Lower Fraser Fisheries Alliance – Climate Adapt and Coastal Restoration Project – Phase 3

A framework for prioritizing climate change adaptation strategies in the lower Fraser River Basin

Prepared for Lower Fraser Fisheries Alliance

ESSA

Climate Adapt and Coastal Restoration Project – Phase 3

A framework for prioritizing climate change adaptation strategies in the lower Fraser River Basin

June 27, 2021

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Lower Fraser Fisheries Alliance

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Cover Photo: Lower Fraser River © 2019 Don Filmer

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Citation: **Porter, M., M. Nelitz, and A. Thompson.** 2021. Climate Adapt and Coastal Restoration Project – Phase 3: A framework for prioritizing climate change adaptation strategies in the lower Fraser River Basin. Final report prepared by ESSA Technologies Ltd. For the Lower Fraser Fisheries Alliance.

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Acknowledgements

The authors would like to thank the representatives of the many First Nations within the LFFA Planning Areas who were good enough to provide their valuable time and knowledge to support this process through formal surveys and/or online webinar discussions. We recognize that effective engagement with the communities is difficult in this time of COVID-19 so we are very appreciative of the flexibility you have shown to assist us in the exercise.

We would also like to recognize Zoetica Environmental Research Services Ltd., Tracy Cone and Sue Grant of Fisheries and Oceans Canada, Mike Pearson of Pearson Ecological, Riley Finn of the UBC Conservation Decisions Lab, and the Pacific Salmon Foundation for their scientific inputs to the project.

Finally we thank the First Nation Adapt program, Crown-Indigenous Relations and Northern Affairs Canada, and Fisheries and Oceans Canada for funding support.

Executive Summary

The Lower Fraser river is predicted to face repeated and severe impacts from future climate change such as flooding, sea level rise, and water temperature increases. The aim of the Lower Fraser Fisheries Alliance (LFFA) Coastal Restoration and Climate Adapt Project (hereafter referred to as the Project) is to support LFFA member Nations in planning for, and dealing with, the impacts of climate change by focusing on the potential impacts of climate change on salmon habitats that support First Nations fisheries. Mapping and climate vulnerability assessments within the Project are intended to provide information about:

- Areas in the lower Fraser that have greater priority/value to First Nations fisheries
- Existing and future threats to First Nations fisheries and fish habitat
- Areas that are most vulnerable to climate change impacts

This information will be used to develop a First Nations driven climate change adaptation plan that can help inform recommendations for future adaptation actions (e.g., habitat restoration, management responses, etc.) and research needs (e.g., environmental monitoring). This report describes work undertaken for Phase 3 of the Project which focused on the development of a framework for prioritizing climate change adaptation strategies within LFFA Planning Areas. Development of the adaptation project prioritization framework within the Project was guided by input provided from the LFFA communities.

Phase 3 analyses to support the prioritization framework leveraged the Intergovernmental Panel on Climate Change (IPCC) framework for characterizing climate change vulnerability and sought to develop associated indicators that could represent the **exposure** of Pacific salmon freshwater habitats to current and future climate change impacts, the **sensitivity** of Pacific salmon and their habitats to these disturbances, and the **adaptive capacity** of salmon populations and their habitats to respond to climate change. Information in regard to these three elements of climate change vulnerability was obtained from prior landscape-scale analyses undertaken in earlier phases (1 and 2) of the Project, new GIS-based analyses and modeling undertaken for Phase 3 of the Project, information on local salmon habitat issues from past LFFA surveys, and further consultation with LFFA Planning Area representatives during a series of Phase 3 webinars undertaken in the fall/winter of 2020.

Decisions on the most useful indicators to develop for evaluating climate change vulnerability and on key habitat adaptation/restoration priorities to consider were informed by representatives for each LFFA Planning Area. It was recognized that current budget constraints required prioritizing the types of restoration actions to consider in the near-term for addressing salmon habitat issues. Planning Area representatives suggested a near-term focus on identifying/addressing Planning Area issues relating to impaired watershed inputs, disrupted fluvial geomorphic processes, and local habitat degradation. Indicators developed during Phase 3 were intended to support evaluations of issues/conditions in relation to these three elements (i.e., watershed inputs, fluvial geomorphic processes, and local habitat) and supplement the detailed local knowledge of watershed issues that was provided by Planning Area representatives. Issues related directly to salmon population impacts (e.g., harvest, hatcheries) and biological interactions with salmon (e.g., predators, competitors, disease), while also important concerns, were not considered within this phase of the Project.

Quantitative GIS-based indicators assembled or developed within the Phase 3 climate vulnerability analyses and linked to LFFA watersheds (as delineated by the province's 1:20K FWA Assessment Watersheds layer) included multiple **"exposure"** indicators relating to different landuse impact categories – Watershed Inputs (i.e., roads, roads on steep slopes, aggregate and mineral mines, railways, pipelines, urban development, rangeland, wastewater discharges, agricultural development), Fluvial Geomorphic Processes (i.e., ECA, points of diversion, second growth forest <60 years old, placer mines), Habitat (i.e., stream and lake riparian disturbance, major dams, roads/stream crossings, passage barriers, total land cover disturbance, contaminated sites), **"sensitivity"** indicators relating to the likelihood of response when exposed to disturbance - Habitat Sensitivity (i.e., surface area of lakes and wetlands, drainage density ruggedness, landslide risk, flood risk, glacier influence), Population Sensitivity (i.e., Salmon Conservation Unit status), and **"Adaptive Capacity"** indicators relating to the ability of the system to decrease exposure or reduce sensitivity to disturbances - Population Adaptive Capacity (i.e., salmon escapement/productivity, salmon distribution extent), Habitat Adaptive Capacity (i.e., parks and protected areas, habitat quality ratings).

Metric values for each indicator were summarized within LLFA Study Area watersheds using R program statistical packages "terra", "sf", and "raster". Each metric was split into quintile values to define watershed benchmarks for comparing the "relative" status of individual indicators across the entire LFFA Study Area or within each of the four LFFA Planning Areas (i.e., Harrison Watershed – Mid Reach Fraser River, Chilliwack, Fraser Canyon, or Lower Fraser River Approach). Results in this regard are to be used in a comparative sense: a watershed's rating for an indicator indicates how it scored/ranked when compared to all other watersheds within the geographic area of comparison. Scored indicators were then aggregated/combined into more easily interpretable indices for each of the indicator categories for use within the prioritization framework. For index development individual indicators were summarized within each of the indicator categories (Exposure, Sensitivity, and Adaptive Capacity) and sub-categories (e.g., Habitat Sensitivity). Within each sub-category the value of the metrics used for each indicator were averaged to determine an overall sub-category value. Finally, within each category, the values of sub-categories were then summed to produce an overall final scored index value for Sensitivity, Exposure and (Ecological) Adaptive Capacity within each LFFA watershed.

A unique R-coded Watershed Vulnerability Tool was then developed for the Project and used to first filter all watersheds according to their Exposure score. Watersheds above a user-defined Exposure threshold value (e.g., the 50th percentile, which corresponds with a specific Exposure score) are passed through for further evaluation, and the remainder of watersheds are filtered out. Next, within the watersheds that are retained, those that are above a user-defined Sensitivity threshold value are passed through, and the remainder are filtered out. Finally, the remaining watersheds above a user-defined Adaptive Capacity threshold value are then selected and mapped as the final priority watersheds to consider in the near-term for restoration or adaptation actions. This filtering mechanism in the Tool is flexible and indicator category threshold values can easily be adjusted, as can the order of prioritization operations (e.g., Sensitivity or Adaptive Capacity could be the first filter if desired).

