly under medium and high emission pathways. However, precipitation trends are different across seasons, with most of the increase occurring in autumn and winter, while summer precipitation remains stable or even declines under higher emission pathways. This combination of intensified summer warming and stable or decreasing summer rainfall may increase the risk of droughts, potentially placing significant pressure on local water resources in the summer when water demand is at the most.

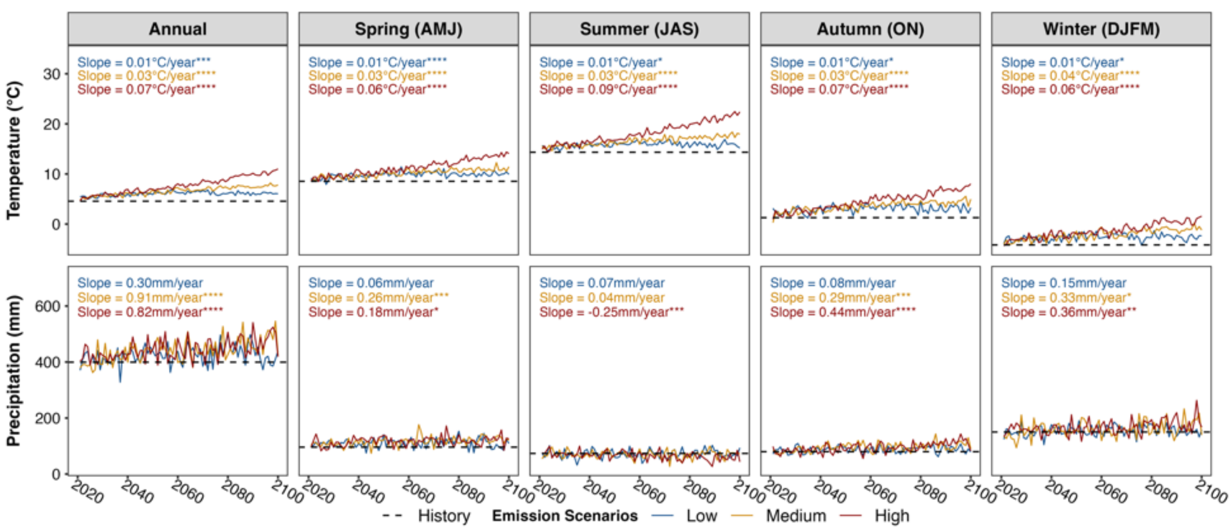


Figure 3 Projected future trends of temperature and precipitation in sqʷʔa (Peachland Creek) watershed.

3.2 Hydrological responses to the combined climate and forest changing scenarios

Future projections continue to reflect similar driving mechanisms as historical attribution, which we illustrated by the relative responses in Figure 4. Due to future climate warming, the snowmelt patterns would change greatly in future. Under extreme scenarios (i.e., high greenhouse gas emissions combined with 75% forest disturbance), peak flows can be 70 days earlier than in the baseline period, with April streamflow reaching six times the historical level. Despite this shift, while climate change can increase peak-flow magnitude by around 20%, while the 75% forest disturbance can offset this effect, resulting in limited overall impact on peak-flow magnitude, even under extreme emission pathway. This is probably because peak flows are normally driven by snowmelt process in the study watersheds, and forest disturbance at low and middle elevations can produce desynchronization effects on snow melting and consequently mute hydrological responses (Zhang & Wei, 2014).

Regarding low flows, forest changes play a more significant role as they regulate water loss through evapotranspiration during summer. In the far future (2050–2100), climate change is projected to reduce summer low flows due to both earlier snowmelt and increased water loss driven by higher temperatures. However, a 75% forest disturbance can offset these negative effects (Figure 4). That said, this offsetting effect diminishes as forests fully recover (0% CECA). However, beyond regulating water quantity, forests can provide complex and positive benefits in maintaining biodiversity, stabilizing soils, and filtering pollutants and reducing sediment runoff. Hence, we remain committed to promoting effective forest restoration.

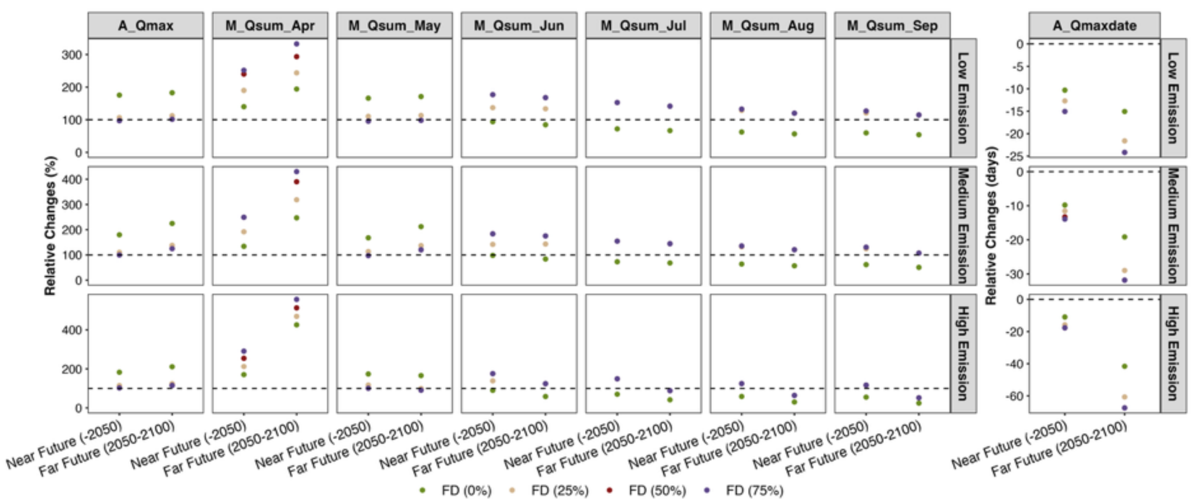


Figure 4 Projected relative streamflow responses to combined climate and forest changing scenarios. In the left panels, the dashed lines at 100% represent the historical baseline, with values above and below indicating the relative percentage increase or decrease in the future, respectively. In the right panel indicating peak-flow timing, the dashed lines at 0 represent the historical baseline, with values below indicating the number of days by which peak flow is expected to advance in the future.

Summary and Possible Implications for Watershed Management

Our assessment clearly shows that climate or future climate change can significantly increase peak flows and April flows, and advance timing of peak flows. Future climate change also greatly decreases summer low flows. These hydrological alterations may impose significant risks to water supply, public safety, aquatic habitat in the downstream community. Future climate change adaptation and mitigation must account for these hydrological changes. Interestingly, forest disturbance has limited effects on peak flows while provides positive effects on summer low flows. Although amplifying effects on peak-flow timing were detected between climate and forest disturbance, there were often offsetting effects on peak flows and summer low flows. The strengths of these offsetting effects are varied depending on climate change and forest disturbance scenarios. Thus, the interacting effects of climate and forest disturbance on hydrology should be considered in managing future water supply and watershed functions.

Next Steps

- Further evaluating the interacting effects of climate change and forest disturbance on peak and low flows.
- Pursuing publications based on assessment results.

Anticipated Gaps in Understanding

- Our work highlights the importance of considering combined effects of climate and forest impacts when studying the hydrological response of forested watersheds.

References

Winkler, R., & Boon, S. (2017). Equivalent clearcut area as an indicator of hydrologic change in snow-dominated watersheds of Southern British Columbia. Extension Note - British Columbia Ministry of Forests, Lands and Natural Resource Operations, No.118, 10 pp. CABI Databases.

Zhang, M., & Wei, X. (2014). Contrasted hydrological responses to forest harvesting in two large neighbouring watersheds in snow hydrology dominant environment: Implications for forest management and future forest hydrology studies. Hydrological Processes, 28(26), 6183–6195. https://doi.org/10.1002/hyp.10107



Theme 2: Urban Water

Risk assessment of the cumulative effects and other stressors to the downstream community (water supply and environmental hazards).

Watershed ecosystems do not require humans to function, but humans are dependent upon the functioning of watershed ecosystems. In the sqʷʔa (Peachland Creek) watershed, people are dependent on water for food, drinking, sanitation, agriculture, recreation, and economic prosperity. Watershed management can be used to ensure that human water needs are met and are balanced with long-term environmental sustainability and ecological integrity. Watershed management looks like purposeful land use and water use in order to meet the needs of humans without compromising environmental sustainability.