In addition to the development of broad-scale indicators and associated indices within the framework for defining the vulnerability status of LFFA Study Area watersheds the locations of specific local areas of concern were summarized from discussions with Planning Area representatives and mapped as precisely as possible within each watershed. These sites were identified as potential sites of concern with regards to fish habitat issues within each of the LFFA Planning Areas. These provide a next level of information for adaptation/restoration prioritization (i.e., identifying areas within priority watersheds that could become the focus for implementing targeted restoration actions to address limiting factors and improve local resistance/resilience to climate change impacts). As a final analytical step in the prioritization process the locations of issues of local concern can be overlaid with priority watersheds identified from the watershed-level indicator evaluations/filtering to identify particular sites/areas within watersheds to target/concentrate mitigation or restoration efforts and help inform the specific actions that could be considered to best restore habitat functioning and promote adaptation to climate change impacts.

For our initial prioritization efforts within Phase 3 using the Watershed Vulnerability Tool we used general defaults in our scoring of Sensitivity and Adaptive Capacity indicators, in that we used the pooled scoring across all salmon species combined, rather than scoring for individual salmon species (although the Tool does allow that level of specificity if desired). Within each LFFA Planning Area we progressively adjusted indicator category scoring thresholds for selecting priority watersheds until we ultimately determined a percentile threshold to use that captured at least 5 identified sites of local concern (as previously identified by LFFA representatives) across the high priority watersheds defined within each of the four LFFA Planning Areas. This meant that different thresholds for prioritization were used in each Planning Area, although the same percentile threshold was used for the Exposure, Sensitivity, Adaptive Capacity indicator categories in a particular Planning Area (e.g., 0.5 for Lower Fraser Approach, 0.2 for Fraser Canyon, etc.). This initial filtering process identified 6 priority sites to consider across 5 watersheds in the Lower Fraser Approach Planning Area, 7 priority sites to consider within 1 watershed in the Harrison Watershed – Mid Reach Fraser River Planning Area, 6 sites to consider across 5 watersheds in the Fraser Canyon Planning Area, and 9 sites to consider across 5 watersheds in the Chilliwack Planning Area.

An additional recommended element of the prioritization framework is to incorporate a multi-criteria decision analysis (MCDA) framework for helping to select which subset of prioritized sites to move forward with on for implementation. This represents a final piece of a multi-level approach involving prioritization initially across watersheds (as per use of the Phase 3 Watershed Vulnerability Tool) within a basin-wide strategy, followed by prioritization of potential projects within watersheds. To assist with Planning Area project prioritization we developed an Excel-coded LFFA Project Prioritization Rubric Tool that can be used by LFFA Planning Area representatives in a workshop setting to score and compare potential projects based on a set of defined ecological, social, and technical/financial criteria; thus allowing a systematic qualitative/semi-quantitative evaluation of the merits of different proposed adaptation/restoration projects.

1. Introduction

The Lower Fraser Fisheries Alliance (LFFA) is comprised of thirty (30) First Nation communities (see **Appendix A**) present from the mouth of the Fraser River to the Fraser Canyon, with a stated mission to promote and support the management of a robust and expanding fishery for the First Nations of the Lower Fraser River (Matheson Hill Consulting 2012). The Fraser River has historically been among the greatest salmon producing river systems in the world, and many First Nations people, with a long history of reliance on fishing, reside within the Fraser River Basin. The Lower Fraser river is predicted to face repeated and severe impacts from future climate change such as flooding, sea level rise, and water temperature increases. The aim of the Lower Fraser Fisheries Alliance (LFFA) Climate Adapt Project is to support member Nations in planning for, and dealing with, the impacts of climate change on their fisheries by focusing on the potential impacts of climate change on salmon habitats that support First Nations fisheries. The LFFA's Coastal Restoration Fund Project also aims to prioritize restoration projects for member Nations as part of a First Nations-led Fish Habitat Strategy.

2. Goals of LFFA Climate Adapt Project and Coastal Restoration Project

The Coastal Restoration and Climate Adapt Project is designed to inventory and map environmental and cultural values of key importance to First Nations fisheries and relate these to the potential impacts of climate change. Specifically, the mapping and vulnerability assessments within this project are intended to provide information about:

- Areas in the lower Fraser that have greater priority/value to First Nations fisheries
- Existing and future threats to First Nations fisheries and fish habitat
- Areas that are most vulnerable to climate change impacts

This information will be used to develop a First Nations driven climate change adaptation plan that can help inform recommendations for future adaptation actions (e.g., habitat restoration, management responses, etc.) and research needs (e.g., environmental monitoring). The Climate Adapt Project is being conducted in 3 phases, the first two of which have been completed in previous years and the third of which (the Adaptation Strategy) is the focus of current work and reporting:

- 2017-18 Phase 1: Mapping and Vulnerability Assessment
- 2018-20 Phase 2: Community-based Adaptation Planning Meetings
- 2020-21 Phase 3: Adaptation Strategy

The LFFA was successful with a DFO Coastal Restoration Fund grant in 2019. The primary purpose of this funding was to begin developing a First Nations lead Coastal Restoration Strategy. As many of the Nations in the lower Fraser region have direct interest in restoring lost habitat, this funding provided an opportunity to bring together a wide array of Indigenous Knowledge from the Lower Fraser First Nations and combine it with western science, thus creating one of the first collaborative First Nations restoration strategies of its kind in the region. Partnering with PSF, the project also aims to develop online habitat mapping resources to outline current restoration efforts across the region and further highlight the importance of this approach in reversing the current declines of all stocks of Pacific Salmon. Funding was provided to begin restoration work in Year 3, guided by this Restoration Strategy, to act as a framework for a collaborative approach to restoring lost or at-risk habitats. Recognizing the importance of climate change and its impact on Fraser salmon, the project has combined efforts with the LFFA Climate Adapt project to create a comprehensive recovery strategy for salmon. Since the goals of both projects are similar and since both projects require a prioritization process to plan for salmon recovery and adaptation, a joint prioritization exercise was undertaken to develop a First Nations led fish restoration and climate adaptation plan. By combining these two projects, the objective is to build a Climate

Adaptation and Coastal Restoration Strategy that encompasses both programs and addresses both biological and environmental concerns raised by the Nations using an adaptive management framework and a Watershed Vulnerability Tool developed for the project.

2.1 Framing the Context and Scope of the Climate Adaptation and Coastal Restoration Strategy

Building on the work undertaken to-date for the Climate Adapt Project and the Coastal Restoration Fund project, the intent within Phase 3 is to use a quantitative, indicator-based approach to better understand vulnerability to climate change and prioritize adaptation and habitat restoration opportunities for Pacific salmon in Lower Fraser watersheds. This approach is intended to leverage the Intergovernmental Panel on Climate Change (IPCC) framework for characterizing climate change vulnerability (Parry et al. 2007) and seek to represent (to the extent possible with readily available information) the current **sensitivity**[1] of Pacific salmon freshwater habitats to disturbance, their **exposure**[2] to current and future impacts, and the **adaptive capacity**[3] of salmon populations and their habitats to respond to the impacts of climate change (see **Figure 1**). To employ this framework it is important that the indicators to characterize sensitivity, exposure, and adaptive capacity are based on a life-history understanding of the potential bottlenecks on productivity of Pacific salmon in order to better identify the adaptation strategies/actions that would be most appropriate for addressing anticipated regional constraints on salmon survival and the particular locations where such actions would be of most benefit.

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[1] **Sensitivity:** the likelihood and nature of response when exposed to the effects of climate change. Sensitivity will be a function off factors such as salmon life history strategy, timing of life history events, abundance, distribution, etc.

[2] **Exposure**: the magnitude and spatial / temporal extent of the effects of climate change or associated disturbances. Exposure will be characterized by how climate drivers may change, how climatic changes might be affected by the inherent natural characteristics of watersheds, and the current level and nature of human stressors/pressures on salmon populations and habitats.

[3] **Adaptive Capacity**: the ability of a system to decrease exposure or reduce sensitivity to climate induced stresses. Adaptive capacity will be a function of the resistance/resilience of habitats to climate change impacts and the responsiveness/plasticity of salmon populations, as well as the responsiveness of humans to mitigate or avoid some of the adverse consequences of climate change.

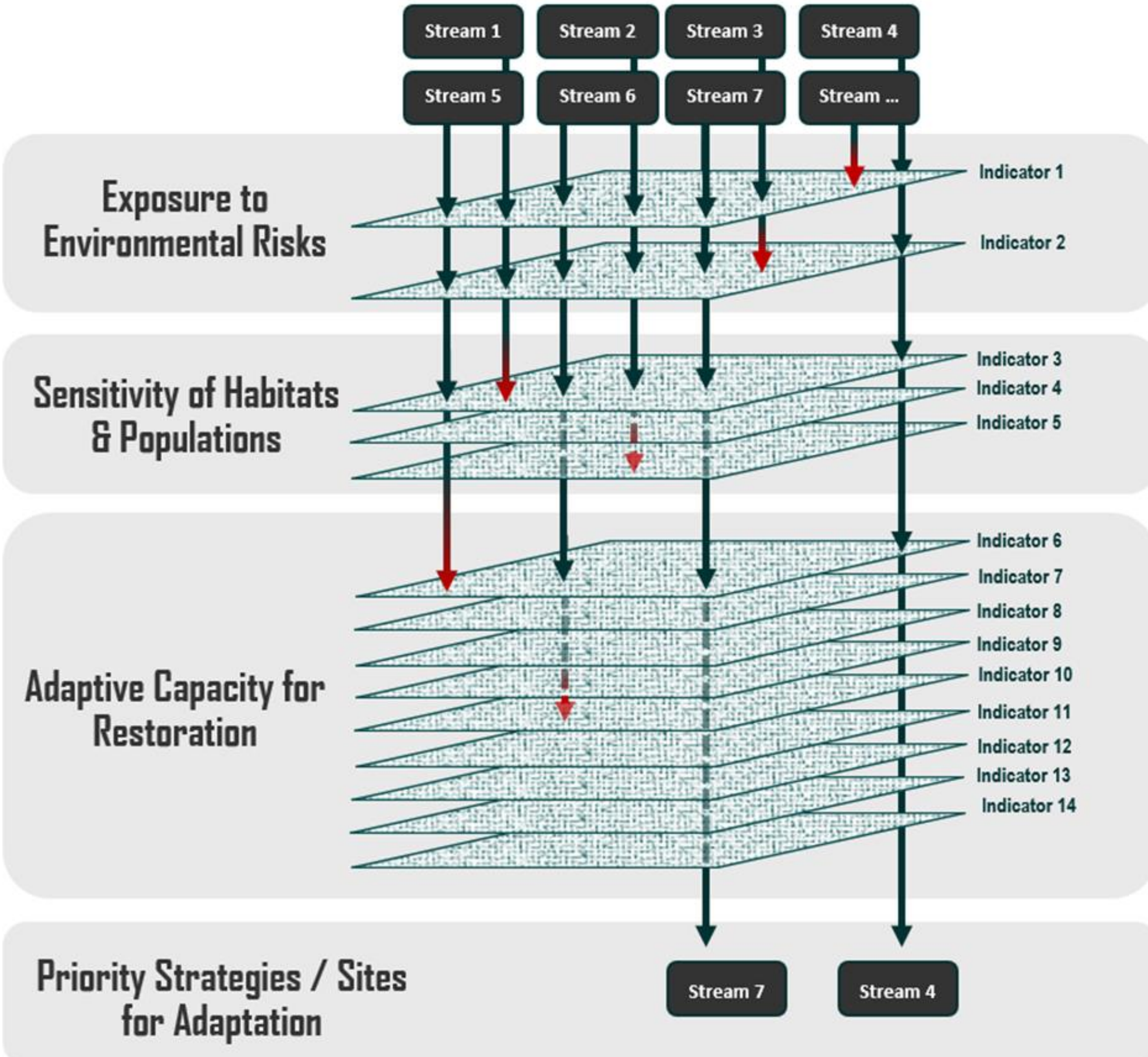

Figure 1 Conceptual illustration of the application of a framework for assessing climate change vulnerability and prioritizing climate change adaptation strategies/actions and the locations (e.g., particular watersheds, stream reaches, sites, etc.) for applying these strategies/actions.

An important first step in adaptation planning is to clarify the context and scope for focusing adaptation priorities. Phases 1 and 2 of the Climate Adapt Project provided an important foundation for understanding the context and scope of climate adaptation planning needs for Pacific salmon in the Lower Fraser. However, further information is required within Phase 3 of the project to allow development of a formal adaptation plan. Additional information needs include:

- Clarifying management context/objectives for adaptation: Management objectives reflect statements about the desired outcomes for "valued components" that LFFA decision makers are trying to achieve through their adaptation efforts or management actions. For example, management objectives may include restoring and/or protecting salmon habitats, maintaining habitats for other important fish species, building the capacity of First Nations communities, building a foundation of baseline knowledge about climate impacts and adaptation options, minimizing the overall cost of adaptation efforts, and/or clarifying the critical uncertainties that affect the ability of decision makers to help salmon adapt to the impacts of climate change.

- Clarifying units for vulnerability assessment, prioritization, and implementation of adaptation strategies: The five species of Pacific salmon have complex life histories that involve utilizing a variety of environments, at different locations, and times of the year across which the impacts of climate change will have different spatial and temporal scales of influence. Moreover, watersheds involve a nested hierarchy of spatial scales that represent salmon habitats in freshwater environments (i.e., nested units representing basin, watershed, tributary, and reach scales). As well, different adaptation strategies will have different spatial and temporal scales over which they can be implemented. These differences will have fundamental implications on the units of assessment and units that form the basis for prioritizing adaptation strategies. The LFFA divides the overall Coastal Restoration and Climate Adapt Project study area (**Figure 2**) into the following four planning units (**Figure 3 - 6**): (1) Lower Fraser River Approach, (2) Harrison Watershed - Mid Reach Fraser River, (3) Chilliwack Watershed, and (4) Fraser Canyon. These geographic delineations provide the foundational units/resolution for broad evaluations across the project area, but it will also be important to understand issues at finer scales to help focus assessment and prioritization efforts.
- Clarifying the scope of adaptation strategies to be considered for **adaptation.** There are a variety of impacts of climate change on salmon and many adaptation strategies that can be used to help Pacific salmon adapt (Nelitz et al. 2007). Adaptation strategies should focus on addressing bottlenecks to Pacific salmon life history stages that are most likely to be influenced by the impacts of climate change, such as water temperature, flow, habitat, and individual fish related measures (e.g., riparian restoration, flow modifications and storage, physical habitat restoration, harvest reduction, or hatchery supplementation). It may not be possible, however, to assess the vulnerabilities to all future climate impacts, and it may not be possible logistically for LFFA to implement all strategies to address limitations on production of Pacific salmon in the Lower Fraser. It will be important to understand and focus on those adaptation strategies that are within the control and influence of the LFFA since each adaptation strategy will have different spatial boundaries and temporal horizons for vulnerability assessment and adaptation implementation. Understanding the scale and scope of adaptation strategies will also be important to ensure that the vulnerability assessment and prioritization of adaptation strategies consider indicators that reflect the potential opportunities associated with these adaptation strategies at the appropriate spatial and temporal scales.