In the sqʷʔa (Peachland Creek) watershed, the impacts of upstream watershed management on the downstream community are being investigated using a lifecycle thinking approach. An integrated urban water management model based on a human health and ecological risk assessment framework will be developed. Based on historical data and climate-induced future scenarios, urban water management interventions and strategies will be prioritized for this multi-use watershed.

Meet the Urban Water Team

Dr. Rehan Sadiq

Dr. Rehan Sadiq is Provost and VP Academic, a Professor of Civil Engineering in the School of Engineering, and a Distinguished University Scholar at UBC's Okanagan Campus. Dr. Sadiq is also co-director of the Digital Learning Factory Initiative, and a co-lead of the Life Cycle Management Laboratory.

He is a world-leading researcher in asset management of water supply systems, environmental risk analysis, and lifecycle assessment of the built environment, and has authored more than 600 peer-reviewed articles, book chapters, and technical reports. His work has ~16K citations, placing him amongst the top 100 most cited civil engineering researchers globally, and the top 2% of environmental scientists.

Dr. Sadiq has served and chaired numerous Canadian and international scientific committees and conferences, and sits on the editorial board of many international journals. Dr. Sadiq has been registered as a Professional Engineer since 2010, and is a Fellow of Canadian Academy of Engineering (FCAE), Canadian Society of Civil Engineering (FCSE), Engineers Canada (FEC) and Engineering Institute of Canada (FEIC).

Emmi Matern

Emmi Matern is a PhD student in the School of Engineering. Emmi received her BASc in Civil Engineering from UBC Okanagan in 2021.

She has worked as an EIT and Junior Hydrotechnical Engineer in rural BC, and has experience with dam engineering and work in and around water. Emmi is currently a PhD student with the School of Engineering and is a Graduate Research Assistant with the interdisciplinary Watershed Ecosystems Project. She is focusing her studies on water quantity, availability, and allocation, as well as its implications for the planning, management, and risk assessment of community water systems.

Research Activity 3: Urban Water: Risk Assessment Framework for the Downstream Community

Researchers: Dr. Rehan Sadiq and Emmi Matern


Main Themes and Objectives

The main objective of this research is to apply an engineering lens to assess and balance the present and future economic, social, and environmental needs of the sqʷʔa (Peachland Creek) watershed, both present and future, considering all of its different parts as an integrated system. This research facilitates the design and application of a risk-based assessment tool for watershed ecosystems, influenced by an Integrated Water Resources Management (IWRM) approach which holistically considers multiple elements at the same time, as opposed to managing them individually with no cross-consultation or communication.

This research applies a scope of integrated and sustainable management to the boundaries of the sqʷʔa (Peachland Creek) community watershed. The scope cannot be too big or too small – the whole system needs to be incorporated, not just the location of certain impacts, and yet the system needs to be of a manageable size with similar community values and goals. Additionally, cumulative effects and interactions should be considered in order to successfully balance watershed needs. The upstream and downstream parts of sqʷʔa (Peachland Creek) will be considered for successful watershed assessment and management, especially as effects from upstream-downstream linkages can be cumulative.

It is impossible to know everything about the environment, let alone economic and social conditions, and so there will always be uncertainty associated with watershed understanding and management. With uncertainty comes risk, as there is the potential for a hazard of consequence to occur [1]. For a successful watershed assessment approach, risk management should be used to identify and mitigate undesirable outcomes, accommodate uncertainty, and provide robust solutions for present and future conditions. Watershed management for the upstream, the downstream, and upstream-downstream relationships in a watershed should include these identified needs.

This research component of the Watershed Ecosystems Project has determined that there is a need for a decision-making support framework that incorporates cumulative effects, risk, and an integrated management approach. This framework should produce outcomes that are sustainable, holistic, and consider crucial needs within the coupled socio-ecological system.

Key Findings

Evaluation of academic literature and industry research has identified several important properties of watershed ecosystems and how they relate to downstream communities. Key findings include:

- Upstream-downstream linkages and stressor-receptor relationships occur over space and time and correspond to the flow of water through the watershed.
- Indicator-based assessment is well-suited to watersheds and other complex systems:
    - Indicators can help link disparate concepts as well as improve communication and understanding among all stakeholders.
    - Indicators aid in packaging large amounts of diverse information and data from multiple dimensions and converting that information into meaningful wisdom.
    - While single indicators may be used to represent positive or negative change in an element of interest, multiple indicators may be used to span multiple dimensions and show relationships between phenomena.
- Elements of sustainable development: society, economy, and environment.
- Watershed assessment elements: water quality, water quantity, ecosystem, landscape, land use, and socio-economic.
- Watershed behaviour under different management strategies and hydrologic hazards may result in unanticipated risks and impacts to vulnerable populations and resources.

As an outcome of this research activity within the Watershed Ecosystems Project, a risk-based watershed assessment tool has been developed. This tool incorporates uncertainty for more robust and useful results and can be used to measure cumulative anthropogenic pressure on the watershed. The tool uses a grey water footprint measure to provide a quantifiable common unit that is supported by standardized methods and is not limited to a single value dimension. Grey water footprint can simultaneously represent a cost to the environment, cost to the economy, and cost to human society and culture without neglecting intrinsic value [2], [3].

The water footprint measure will be applied to different watershed conditions and predictions, and results will be incorporated into a management strategy selection framework for sqʷʔa (Peachland Creek). The selection framework (or decision-making support framework) can compensate for limited access to funding and expertise and promotes consideration of multiple elements of sustainability. The management strategy selection framework can take many different perspectives into account and has a built-in approach for considering uncertainty.

Upon the completion of this research activity, recommendations will be provided to Peachland Creek Watershed interest groups based on the common goal of sustainability through an uncertain future. This research will develop best management practices and risk mitigation guidelines that are tailored to the unique characteristics and anticipated future conditions of the sqʷʔa (Peachland Creek) watershed.

Next Steps

- Finish edits to paper on indicator selection and submit to journal for publication;
- Conduct data collection with the aid of stakeholders;
- Propose methodology for third paper on indicator relationships using a stochastic approach;
- Write and publish third paper once methodology is accepted;
- Conduct review of machine learning modelling techniques for watershed dynamics;
- Determine qualitative relationships between water quality and downstream risk for various contaminants; and
- Determine qualitative relationships between water quantity and downstream risk for various hydrological conditions (drought and flood).

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Theme 3: Fish

Risk assessment of the cumulative effects and other stressors to fish habitat/ population

Forest disturbance and climatic variability/change threaten *kəkniʔ* (kokanee) salmon through altered thermal and hydrological regimes. This research will investigate the impact of historical and future variations in water quality, quantity and timing (temperature and flow) on the timing and duration of the spawning run in the sqʷʔa (Peachland Creek) watershed. This information will support watershed cumulative assessment and integrated modelling (Theme 5).

sqʷʔa (Peachland Creek) supports critical habitat for *kəkniʔ* (kokanee) salmon due to its innate capacity to produce healthy *kəkniʔ* (kokanee) populations. Understanding the drivers of spawn timing and the potential impacts of climate change is critical to the management of the watershed for both land use and water.

Meet the Fish Research Team

Dr. Sheena Spencer

Dr. Sheena Spencer is a research hydrologist with the Ministry of Forests and an Adjunct Professor in the Department of Earth and Environmental Sciences. Sheena conducts research on the hydrologic response to forest disturbance and regrowth as well as runoff generation in headwater catchments.

Sheena is project lead for the Upper Penticton Creek Watershed Study, a long-term research site addressing the effects of logging and subsequent regrowth on streamflow quantity and quality, snow accumulation and snowmelt, and subsurface flow. She serves as the Chair of the Okanagan Basin Water Board (OBWB) Okanagan Water Stewardship Council.

Emily Moore

Emily Moore is an MSc student in the Department of Earth and Environmental Sciences. Emily moved to the Okanagan after completing her BSc. in Environmental Science at the University of Calgary, where she is originally from.

Emily's research interests are centered around the interactions of hydrology and fish ecology, forming the basis of her role in the research cluster here at UBCO. Alongside Sheena Spencer and Adam Wei, Emily will be investigating the sources of yearly variation in spawning timing of *kəkniʔ* (kokanee) salmon in *sqʷʔa* (Peachland Creek) watershed. By determining which hydrologic and climatic variables are the most important to the success of the *kəkniʔ* spawning run, watershed managers will be able to efficiently allocate water to fish flow needs exactly when and where they're needed.

Research Activity 4: Predicting the Effects of Climate Change on Spawn Start Time

Researchers: Dr. Sheena Spencer and Emily Moore

Main Themes and Objectives

- Confirm that the *kəkniʔ* (kokanee) spawning period has advanced over the past 30 years;
- Determine which hydroclimatic factors could be driving this advancement; and
- Predict the effect of climate change on spawn start time.

Key Findings

Analysis of historical *kəkniʔ* (kokanee) spawn timing data in both Peachland and Trepanier Creeks demonstrated that kokanee spawn timing has advanced over the past 30 years. This was indicated by an earlier peak spawn date in more recent years. This advancement in spawn timing was also correlated with increasing summer temperatures, which may have important implications for (increases in) stream temperature during late summer months. This correlation suggested that air temperatures played a role in determining spawn start time.

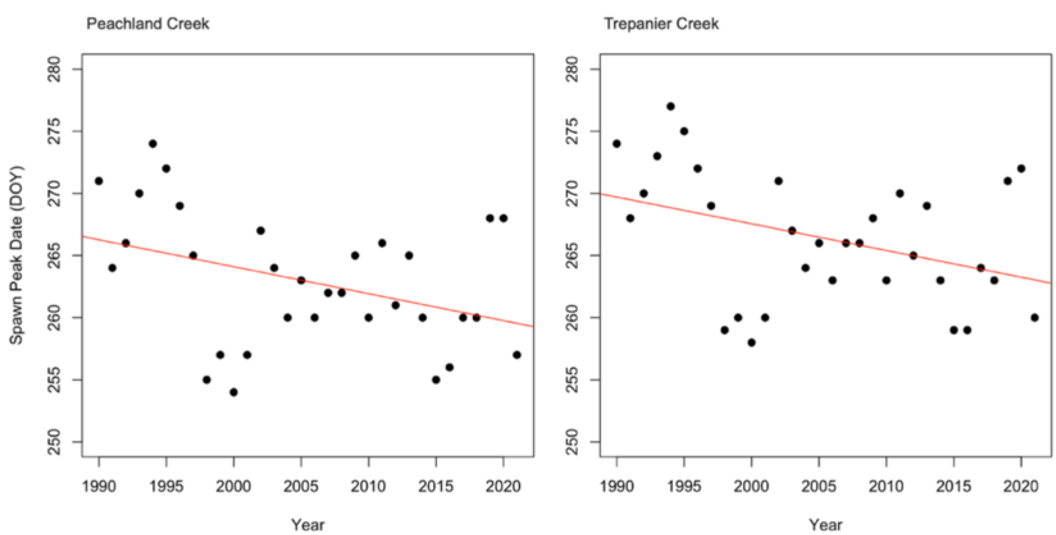

Figure 1 – Spawning peak date (as day of year) at Peachland and Trepanier Creeks over the period of record (1991-2021). Red trend line shows that the peak spawn time has become earlier (advanced) over time.

To determine the key drivers of *kəkniʔ* (kokanee) spawn timing, linear models that could predict historical spawn timing were developed. The approach was to find the best model to predict spawn start time using ecologically relevant hydroclimatic variables such as seasonal air temperature, dryness, streamflow, and precipitation. The best models consistently included metrics of air temperature as the most powerful predictors of spawn start time, where higher temperatures were correlated with earlier spawn start times. Accumulated thermal units (ATU) was an important temperature metric in the model, which is defined as the sum of all air temperatures experienced over a given time frame. Other predictors include dryness, the date of peak flow, and the amount of precipitation the week before spawning (Figure 2).

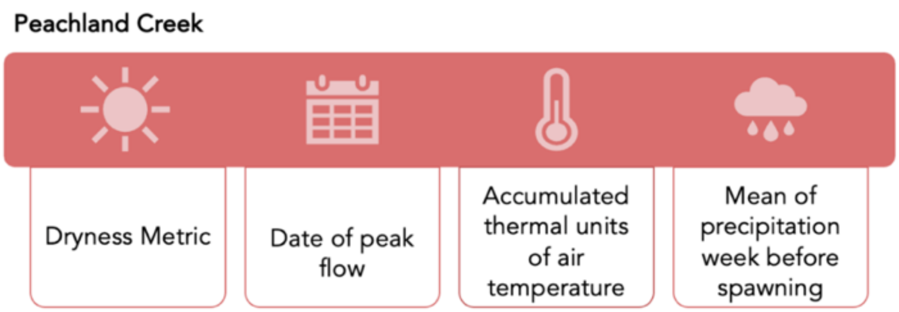

Figure 2 – Hydroclimatic variables included in the best model to predict spawn start time in sqʷʔa (Peachland Creek).

To investigate the effect of climate change on the timing of the spawning period, modelled future climate data was input into the models created to predict spawn timing. In this way, relationships between spawn start time and hydroclimatic variables established in the previous objectives could be forecasted into the future. Key predicted outcomes of climate change in the Okanagan included higher air temperatures and lower streamflow. Consistent with the relationships established between air temperature and spawn start time, the higher air temperatures expected under climate change resulted in a predicted further advancement in spawn start time under the more extensive climate change scenario (8.5). Spawn start date was not significantly different under the more moderate climate change scenario (4.5), however, this is the less likely scenario.

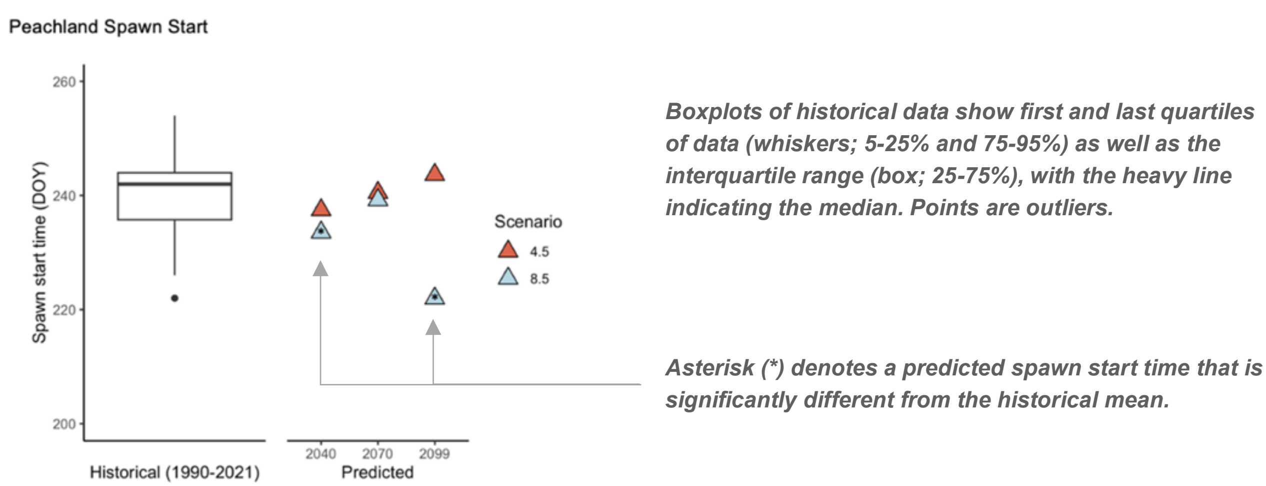

Figure 3 – Changes in spawning start time in sqʷʔa (Peachland Creek) watershed under future climate warming scenarios.

The biological mechanism behind an advancing spawning period for a fall-spawning ecotype of salmon is unknown as they exhibit the counterintuitive behavior of exposing themselves to elevated water temperatures, instead of delaying spawning until water temperatures cool. However, this behavior has been observed in other fall-spawning Pacific salmon populations and is usually associated with high pre-spawn mortality.

For the specific case of Peachland Creek *kəkniʔ* (kokanee) there are likely two possibilities for the mechanism driving spawning advancement. The first is that it may represent an emerging mismatch between the timing of key *kəkniʔ* (kokanee) life events and their environment as they respond negatively to a changing climate. The second is that it could represent an adaptation to climate change that provides their progeny with better conditions to emerge in in the spring. It is possible that the ideal emergence time in the spring is advancing as well, and therefore an earlier spawn timing may benefit the next generation. However, more work is needed to determine the possible mechanism because this cannot be concluded from this study alone.