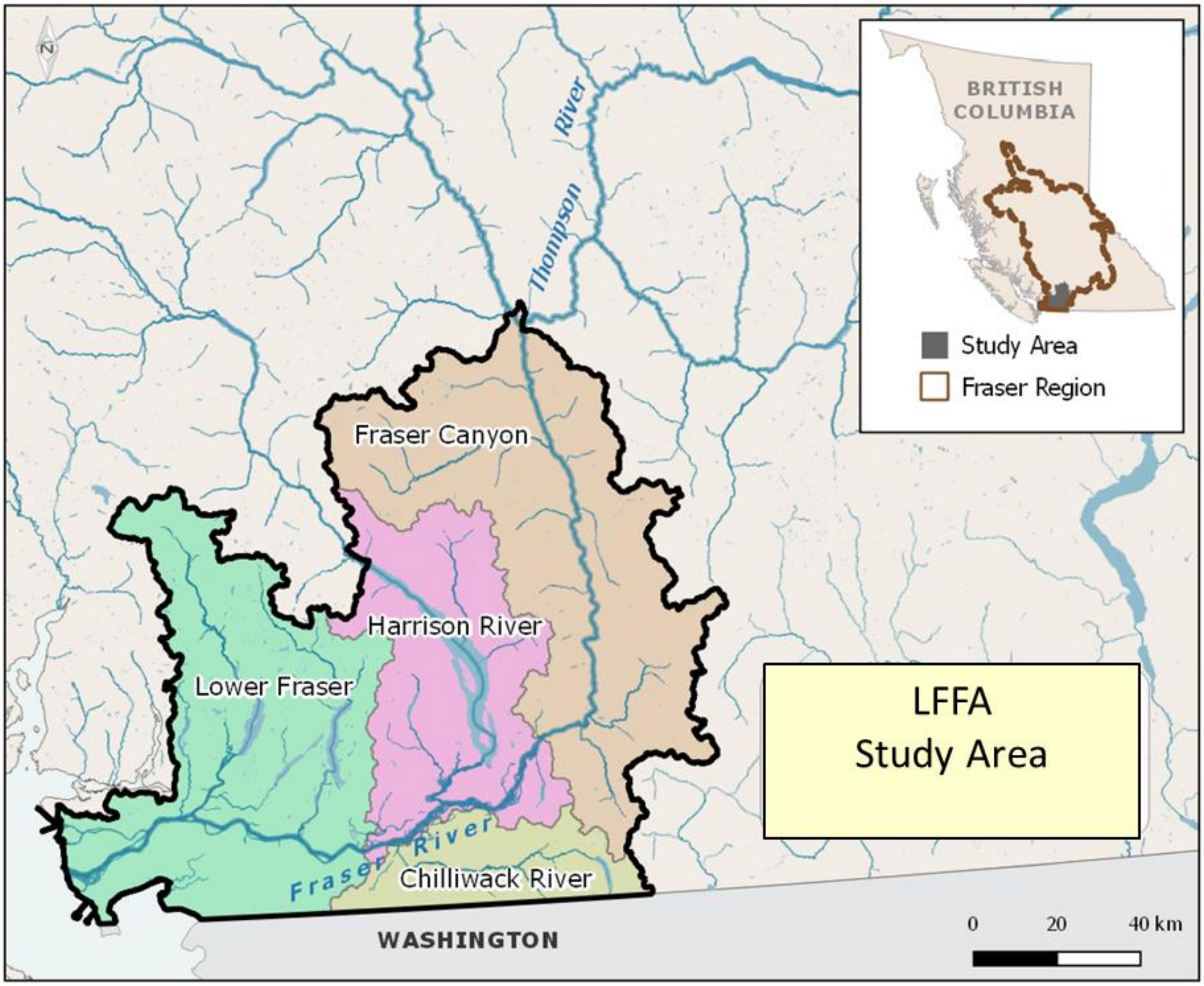

Figure 2 Map of the overall LFFA Climate Adapt Project study area and individual planning watersheds (Fraser Canyon, Harrison River- Mid Reach Fraser River, Chilliwack River, and Lower Fraser River approach).

Figure 3 *Map of the* ***Lower Fraser River Approach Planning Area*** *for the LFFA Climate Adapt Project (bounded area with darker green background).*

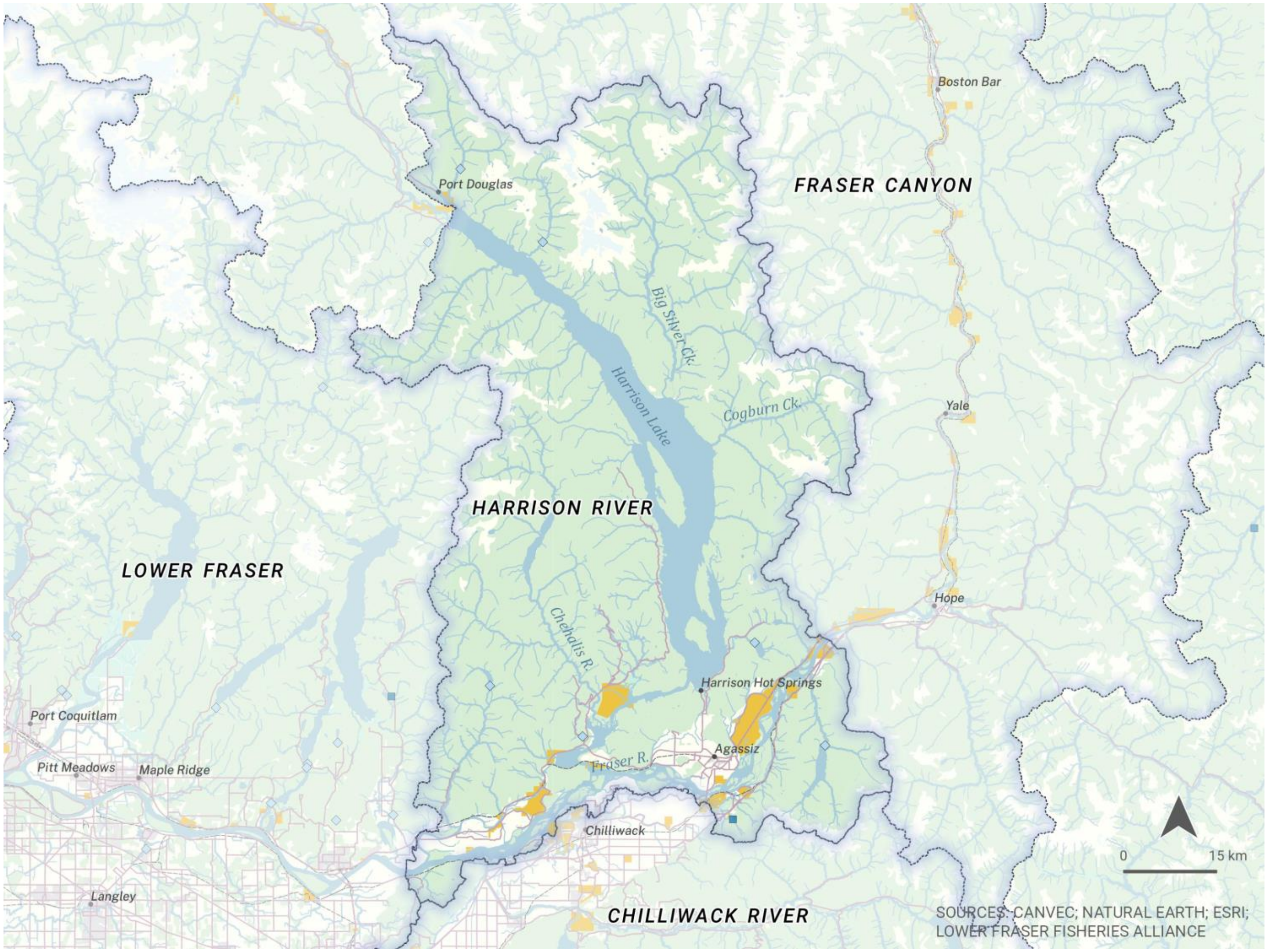

*Figure 4 Map of the **Harrison Watershed - Mid Reach Fraser River Planning Area** for the LFFA Climate Adapt Project (bounded area with darker green background).*