Research Timeline and Status

- Emily Moore's M.Sc. thesis is available on the UBC thesis database for public viewing: Hydroclimatic controls and the influence of climate change on the timing of the kokanee spawning period in Peachland, BC.

Anticipated Gaps in Understanding

- While this study investigated the influence of hydroclimatic variables on spawning *during* the spawning period, there are undoubtably relationships that exist in other stages of the kokanee life cycle (emergence, fry, adult).
- Additionally, while key relationships between rising air temperatures and the timing of the spawning period were identified, a better understanding of how changes in hydroclimatic variables may influence spawn timing could be achieved through the investigation of how the timing of other life stages respond to these changes beyond just during the spawning period.

Next Steps

- A publication of the completed research is currently in progress.

Theme 4: Syilx Knowledge and Values

Risk assessment of the cumulative effects and other stressors on Indigenous Okanagan Syilx values

The Indigenous First Nation Communities of Westbank First Nation and the Penticton Indian Band, part of the Okanagan Nation Alliance, are the unceded title holders of the selected research area. Historically, they have been excluded from governance and decision-making in watershed management. In order to right these historic wrongs, and in accordance with both syilx water law and recent Supreme Court of Canada decisions, collaborative approaches must be developed that centre syilx values and knowledge in the creation of frameworks for research and governance. Co-developed design that includes the Westbank First Nation and Penticton Indian Band Natural Resources departments, as well as syilx Traditional Ecological Knowledge (TEK) Keepers will be used to inform the overall research objectives and questions, and directions moving forward.

We acknowledge and respect Indigenous Syilx rights, knowledge, and water law. We acknowledge syilx knowledge as empirical, evidence-based, verifiable and modern science.

We are committed to working in a manner that reflects the 5Rs of Indigenous-engaged research: relevance, respect, reciprocity, relationships, and responsibility.

Meet the Syilx Knowledge Team

lax̌lax̌tkʷ Dr. Jeannette Armstrong

lax̌lax̌tkʷ Jeannette Armstrong is an associate professor of Indigenous Studies and former Canada Research Chair in Okanagan Indigenous Knowledge and Philosophy at UBC Okanagan.

Dr. Armstrong is the academic coordinator of Interior Salish languages at UBC Okanagan. She is a member of the Royal Society of Canada and an Officer of the Order of Canada. She was born and grew up on the Penticton Indian Reserve.

Dr. Armstrong is an award-winning writer, visual artist, researcher, educator, leader and activist. Her research is in Indigenous philosophies and Okanagan syilx thought and environmental ethics coded into syilx oral literatures. She collaborates with Salish speaking groups to re-establish Indigenous languages, historical relationships, and food resource ceremonies through gatherings, trading and protection of water and land practices.
As an influential advocate for Indigenous peoples' rights, Dr. Armstrong has been a force of change and widescale community impact through her artistic, research and educational vision.

Jeannette has an interdisciplinary PhD in environmental ethics in Syilx oral literatures from the University of Greifswald. Her research and study as Canada Research Chair in Indigenous Okanagan Philosophy, and as the lead for the Adaptation, De-colonization, and Indigeneity research cluster under the Institute for Community Engaged Research (ICER) is focused in contemporary applications of Syilx traditional knowledge in environmental ethics and practice from within the Syilx framework.

Dawn Machin

Dawn Machin is a member of the Okanagan Indian Band, part of the Okanagan (Syilx) Nation, and a Masters student in the Department of Biology at UBC Okanagan. She holds a B.Sc. from the University of British Columbia and is currently pursuing her M.Sc. at the University of British Columbia Okanagan.

After receiving her degree, she started as the Okanagan regional biologist for the then Canadian Columbia River Inter-Tribal Fisheries Commission, and then moved the Okanagan Nation Alliance where she was responsible for program management of the Fisheries Department. Key tasks were related to the Nation's vision to restore Okanagan Sockeye to the Basin, and establishing strong technical partnerships with the Department of Fisheries and Oceans and the then Ministry of Environment, and with our Okanagan relations in Washington State. At this time, Dawn was a board member of the provincial crown corporation Fisheries Renewal BC (1997-2001) and participated in local stewardship groups, such as the Thompson Basin Fisheries Council. She was then blessed with three boys and the opportunity to devote her time to raising them and learning *nsyilxcn* (the Okanagan language). She has since returned to the Okanagan Nation Alliance to reconnect with the people and community involved in the management of Syilx resources. She was appointed as a Board Member of the provincial Wild Salmon Advisory Council, summer 2018 to spring 2019. Dawn is currently the Treasurer of the First Nations Fisheries Council of BC.

Research Activity 5: Syilx Knowledge and Values: Risk Assessment of the Cumulative Effects and Other Stressors on Indigenous Okanagan Syilx Values

Researchers: Dr. Jeannette Armstrong and Dawn Machin

Main Themes and Objectives

The main themes and objectives in this activity include a risk assessment of the cumulative effects and other stressors in the sqʷʔa (Peachland Creek) watershed on Indigenous Okanagan Syilx values, and the co-creation of an entity for co-governance.

Key Findings

The history of settler colonialism and colonial management practices in the sqʷʔa (Peachland Creek) watershed has had marked negative impact upon the relationship of syilx community members with the watershed. From the onset of colonization, syilx communities have been excluded from meaningful participation in the decision-making and regulatory processes of the watershed, despite it being situated within their unceded and ancestral territories and the high importance of Hardy Falls and the surrounding area for syilx cultural practices and sustenance procurement.

Despite this, syilx peoples maintain their unceded rights and title to the watershed, upholding their jurisdiction and responsibilities. Syilx policy and legal frameworks encompassing water relationships, including those with sqʷʔa (Peachland Creek), include the following:

- *Okanagan Nation Declaration* (1987);
- *Okanagan Nation Water Declaration* (2014);
- syilx siwɬkʷ (Water) Strategy (2021), and
- Okanagan and Similkameen Watersheds Responsibility Planning Initiative (ongoing).

Syilx Okanagan peoples possess unceded and unrelinquished rights and title throughout syilx ancestral territory, including the sqʷʔa (Peachland Creek) watershed. This territory is recognized and affirmed by Section 35 of the *Constitution Act* (1982).

As of 2019, the provincial government is legally obligated, through the *Declaration on the Rights of Indigenous Peoples Act* (DRIPA), to see that it takes “all measures necessary to ensure the laws of British Columbia are consistent with the United Nations Declaration on the Rights of Indigenous Peoples…” (British Columbia, 2019). As such, Articles 25, 27, and 31 of the UNDRIP are of relevance to the sqʷʔa (Peachland Creek) watershed, and all unceded territories of the syilx Okanagan; citing that syilx possess the right to, (amongst other rights), "maintain and strengthen unique spiritual relationships with, and responsibilities to, traditional lands, waters, and other resources for current and future generations" (Article 25, United Nations Declaration on the Rights of Indigenous Peoples, 2007).

Research Timeline and Status

From project implementation and ongoing, Dr. Armstrong and Dawn Machin facilitate regular dialogue with representatives from Syilx communities including Natural Resources (NR) Managers, Councillors, Natural Resources portfolio holders, Technical Managers for referrals and forestry, and Traditional Ecological Knowledge leads.

Conclusions and Next Steps

The next steps for this activity include:

- Ongoing and iterative discussion of the benefits and risks to syilx communities;
- Opportunities for the Watershed Ecosystems Project team to present their research and findings to date to water leaders from the Penticton Indian Band and Westbank First Nation;
- The development of a letter of information sharing (MOU agreement) amongst researchers, the Penticton Indian Band, and Westbank First Nation;
- Syilx community water leaders from Penticton Indian Band and Westbank First Nation to host on-site visits to the upper watershed area. Though this process has been impacted by stressors like fires and floods, this placed-based learning is a critical aspect of this research process;
- The co-design of a co-governance entity for the sqʷʔa (Peachland Creek) watershed, positioning syilx communities as co-decision makers and leaders in watershed governance.

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United Nations. 2007. United Nations Declaration on the Rights of Indigenous Peoples. Resolution adopted by the General Assembly. September 13, 2007. https://www.un.org/development/desa/indigenouspeoples/wp-content/uploads/sites/19/2018/11/UNDRIP_E_web.pdf.

Theme 5: Integrated Modelling

Integrated modeling under a changing environment.

This activity involves the development of an integrated modeling platform that incorporates Indigenous and scientific knowledge about the sqʷʔa (Peachland Creek) watershed, and links to the data and models developed in research activities 1 - 4. The modeling platform will support dialogue and decision making by showing the trade-offs inherent in different management scenarios (e.g., timber vs. wildlife habitat vs. water quality vs. cultural values vs. recreation vs. range). The model will forecast how these trade-offs can be expected to evolve with climate change over the next century, and serve as an example of how an integrated approach to understanding the dynamics of a watershed can lead to more sustainable management of our province's natural resources. Output from the model will support conversations about governance.

Meet the Integrated Modeling Research Team

Dr. Lael Parrott

Lael Parrott is Dean and Professor in Sustainability for the Irving K. Barber Faculty of Science. Dr. Parrott is cross-appointed in the Departments of Earth and Environmental Sciences and Biology. She is the former Director of the Okanagan Institute for Biodiversity, Resilience and Ecosystem Services (BRAES). Prior to joining UBC, she was an Associate Professor in Environmental Geography and Director of the Complex Systems Laboratory at Université de Montréal (2001-2012).

Lael leads an internationally recognized research program in modeling and characterising contemporary regional landscapes and ecosystems as complex human-environment systems. Dr. Parrott promotes a holistic, complex systems vision of managing land and water resources at the landscape scale. She has extensive experience in leading multipartite groups to share this vision to find sustainable management solutions that reconcile ecological, societal and economic objectives.

Corrie Greaves

Corrie Greaves (M.Sc., R.P.Bio.) is a PhD student in the Interdisciplinary Graduate Studies – Sustainability program at UBC Okanagan. For her doctoral research, Corrie is exploring how we can better understand watersheds as integrated systems of people and ecosystems that interact in dynamic ways.

Prior to starting her PhD, Corrie was a professional biologist, where she worked closely with Indigenous communities, government, and industry to evaluate cumulative effects and guide regional land use planning throughout British Columbia. She has been actively involved in species at risk conservation, stewardship, and advocacy projects, and has experience dabbling in fish, aquatic, and wildlife biology. Corrie grew up in Kelowna and maintains a close connection to, and passion for, the Okanagan. Outside of work and school, she divides her time between cross country skiing in the winter and cycling in the summer.

Research Activity 6: Integrated, Whole-of-Ecosystem Approaches to Understanding Impacts of Cumulative Effects

Researchers: Dr. Lael Parrott and Corrie Greaves


Main Themes and Objectives

The main objective of this research is to understand how cumulative effects are impacting the Peachland watershed by using integrated, whole-of-ecosystem approaches centered on the concept of ecological resilience.

We aim to:

- Understand the current state of affairs for the sqʷʔa (Peachland Creek) watershed: how problematic are cumulative effects in this watershed and across the Okanagan Watershed, and why are current methods for navigating cumulative effects failing?
- Evaluate the extent to which cumulative effects have influenced the trajectory of the sqʷʔa (Peachland Creek) watershed, and,
- Explore different, more integrated approaches for evaluating cumulative effects that center ecological resilience, and propose a series of guiding principles and decision-support tools for managing cumulative effects that may help ensure the long-term resilience of the sqʷʔa (Peachland Creek) watershed amid ongoing and future change.

Cumulative effects are conceptually simple: while the impact of a single activity or project is unlikely to be significant, their combined impact across space and time can be profound.

This is well-exemplified in the sqʷʔa (Peachland Creek) watershed where our human footprint appears negligible from the perspective of individual impacts. However, a different story emerges when we consider these incremental human activities collectively rather than individually. From a cumulative perspective, provincial mapping indicates that 33.5% of the watershed's land base has been impacted by a combination of forestry, power production/transmission, urban development, and mining and resource extraction (BC Collaborative Stewardship and Cumulative Effects Management, 2023). As ongoing human activities exacerbated by climate change continue to pressure sqʷʔa (Peachland Creek) Watershed – and indeed watersheds across British Columbia - unease grows that we may soon surpass ecological tipping points. This is a remarkably common story in British Columbia: while human activities may be individually negligible, they are cumulatively profound.

In British Columbia and across Canada, a *cumulative effects assessment* is the principal tool used to understand how cumulative effects impact ecosystems and subsequently make informed decisions about when and where we continue to allow destructive practices to occur. However, as the challenge of cumulative effects in the sqʷʔa (Peachland Creek) watershed poignantly illustrates, cumulative effects assessments have been criticized in their ability to make meaningful progress toward slowing the rate or impact of ecological destruction.

There are a number of factors that explain why, despite cumulative effects assessments being a common decision-making tool, the problem of cumulative effects continues to worsen. We find the following factors underpin most others:

1. **Highly siloed and reductionist approaches to assessing cumulative effects**. While it is intuitively understood that cumulative effects are a whole-of-ecosystem challenge that emerges at the scale of landscapes, not projects, cumulative effects assessments rarely capture this. Instead, highly reductionist and siloed methods for assessing cumulative effects are commonly used. Ecosystems are evaluated in relative isolation from each other (water-vegetation-wildlife-people) and on a project-by-project basis. This makes it extremely difficult to *see the forest for the trees* in decision-making. Without a whole-of-ecosystem approach that evaluates cumulative effects from integrated, holistic perspectives, it is challenging to account for the true impact of society's footprint.

2. **A lack of decision-making thresholds for cumulative effects.** Any one individual project is unlikely to be the straw that breaks the camel's back, so to speak. Yet it is obvious that the totality of human impacts across space and time can be substantial. Theory suggests that there are ecological limits that, if crossed, may lead to a substantial change in ecosystem structure, function, and identity. Without a mechanism for evaluating cumulative effects against such ecological thresholds, however, we may soon surpass them. Understanding where we are against ecological thresholds requires first knowing where the threshold is. Although there are management thresholds for parts of ecosystems – like water quality thresholds – there are, to our knowledge, no methods for evaluating where such ecological thresholds are from integrated, holistic perspectives.

One prospective approach to move cumulative effects assessments towards more integrated and holistic approaches is to draw on the concept of ecological resilience. Ecological resilience describes the capacity of a system to absorb disturbances without compromising integrity or health. Resilience is inherently an ecosystem-level property that necessitates an integrative and holistic mindset to understand. Bringing resilience into cumulative effects assessments, therefore, may offer a real opportunity to transition away from compartmentalized approaches that have long been problematic in decision-making arenas and towards a strong emphasis on systems.

Despite the potential of ecological resilience to drive more integrated cumulative effects assessments, few examples have achieved this, and guidance on how to bring these two spheres together is lacking. This is the central gap this research component is tackling: *how do we reimagine cumulative effects assessments through an ecological resilience lens in order to drive more integrated, whole-of-ecosystems methods for understanding cumulative effects?*

A path forward: shifting from silos to ecosystems and establishing the limit for cumulative effects

We propose a new approach for evaluating how cumulative effects are impacting ecosystems: by using a safe operating space rooted in ecological resilience. Put simply, a safe operating space defines our "safe zone" for ongoing human disturbance. Provided the magnitude of human disturbances stays within the safe operating space for a particular watershed, we can be reasonably confident that human activities – like forestry, recreational opportunities, mining, agriculture, and urban expansion - can continue without compromising ecological health and integrity. In this sense, safe operating spaces are intended to function like guard rails around a dangerous cliff. We reduce the risk of an accidental fall by keeping society well away from the edge. However, if the magnitude or pace of human disturbance exceeds the safe operating space, there may be an imminent risk of eroding ecosystem health and integrity, perhaps leading to profound ecological degradation.

To apply the concept of safe operating spaces to local watersheds, we propose structuring the boundaries for human development around ecosystem properties important to ecological resilience (Figure 1). We envision this as a three-step process:

(1) Identify the fundamental ecological values that are so important to a watershed that if they are lost, it would no longer be the same watershed. Around these central values, the safe operating space is defined.

Unlike conventional cumulative effects assessments that evaluate impacts on a project-by-project, component-by-component basis, a safe operating space is centred on the values that are fundamental to an ecosystem; if they were to change or be lost, it would no longer be the same ecosystem. For example, values like clean drinking water, healthy forests, habitat for rich flora and fauna, and healthy communities are great examples of values that could define a safe operating space.