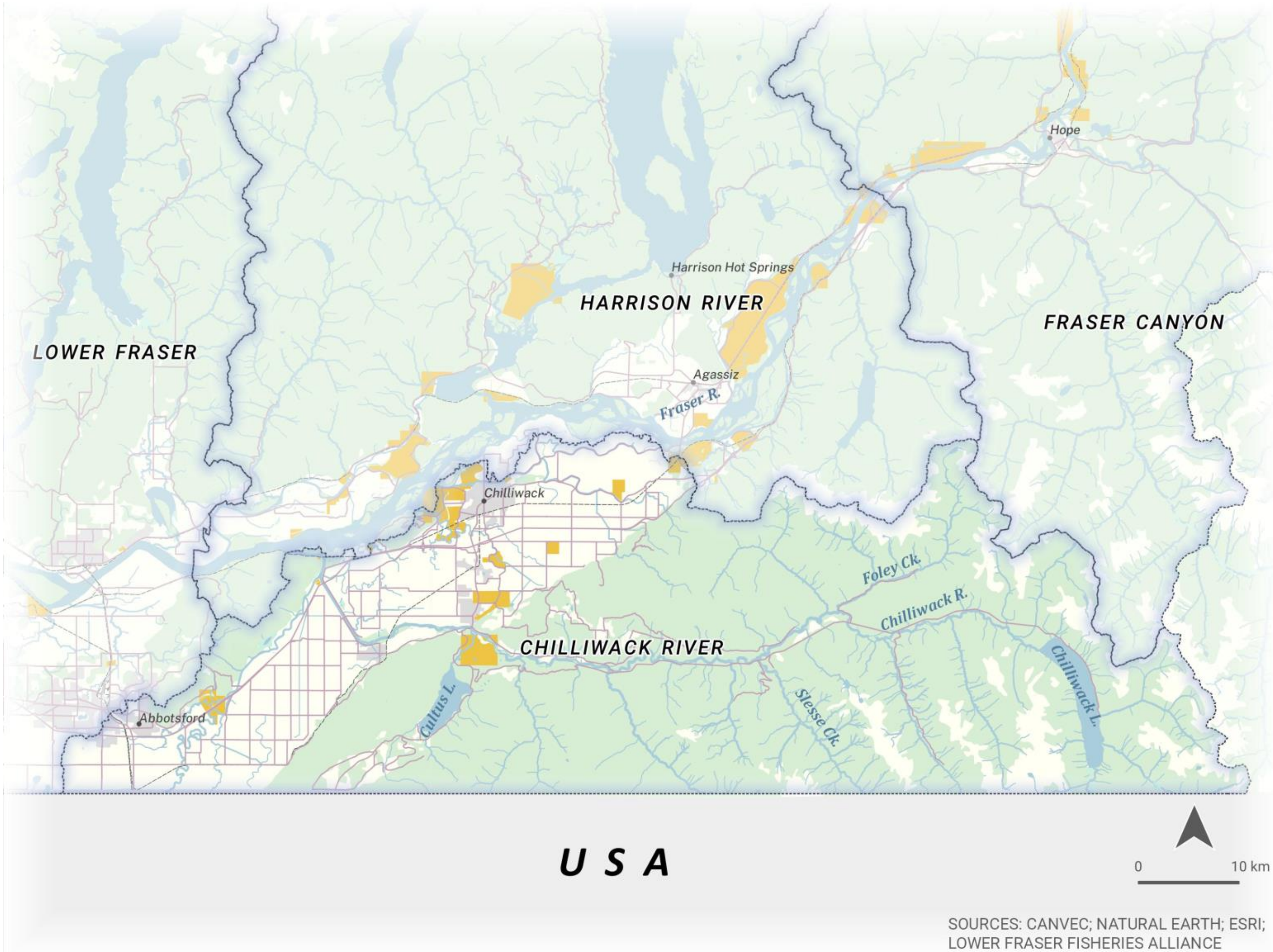

*Figure 5 Map of the **Chilliwack Watershed Planning Area** for the LFFA Climate Adapt Project (bounded area with darker green background).*

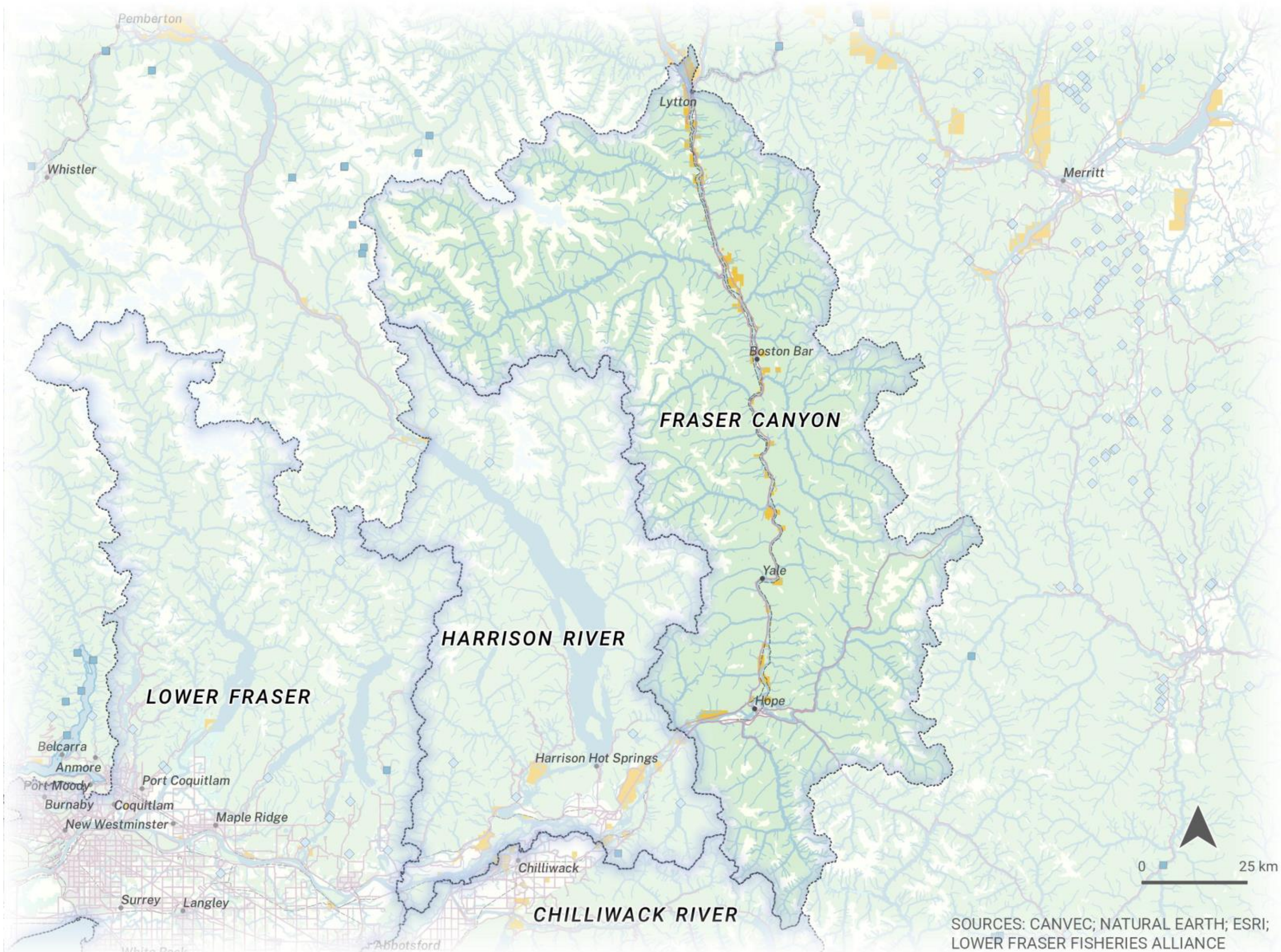

Figure 6 Map of the ***Fraser Canyon Planning Area*** *for the LFFA Climate Adapt Project (bounded area with darker green background).*