(2) Define the boundaries of the safe operating space around these central values that are fundamental to a watershed.

To define the boundaries of a safe operating space around these central values, we propose bridging ecological and social factors. In this sense, ecological considerations, like how much disturbance an ecosystem has evolved to absorb, are used to paint the first brush strokes of where a boundary might be. Social considerations, like risk tolerances, levels of acceptable change, and values, are then used to decide where specifically to place the boundary of the safe operating space. The boundaries of a safe operating space must be defined conservatively, meaning they are placed 'well downstream' of true ecological thresholds.

(3) Measure where we currently are against the safe operating space

This is undoubtedly the most important step – determining if we are within or outside of the safe zone for a watershed. When an ecosystem is no longer within its safe zone, further destruction is very strongly contraindicated, as it is possible every additional impact may be the metaphorical straw that breaks the camel's back and moves an ecosystem beyond a tipping point. In these cases, a safe operating space becomes a compelling metaphor for the profound impact humans have had in driving watersheds toward an uncertain future. And, perhaps, a bellwether calling for a shift from the status quo towards a management ethos centred on stewardship, respect, and sustainable development. When a watershed is beyond its safe operating space, the ways in which people and society can have a positive impact on ecosystem needs to become centered. Instead of focusing on mitigating harm, the narrative must shift to restorative practices that may allow our watersheds to heal. In contrast, for ecosystems within the safe operating space, there is room to consider projects that contribute to cumulative effects without worrying that ecological resilience is at risk.

Unless we can work towards navigating our interactions with landscapes to safeguard ecological resilience, it is likely that through the process of “death by a thousand cuts,” ecosystems will soon be pushed beyond the safe zone. We may indeed find that most already are.

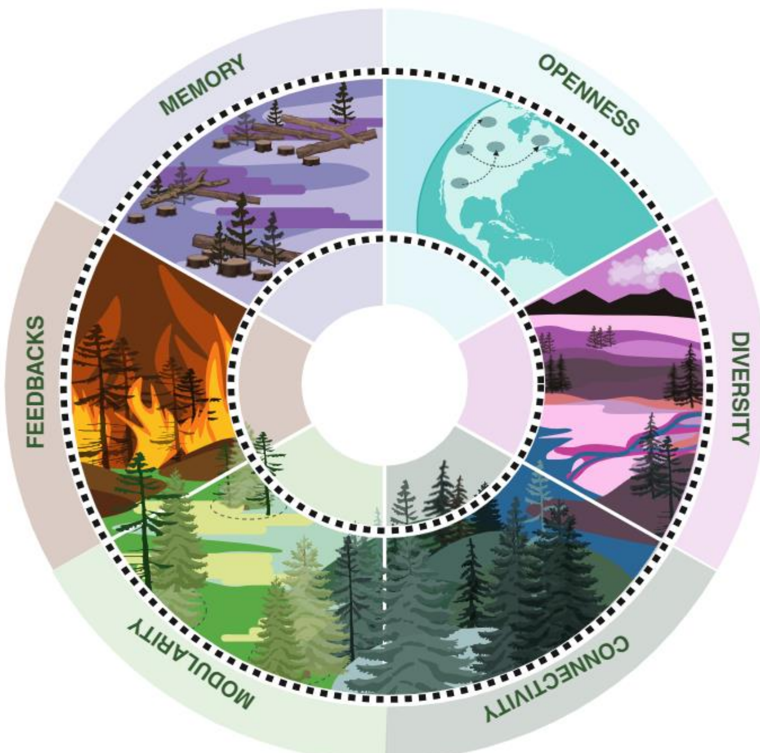


Figure 1. A regional safe operating space for maintaining a resilient ecosystem (regional safe operating space for resilience).

The regional safe operating space for each attribute of a resilient ecosystem is delineated by an upper and lower boundary (hashed lines). When the magnitude of cumulative effects pushes ecosystems beyond the boundaries of the regional safe operating space, we can no longer be confident that further human impacts will not erode the ability of the system to adapt and transform to further disturbance, thereby risking the ecosystem structures, functions, and processes on which we depend. When a system is within its regional safe operating space for resilience, it may still be able to accommodate and recover from additional human disturbances.

Research Timeline and Status

This research is now complete and has resulted in the following reports and publications:

- The first contribution from this research, which explores conceptual shifts needed to move towards integrated approaches for understanding cumulative effects, is now published and publicly available.
- The second contribution, which proposes using a safe operating space to define cumulative effects, has been published and is publicly available.
- The third contribution, which explores how cumulative effects have influenced ecosystems in the sqʷʔa (Peachland Creek) watershed over the last 40 years, has been submitted for publication and is undergoing peer-review.
- The last contribution provides initial reflections on how these ideas, concepts, and findings may translate to a real-world case example using the sqʷʔa (Peachland Creek) watershed. This work is complete, and will be made publicly available following peer-review.

Anticipated Gaps in Understanding

- It is not possible to assess everything in a cumulative effects assessment. This study, therefore, necessarily proposes a focus on central values identified by the community.
- Since we primarily use satellite imagery for this study, we are limited to evaluating cumulative effects that visibly alter landscapes. Cumulative effects that are invisible yet still contribute to ecological harm – like changes in water quality, decreased wildlife abundance, and invasive species propagation – will be underestimated in this study.

Next Steps

- This work is complete and Corrie Greaves is expected to defend her dissertation in fall 2025.



Theme 6: Governance

Development of a locally inclusive, socio-ecological watershed governance model and assessment of the enabling conditions for its practical implementation.

We are amidst a period of marked evolution in water and watershed governance in the Okanagan basin. With increasing pressures on source water from domestic demand and agriculture, and intensifying watershed stressors like forest harvest, resource infrastructure development, and recreation – communities are being forced to make difficult decisions about how to balance a diversity of needs. This complexity is further heightened by climate change considerations, which add an additional layer of uncertainty to watershed ecosystems and future water supply modelling. The sqʷʔa (Peachland Creek) watershed is an open, highly multi-use community watershed with marked impact from both legacy and modern resource extraction processes. For the Peachland Creek community watershed, Syilx communities, local government, and other interest groups are reimagining and redesigning appropriate approaches to collaborative governance.

Development of a watershed co-governance model

This research seeks to define a potential framework for inclusive co-governance, collaboratively developed with representatives from Syilx communities, municipal, and regional governments - informed by locally-defined values and interest group engagement. Interest groups include source water users, tenure and permit holders, recreators, environmental organizations, and university researchers. This activity facilitates ongoing meetings, workshops, and other engagement sessions to deepen relationships and support continued partnership development, share project results and findings, identify common priorities, and create space for partner governments, within their own authorities, to define an appropriate co-governance entity through which to influence decision-making in the watershed.

Meet the Governance Team

Dr. John Wagner

Dr. John Wagner is a professor of environmental anthropology in the Department of Community, Culture and Global Studies in the Irving K. Barber Faculty of Arts and Social Sciences. John conducts research on human/water relations in the Okanagan Valley, the Columbia River Basin in Canada and the United States, and in Papua New Guinea.

In his Columbia River Basin research, John focuses on water governance and the relationship of the Columbia River Treaty to irrigation, food security, food sovereignty and Indigenous rights.

In the Okanagan Valley, he has conducted research on settler colonialism, the history of water management, and floodplain restoration as a climate change mitigation strategy. As a co-investigator for the Watershed Ecosystems Project, his focus is on watershed governance.

Rheanne Kroschinsky

Rheanne Kroschinsky is a water governance researcher currently pursuing her PhD at the University of British Columbia, Okanagan. Her work, made possible through the Social Sciences and Humanities Research Council of Canada and the University of British Columbia, Okanagan, explores governance and decision-making frameworks for community (source) watersheds in British Columbia. Through partnerships with Syilx communities and the District of Peachland, her research emerges from the UBC Okanagan Watershed Ecosystems Project, a community-engaged initiative focused on the sqʷʔa (Peachland Creek) watershed.

She also is a research assistant with the Watershed Research and Extension Program in the Department of Earth and Environmental Sciences, building community partnerships and bridging institutional resources into community-identified watershed challenges. Rheanne is a Visiting Governance Research Fellow at the University of Victoria’s POLIS Water Sustainability Project, where her work is focused on the exploration of a watershed boards framework for British Columbian watersheds.

Research Activity 7: Developing a Watershed Co-Governance Model for sqʷʔa (Peachland Creek)

Researchers: Dr. John Wagner and Rheanne Kroschinsky

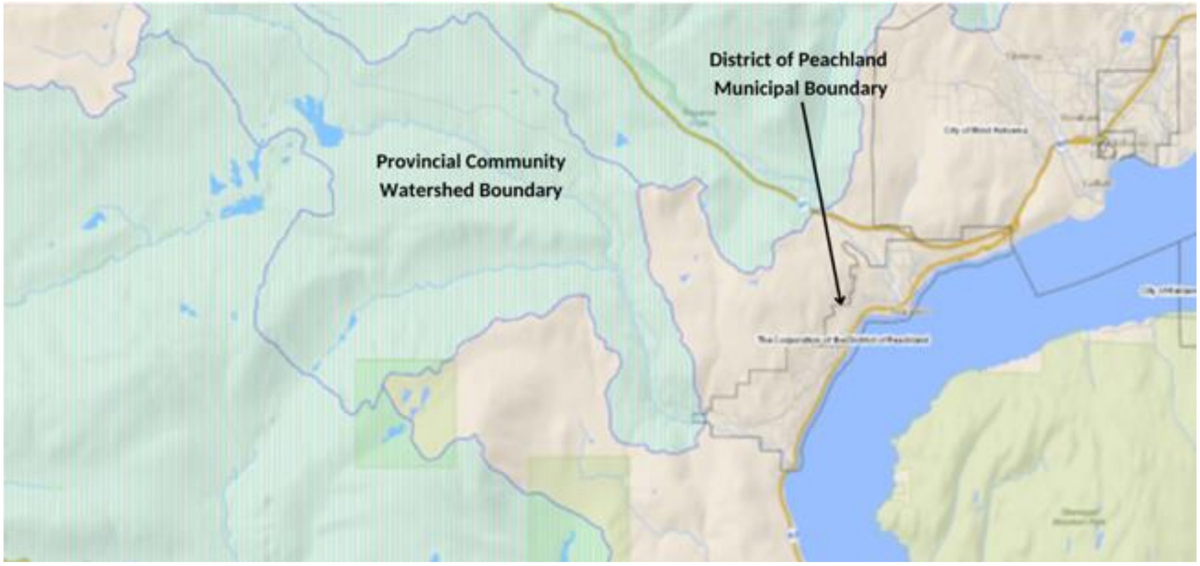
Main Themes and Objectives

- Identification of the distinct interest groups comprising the hydrosocial landscape of Peachland Creek community watershed, to better understand their unique positionalities and relationships with the watershed and each other.
- Identification of anthropogenic activities of impact (regulated and non-regulated) on the ecology of the watershed (historical and current), and understanding of how this impact is perceived by other groups.
- Map the existing governance, or decision-making framework of the community watershed at all levels of government (First Nations, Municipal, Regional, Provincial, Federal) and in relation to processes of engagement with the public and specific interest groups.
- Identification of the gaps in the current legislative framework that leave multi-use community watersheds like sqʷʔa (Peachland Creek) vulnerable; and understand potential interventions and mechanisms for its better protection.
- Facilitate community meetings amongst diverse interest groups to discuss watershed issues and collaboratively design a collaborative "vision" for the watershed.

Key Findings

Peachland Creek Watershed is a colonized and unceded space. The *sqʷʔa* Peachland Creek (also known as Deep Creek) watershed is situated within the traditional and unceded territory of the Syilx Okanagan Nation, the sole source watershed for what is now known as the District of Peachland. From the onset of the colonization period (1850s) in the *sqʷʔa* (Peachland Creek) watershed and throughout the Okanagan region, Syilx rights and legal systems, along with those of all Indigenous Nations, have been systemically ignored and overwritten by colonial legal frameworks that have gradually evolved into the provincial and federal systems still in place today.

Despite this, Syilx peoples maintain stewardship of this watershed, with main responsibilities lying with the communities of Westbank First Nation (WFN), the Penticton Indian Band (PIB), and the Okanagan Indian Band (OKIB), each holding specific interests for vested cultural, sustenance, and ancestral purposes.



The sqʷʔa (Peachland Creek) Watershed Provincial Community Watershed Boundary and the District of Peachland Municipal Boundary
(©British Columbia 2023a. https://maps.gov.bc.ca/ess/hm/imap4m/. By permission.)

Currently, the District of Peachland hosts a population of just over 5,000 people (Statistics Canada 2021), though this number is rapidly expanding and could possibly reach 19,000 by 2034 (Urban Systems 2015). Peachland Creek is a medium-sized watershed, spanning 145km, with 125km positioned above the municipal water intake (Golder Associates 2010). As of April 2022, the Peachland Creek watershed serves as the sole source of drinking water for Peachland's municipal distribution system, with the District of Peachland's new 24-million-dollar water treatment plant running at full capacity.

The community maintains a heightened awareness of source water issues resulting from years of sub-standard water quality and frequent boil water advisories from sediment in source water streams. Public discussions surrounding water quality and quantity have steadily occupied the community discourse over the past decade, and the topic frequently features in local headlines and municipal government discussions (see Parfait 2019). Many of these issues are to be addressed through recent investments in upgraded water treatment, but concerns remain regarding source water protection from the watershed's variety of anthropogenic activities.

sqʷʔa (Peachland Creek) is a community watershed. Peachland Creek is designated as a "community watershed" under the *Forest and Range Practices Act* (2004) (FRPA) and Government Actions Regulation (GAR), but research suggests an inadequacy within this legislation, as it stands, to provide meaningful protection for watershed sustainability and water security.

Peachland Creek is currently one of 466 designated community watersheds in the province, with 464 of them being open, multi-use and only two remaining "protected" or closed watersheds (Metro Vancouver and Greater Victoria) (see Kroschinsky 2023, "Peachland Creek as a Community Watershed" p. 94-99 for more on this designation and its implications for Peachland Creek).

Resulting from a variety of complex and interconnected reasons, this study has found that the community watershed designation has inadequately served Peachland Creek, primarily due to:

- Poorly defined objectives in *FRPA* for crown land licences relating to the impact of regulated activities within community watersheds; specifically objective 8.2(2)(a) relating to "material adverse impact on the quantity of water or the timing of flow to the waterworks".
- The Forestry Stewardship Plan (FSP) framework, and immeasurability of strategies and results in meeting unclearly defined *FRPA* and FPPR objectives, as well as the limited capacity of the province to monitor or enforce these plans.
- The presence of cumulative impacts from a variety of resource activities (legacy and modern) within the watershed, which are difficult to assess and managed by a fragmented and disconnected provincial agency framework.

There are many challenges faced by this open, multi-use community watershed. Through an in-depth, 4-year collaborative research process, Governance activity researchers applied a multi-faceted approach to data gathering including archival research, published material study, semi-structured interviews, community meetings, workshops, and other facilitated community engagements. Through this process, researchers have identified a specific set of key historical and modern challenges to the watershed socio-ecology including:

- Exclusion of Syilx authority within the provincial regulatory framework;
- Lack of local (Municipal) government influence in regulatory decision-making;
- Logging and forest management practices (current and legacy), and insufficiencies in community watershed legislation.
- Legacy impacts from mining;
- Resource road infrastructure and unclear guidelines and legal frameworks regarding responsibility and decommissioning;
- Public recreation and unmonitored access;
- Commercial activities - recreation and aggregates;
- Range practices; and
- Development and concerns regarding source water supplies.

As a result of this complex set of socio-ecological concerns, the hydrosocial fabric of the Peachland community is notably divided. While there's significant social consciousness surrounding water, opinions differ greatly regarding the current ecological functionality of the watershed, the regulated activities impacting it, and its capacity for source water provision. Water-related discussions are often contentious and polarizing.

Current governance of the sqʷʔa (Peachland Creek) watershed is highly fragmented, with decision-making authorities restricted by insufficient channels of communication and information sharing. Jurisdictional authority of the watershed is divided amongst various levels of government with agencies possessing authority over the arbitrarily segmented ecological processes and human activities. This has resulted in a framework with operational gaps and poorly coordinated decision-making. With limited human and fiscal resources, Peachland, like many other small municipalities, faces significant challenges in representing and advocating for local issues.

Syilx communities possess limited authority, within the provincial framework, over the regulated processes of the watershed, restraining their capacity to hold relationship with and sustainably steward the watershed as they have done since time immemorial.