Development of the adaptation project prioritization framework within the Coastal Restoration and Climate Adapt Project was guided by input provided from the LFFA communities. Specific information and feedback solicited from LFFA communities in Phase 3 of the Climate Adapt Project included:

- Input to proposed context and scope elements of the adaptation strategy
- Input on specific indicators to consider developing for quantifying watershed "vulnerability" to climate change
- Input on specific issues and locations of concern within each LFFA Planning Area
- Feedback on the finalized framework for prioritizing adaptation strategies

3. Context and Scope for the Climate Change Adaptation and Coastal Restoration Strategy

To build the required elements of a prioritization framework for the Coastal Restoration and Climate Adapt Project within the defined study area, representatives from LFFA member communities in each Planning Area were asked a series of questions to help to define the context and scope for focusing future climate change adaptation priorities. Specific questions asked of Planning Area representatives were:

- What are the salmon species (current or extirpated) in your Planning Area?
- Are there specific salmon populations/stocks and/or life history stages/related habitats of particular concern?
- What are the associated values of importance for your Nation related to salmon populations and their habitats?
- What are the key current bottlenecks/limiting factors for salmon and their habitats in your Planning Area?
- What do you anticipate as key stressors for salmon and their habitats in your Planning Area under potential future climate change conditions?
- What are the key spatial scales of information to consider for assessing vulnerability to climate change?
- What would be the key climate change-related adaptation strategies/actions (both hard[4] & soft[5] infrastructure options) to consider implementing in your Planning Area?
- What do you see as useful criteria/conditions for evaluating success of adaptation strategies/actions that could be implemented within your Planning Area?

Responses to these questions were compiled from a SurveyMonkey questionnaire sent out to First Nation representatives and invited experts (Oct–Nov 2020), from LFFA/ESSA-led Zoom meeting webinars convened for each Planning Area (Oct–Nov 2020), and/or from interviews conducted by the LFFA with individual First Nation representatives as part of earlier Phase 2 data collection (June–Dec 2019). Information providers from each Coastal Restoration and Climate Adapt Project Planning Area are identified in **Appendix B(a)** and a summary of responses to these

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[4] **Hard Infrastructure:** Engineering or technology-focused innovations that can be implemented on-the-ground to either help salmon adapt to climatic changes, mitigate the effect of changes in habitats, compensate for climate-induced losses to salmon, or restore habitats affected by past deterioration in habitats.

[5] **Soft Infrastructure:** Changes in local governance, regulations, policy, or agency management approaches that encourage innovation and more efficient / effective use of society's hard infrastructure assets.

questions for each Planning Area is provided in **Appendix C**. A synthesis of key issues identified across the Planning Areas is presented in **Table 1**.

Table 1 Synthesis of responses to key themes/questions for the Coastal Restoration and Climate Adapt Project study area as identified through interviews/discussions with Planning Area representatives.

Theme	Study Area Synthesis	Individual Planning Areas
Salmon Species	Coho, Pink, and Chum are found in all Planning Areas Chinook and Sockeye are found in all Planning Areas but within Fraser Canyon Planning Area these species only present in the mainstem Fraser River during adult and smolt migration periods	See Appendix C for summary of species present within each Planning Area, including information about extirpated populations
Salmon populations or life history stages / associated habitats of key concern	Populations, life history stages, and habitats of key concern were unique to each Planning Area.	See Appendix C for summary of key populations of concern / associated habitats identified by participants specific to each Planning Area
Associated First Nation Values of key concern	Salmon harvest opportunities Cultural heritage of salmon as critical to First Nations identity Stewardship of salmon and salmon habitat diversity Reconnection and/or restoration of lost habitats Indigenous perspectives and practices acknowledged and incorporated in all development within First Nations lands / territories	See Appendix C for summary of key Values identified by participants specific to each Planning Area
Key *Current* stressor categories for salmon and salmon habitats	Restricted fish access/barriers to spawning and rearing habitats Limited and/or degraded spawning and rearing habitats Water withdrawals Decreased summer flows in tributaries High water temperatures Water quality impairment Degraded riparian condition Fine sediment infilling of tributaries / sloughs Overfishing (commercial/recreational) Accelerated water run-off / associated scouring flows Predation from coastal predators and invasive freshwater fish species	See Appendix C for summary of key current stressors identified by participants specific to each Planning Area

	Competition with hatchery fish Decreased stream productivity (due to diminished escapements and return of marine nutrients) Limited mainstem holding areas for migrating salmon adults and smolts	
<u>Key</u> anticipated <u>*Future*</u> stressors for salmon and salmon habitats under changing future climate conditions	Increased incidences of fish disease Increased frequency and magnitude of peak flows / associated increased scouring of salmon redds Increased frequency and magnitude of low flow periods / associated stream drying Increased water temperatures Restricted access to tributaries due to lower flows, debris blockages Increased abundance of invasive fish species Further impaired water quality (DO, fine sediment) Degraded suitability of spawning and rearing habitats Changes in rates of fish growth Changes in adult run timing and/or time of outmigration leading to altered predation, competition, or food availability	See Appendix C for summary of key anticipated future climate change-related stressors identified by participants specific to each Planning Area
Key suggested climate change adaptation strategies/actions to pursue	**<u>Hard Infrastructure Strategies</u>** ***Connectivity*** Remove physical barriers to fish passage Improve habitat connectivity by opening up sloughs, dikes, etc. ***Population Manipulation:*** Transplant salmon into extirpated or new refuge areas Expand or build new First Nations co-managed hatcheries to supplement salmon populations ***Habitat Improvement:*** Restore key habitats Plant riparian vegetation	See Appendix C for summary of key adaptation strategies suggested by participants specific to each Planning Area

	Enhance instream habitat Re-engineer mainstem reaches to create slower flow, mainstem resting areas for migrating salmon Move dikes back from rivers ***Water Quality:*** Implement low impact irrigation practices Implement low impact grazing practices Install water meters Manage cold water releases (where possible) Enrich streams/lakes with nutrients (where needed) Reduce impervious surfaces and other measures to reduce surface water runoff ***Water Quantity:*** Build and manage additional water storage capacity Implement low impact forestry practices Recycle water in industry Manipulate surface water / groundwater interactions Require effective operating licenses for water management <u>**Soft Infrastructure Strategies**</u> ***Population Manipulation:*** Coordinate / implement improved / integrated fisheries management frameworks for salmon ***Water Quantity / Quality:*** Improve storm drainage management plans (which are currently designed to get rid of water quickly) to achieve a more natural hydrologic state (i.e., infiltration, runoff) Develop coordinated flood response strategies based on the concept of water storage and integrating First Nation concerns around salmon as a central element	

	Require effective operating licenses for water management Develop regional water budgets Entrench ecosystem rights to water Improve partnerships around water / habitat stewardship ***Habitat Protection:*** Ensure protection of critical habitats Implement and enforce improved prescription-based habitat management (e.g., expanded riparian buffer zones) Compensate for unavoidable / non-mitigated project impacts Coordinate / implement improved planning frameworks Encourage local champions in the community to protect seasonal creeks in key drainages	
Relevant scales of information for climate change vulnerability assessments	***Site scale*** (e.g., culvert condition rating) ***Reach scale*** (e.g., stream specific condition rating) ***Watershed scale*** (e.g., extent of disconnected wetlands and streams, extent of Infilling, extent of riparian disturbance, etc. within a watershed) ***Multi-watershed scale*** (e.g., run timing, abundance, stock differentiation at different points along migration corridor)	
Locations of key concern	Locations of key concern were unique to each Planning Area.	See Appendix C for key locations of local concern identified specific to each Planning Area.
Hopes for the Climate Adapt Project	Vision of what things might look like with changing climate and how any impacts might be managed. A consensus strategy that many can come together under to effect change in the Lower Fraser An inventory of previous salmon habitat usage and preference An inventory of sites for potential repair or upgrading Improved working relationships between biologists and regional drainage program managers so that drainage engineers/managers can	See Appendix C for summary of hopes for the LFFA Climate Adapt Project identified by participants specific to each Planning Area

	ensure sufficient water storage/flood control AND protect salmon habitat. Creating a sense of ownership so that people living in the Lower Fraser will appreciate and protect the values that come from salmon and healthy watersheds A decrease in destructive resource management practices and better protection of regional fish and wildlife A process that can help coordinate and bridge gaps between governments (federal/provincial/Fraser Basin Council/FNs) to develop regional goals for restoring salmon habitats and populations Ultimately, the restoration of fish numbers locally and regionally	

4. Indicator Development and Structuring of the Prioritization Framework

The prioritization process for the Climate Adapt Project and Coastal Restoration Fund project focuses on evaluating and prioritizing adaptation strategies around which the LFFA should invest additional on-the-ground efforts. Building on the work done to-date within the Climate Adapt Project and the Coastal Restoration Fund project, the intent was to develop an indicator-based approach to further characterize vulnerability, and identify climate change adaptation opportunities for Pacific salmon within LFFA Planning Areas. These indicators[6] were used (as possible) to broadly quantify elements of sensitivity, exposure, and adaptive capacity in relation to Pacific salmon vulnerabilities in each of the LFFA Planning Areas; elements that have been identified/characterized through the ongoing discussions with Planning Area representatives. Information from these discussions will be integrated with supporting indicator development to clearly identify and understand what and where adaptation opportunities would be most beneficial for addressing the perceived constraints on salmon survival.

4.1 Organizing Structure

Figure 7 provides a simple organizing structure for visualizing the broad hierarchy of linked processes and stressors that can affect condition of fish habitats and associated fish communities in the Lower Fraser River Basin. Within the general framework presented here, various watershed inputs (e.g., water, sediment, large woody debris, nutrients) are considered to drive fluvial geomorphic processes (e.g., sediment transport/deposition/scour, channel migration, bank erosion, floodplain development, surface and groundwater interaction) that will determine physical geomorphic attributes and the structure and complexity of habitats in the basin. Habitat

[6] **Indicators** are measures of pressures, states, and/or responses used to depict condition of habitats or populations.

structure, quantity and quality (e.g., instream aquatic habitats, riparian habitat, wetlands, water quality, contaminants, migration barriers, etc.) will in turn drive biological responses and are important determinants of fish abundance, distribution, and community composition. Stressors on any of the key inputs or processes at different levels of the hierarchy could affect salmon populations either directly or indirectly. For example, a disease that kills fish would directly affect fish populations, while increased forestry activity would indirectly affect salmon through a cascade of changes - reduced shade in riparian zones, which would increase river temperatures, which may increase physiological stress on salmon. Even where stresses can act directly on fish populations (i.e., at the biological response level), it is likely that the degree of response will be affected by the condition of processes/attributes at the higher levels. Different stressors could also potentially act at multiple levels in the hierarchy. Assessments of condition could be undertaken directly at the level of biological responses, or at the higher levels of the hierarchy. Similarly (as illustrated in

Figure 7) restoration actions or improved management actions could be targeted to address key stressors identified at different levels of this hierarchy.

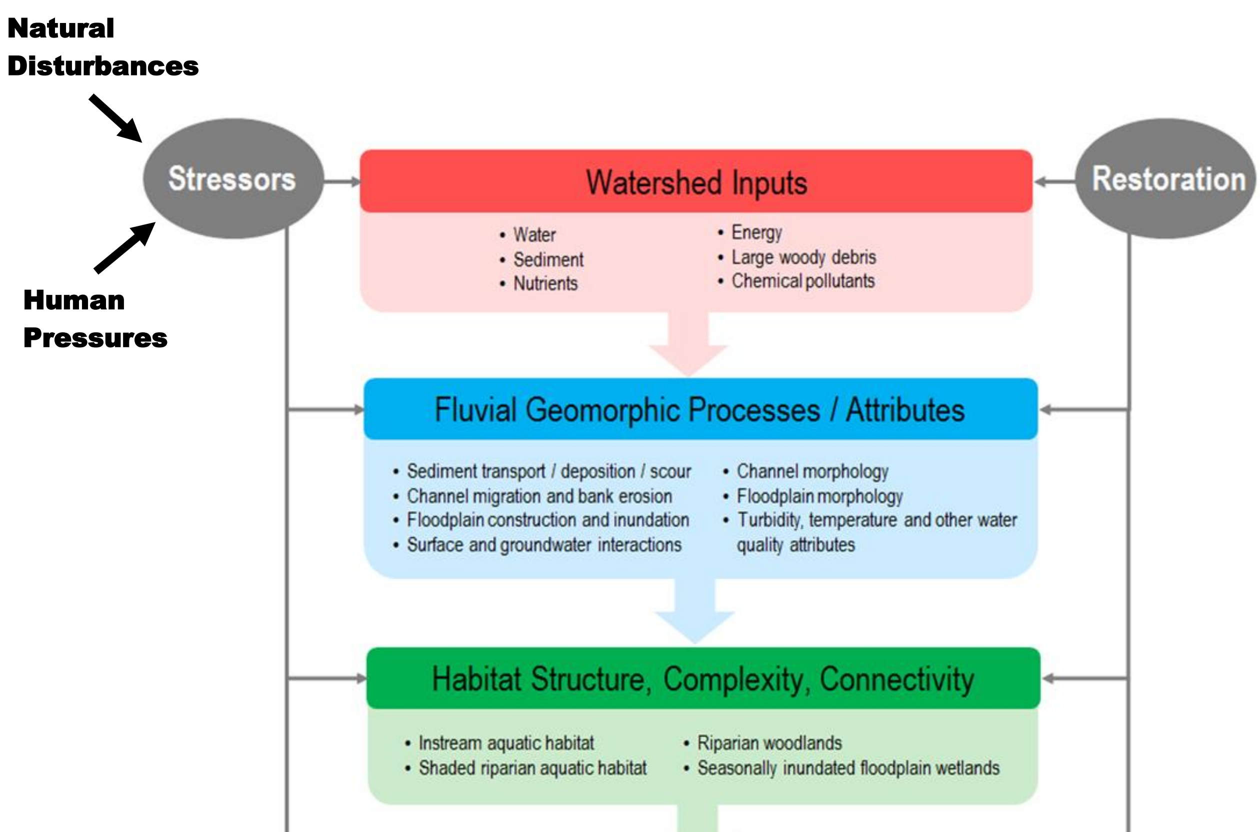

Figure 7 Hierarchy of inter-related impact linkages cascading from both natural and human-induced pressures/stressors on watershed and stream-scale/lake-scale processes that, ultimately, cause changes in the condition of fish habitats and associated aquatic communities. Cause-effect linkages flow from the top of the figure to the bottom, with stressors acting either indirectly or directly on the yellow box at the bottom representing fish and other aquatic biota. All these processes could be influenced by climate change to a significant extent. Identification of key stressors provides the foundation for designing restoration actions that could be employed at different levels in the hierarchy to remove, mitigate or compensate for these effects (Figure source: ESSA 2017).