Research Timeline and Status

- The governance research in the sqʷʔa (Peachland Creek) watershed continues into its fourth year, with graduate student, Rheanne Kroschinsky in the second year of her PhD studies, co-supervised by Dr. John Wagner and Dr. Natalie Forssman.
- Rheanne's M.Sc. thesis is available on the UBC thesis database for public viewing: Watershed Ecosystems and Human Interconnections: A New Model of Governance for Peachland Creek, B.C.

Conclusions and Next Steps

- A locally appropriate, integrated framework for the co-governance of the sqʷʔa (Peachland Creek) watershed is necessary to ensure comprehensive and appropriate decision-making in the coming decades. Phase one of the governance research activity concluded with preliminary recommendations for a watershed board decision-making structure for sqʷʔa (Peachland Creek) community watershed and suggested consideration of provincial legal tools through which to promote watershed sustainability and water security.
- The next phase of governance research, in partnership with syilx community representatives and the District of Peachland, will facilitate an extensive collaborative engagement process to further articulate potential pathways to collaboration for integrated decision-making for sqʷʔa (Peachland Creek) watershed.
- Dr. Wagner and Rheanne Kroschinsky are currently finalizing a paper for publication based on this research, which draws on this research to position the sqʷʔa (Peachland Creek) case study as illustrative of the opportunities and challenges associated with the Province's new Forest Landscape Planning (FLP) process.

Extension and Community Engagement

Watershed Extension at the University of British Columbia, Okanagan

The Watershed Research and Extension Program serves as a bridge between communities and the university, supporting partnerships defined by mutual respect and reciprocity. This program is managed by our Watershed Research Extension Facilitator and housed in the Department of Earth and Environmental Sciences.

The Watershed Research and Extension Program is focused on:

- Fostering and maintaining long-term community partnerships to promote mutually beneficial collaborations and project development;
- Serving as a conduit for knowledge exchange;
- Advancing community-engaged partnerships, research initiatives, and funding opportunities;
- Facilitating student enrichment.

Meet the Watershed Research Extension Facilitator

Marni Turek

Marni Turek is the Watershed Research Extension Facilitator in the Department of Earth and Environmental Sciences in the Irving K. Barber Faculty of Science. Marni has over 27 years of experience working on a wide range of sustainability related initiatives in multiple sectors, including local government, not-for-profit, junior mineral exploration, collaborative watershed-based organizations and academia. Catalyzing opportunities to bring people together across disciplines and sectors to create value-added partnerships and progress towards achieving shared goals has been at the core of Marni's work. In her role as the Watershed Research Extension Facilitator, she works to create programs to increase knowledge sharing opportunities and engage with the community on water and watershed related topics. Marni coordinates the Watershed Research and Extension Program and provides facilitation and extension support to the Watershed Ecosystems Project.

The Watershed Research and Extension Program convenes and facilitates engagement and knowledge exchange opportunities, provides research facilitation for the day-to-day operations of the Watershed Ecosystems Project, and fosters long-term relationships.

Next Steps

Continuation of Existing Research Activities (2025 – 2026)

At the end of October 2025, the WEP will have completed its first phase of operation. While some research teams have presented their final results, others are working with longer timeframes and are still in development. We will continue to work on the existing research activities described in this interim report, host workshops and other engagements with syilx communities, local government representatives, and interested parties to communicate project outcomes and discuss future steps together; as well as training and extension opportunities on Syilx values and the findings of ongoing research in the *sqʷʔa* (Peachland Creek) watershed.

Develop Interdisciplinary Publications (2025 – 2027)

The Watershed Ecosystems Project team is working together to create a series of papers that reflect integrations between the research activities around the following central themes of:

- Watershed Ecosystem Science (research at a watershed ecosystem scale);
- Thresholds and Resilience; and
- Governance and Syilx Values.

Host Collaborative Watershed Governance Workshop Series (Fall 2025)

As part of the continued partnership development and governance evolution of the *sqʷʔa* (Peachland Creek) watershed, a workshop series will begin in the fall of 2025 – in partnership with syilx communities, the District of Peachland – which will support the collaborative design of an inclusive, co-governance entity for the watershed. This workshop series will identify collective priorities and goals for the watershed, engage and coordinate watershed leadership, and identify a potential structure for watershed co-decision making with pathways for sustainable funding.

As an extension of the research partnerships established through the Watershed Ecosystems Project, the Governance team, with support from the Syilx Knowledge team, has applied for funding through the MITACS Accelerate program to undertake a collaborative governance workshop series tentatively scheduled for the fall of 2025. The proposed project catalyzes the relationships and data amassed in the Watershed Ecosystems Project pilot phase to position sqʷʔa (Peachland Creek) watershed, on the provincial stage, as an ideal case study illustration of the variety of complex socio-ecological challenges faced by multi-use, source (drinking) watersheds throughout the province, and the opportunities here for the implementation of a collaboratively designed, co-governance entity.

Establish a Centre for Watershed Ecosystems (November 2025 – November 2026)

We are excited to be developing a UBC Okanagan Centre for Watershed Ecosystems to support the ongoing research activities and partnerships of the Watershed Ecosystems Project and enhance our ability to work with community partners across disciplines and institutions, towards more sustainable and respectful relationships with water and all that it sustains. Our ambition is to create a unique centre that promotes interdisciplinary, collaborative, and community-based research on critical environmental, social and economic processes in relation to water and watershed ecosystems.

Moving into x̌əl sic snpax̌nwixʷtn (Fall 2026)

We are thrilled that the Watershed Ecosystems Project has been selected to be a part of the inaugural community in x̌əl sic snpax̌nwixʷtn, a new collaborative space for engagement currently under construction at UBC Okanagan. x̌əl sic snpax̌nwixʷtn – an Nsyilxcn name generously gifted to UBC Okanagan from the En'owkin Centre – means *for the purpose of new innovation in a place where people work together to enlighten and inform each other*.

Set to open in November 2026, the building will be a unique space dedicated to bringing together researchers, scholars, students and the community. It will be UBC Okanagan's biggest platform for interdisciplinary research, promoting team-based approaches to solve complex problems, and supporting collaborations with Indigenous partners, community members and industry.

x̌əl sic snpax̌nwixʷtn will symbolize and cultivate UBC Okanagan's substantive commitment to Truth and Reconciliation and partnerships with the Syilx Okanagan Nation, and will be home to our Interior Salish language fluency programs and the Centre for Contemporary Interior Salishan Studies. Indigeneity has been a guiding principle for this building at every stage of planning and design, with a vision to incorporate syilx knowledge and values, as appropriate, across research and learning programs in the building.

This will be an incredible opportunity for the Watershed Ecosystems Project team to continue to advance both internal and external relationships.

Planning for the Future: Mapping Out the Long-Term Vision (November 2025)

The Watershed Ecosystems Project team intends on continuing our collaborative research on emerging and critical topics (e.g., thresholds, resilience, integrated modelling, ecosystem-based governance) and further expand the research scopes/scale.

The Watershed Ecosystems Project team has been reflecting on progress and lessons learned to date and is using this to inform next steps, future directions and a long-term vision over the next 3 – 5 – 10 years, and will identify resources needed and future funding opportunities to support this vision. Opportunities for knowledge exchange and extension will be identified.

Our long-term goals are to:

- Build and maintain lasting and respectful relationships with the community;
- Establish a center/ institute on watershed ecosystems (underway);
- Advance watershed ecosystem science “Watershed Ecology”; and
- Consider a new journal on Watershed Ecosystems.

A funding strategy will be developed and we will seek out external funding to advance the work over the longer term. We have been actively pursuing funding to advance longer-term goals and will be applying for other grants to support the longer-term directions of the Watershed Ecosystems Project in the coming year. The Watershed Ecosystems Project will maintain a strong relationship and partnership with sqʷʔa (Peachland Creek) communities, and will explore the implementation of the sqʷʔa (Peachland Creek) process in other watersheds across the Okanagan basin. The Watershed Ecosystems Project team is expected to expand, and integrate additional fields and activities of research inquiry.

Contact Us

We are keen to hear your thoughts and engage with you.

For questions, comments or thoughts on this interim report, or to get in touch with the team, please contact:

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To learn more about the Watershed Ecosystems Project, please visit our website:

https://watershed-ecosystems.ok.ubc.ca/

To receive updates via email, you can sign-up for our electronic newsletter on the website.