The conceptual organizing framework is intended to be holistic in considering stressors and interactions amongst watershed inputs, water quality, fluvial geomorphic processes, physical habitat, and biological responses. In our experience, such decision support exercises must include assumptions about what will be included and excluded to keep the effort tractable. This involves seeking a balance of core performance indicators (CPIs)[7] for evaluation given the state of scientific knowledge, data availability, the types of decisions the effort is meant to support, and budgetary resources.

4.2 Restoration Priorities in the LFFA Study Area

Decisions on habitat restoration priorities and useful indicators to develop were informed by a second series of online webinars that were convened with LFFA Planning Area representatives between Nov. 10-20 of 2020. Representatives that provided information at or subsequent to these webinars are indicated in **Appendix B(b).** Indicators considered included those supported by data layers already developed during Phases 1 and 2 of the Coastal Restoration and Climate Adapt Project, as well as new indicators that were proposed as necessary to further reflect landscape pressures and salmon vulnerability across different spatial scales to assist in

[7] Although a wide range of candidate indicators of habitat and/or population and condition exist, only a smaller, critical subset can likely be reliably tracked given constraints on time and funding. The indicators selected for this purpose are known as **Core Performance Indicators (CPIs)**.

prioritizing adaptation measures. Potential indicators that could be used to evaluate salmon and salmon habitat condition and vulnerability are outlined in such reports as Stalberg et al. (2009) and Nelitz et al. (2007a, 2007b, 2011).

Guiding criteria for indicator selection/development can include such factors as data quality, spatial coverage, relevance, ease and feasibility of analysis, and time and cost (practicality) of compiling data for an indicator. **Figure 8** provides an illustration of how indicator status at different functional tiers can be used to help inform restoration action decisions. Within the current Coastal Restoration and Climate Adapt Project budget it may not be feasible in the near term to develop restoration projects that can address all five of the functional tiers, so Planning Area representatives were asked to identify their priorities for addressing perceived habitat issues in the study area (i.e., key near term focus of restoration efforts). Associated choices as to the priority indicators to develop within and/or across tiers for evaluating stressors and vulnerability were part of discussions during the second round of subbasin webinars. Indicator information is intended to support and supplement the detailed local knowledge of watershed issues provided by Planning Area representatives through the subbasin webinars.

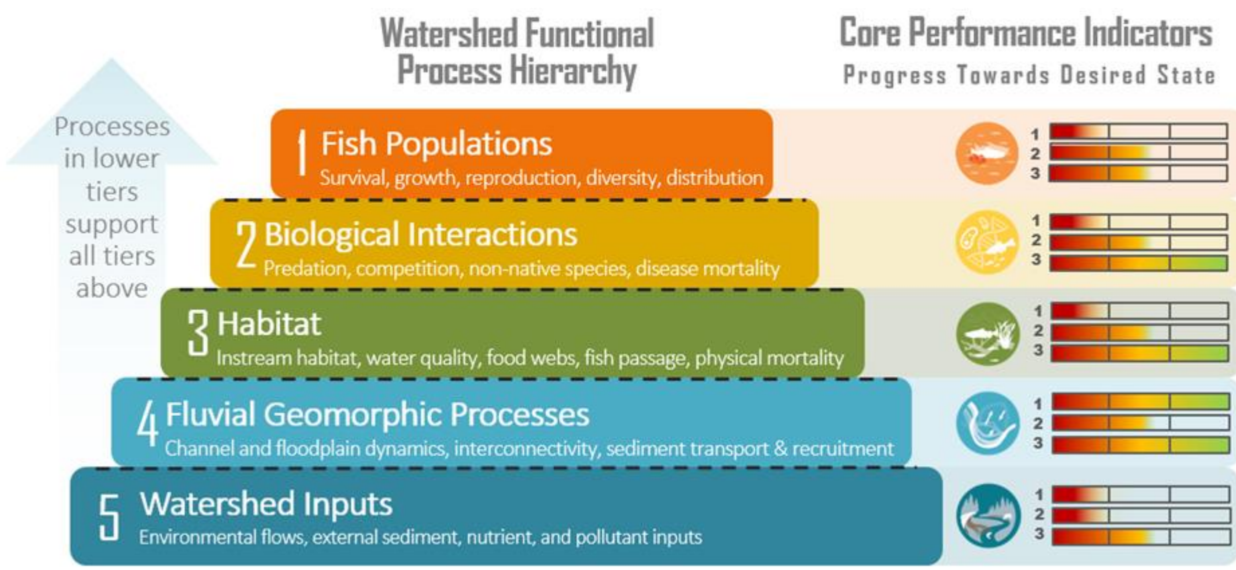

Figure 8 Schematic illustrating the concept of (bottom-up) restoration considerations by tier of watershed processes, where (although not always possible) priority should be given to addressing the underlying causes at or closer to the base of the functional hierarchy before focusing on restoration actions in the higher tiers that rely on this foundation (after Roni and Beechie 2013; Harman et al. 2012). (Figure source: ESSA 2019). Sets of measurable, core performance indicators (CPIs) for each functional tier should be identified and their state/status assessed (i.e., red, yellow, green condition) (as in Figure above) at relevant spatial scales for use as single or integrated measures of the performance of key processes at that particular functional tier.

Prioritization scoring provided by representatives for each LFFA Planning Area across each of the five functional tiers (i.e., Watershed Inputs, Fluvial Geomorphic Processes, Habitat, Biological Interactions, and Fish Populations) and rationales for their scoring are presented in **Table 2.** Average scoring for each tier provides a means of focusing the priorities for near-term restoration actions (recognizing that restoration efforts ultimately will need to span all five tiers). Consistently across all five LFFA Planning Areas the three highest priority ranked functional tiers for focusing near term restoration actions in the Study Area were Watershed Inputs, Fluvial Geomorphic Processes, and Habitat (although the priority order of these three tiers varied across Planning Areas).

*Table 2 Prioritization scoring of watershed functional process tiers for near term restoration focus in the LFFA Planning Areas. Functional tier scores range from 1 to 5 (**with 1 = highest priority and 5 = lowest priority**). Scores presented in the table represent the average of scores across participating representatives for each Planning Area (the number of participants for each Planning Area is indicated by "n" in the first column). The top three near term priority tiers for each Planning Area based on average scores are highlighted in yellow. Selected rationales for scoring decisions from Planning Area representatives are provided in the last column.*

LFFA Planning Area	Watershed Inputs	Fluvial Geomorphic Processes	Habitat	Biological Interactions	Fish Populations	Rationales
Fraser Canyon **(n = 7)**	2.4	1.4	2.3	4.6	4.3	• Protecting the water is the most important action. Once water is protected, everything else will fall into place. • Systems need to be in place to ensure supports for fish first, hen address fish specific issues. • Main issues are related to distribution of water flows - very high and very low flows. • Fish barriers a key issue – e.g., culverts • Not concerned about biological interactions currently as no other species is a threat and there is no disease. • Concerned about sediment inputs and impacts on floodplain

Harrison Watershed-Mid Reach Fraser River **(n = 8)**	3.0	2.8	1.6	3.9	3.8	• Without adequate habitat (in sloughs, creeks), cannot increase salmon numbers • Important to note protection of springs on hillsides - protect groundwater. • Fish passage -critical to remove culverts with bridges, provide fish friendly pumps and gates • Nutrients and agricultural pollution and flood infrastructure are major impacts in some areas • Lots of potential habitat available that can be fixed • Have lost 90% of chum spawning capacity in sloughs. • FIRST thing to restore - form and function
Chilliwack Watershed **(n = 8)**	1.8	2.6	1.8	4.3	4.6	• Would prioritize habitat and watershed inputs • Fish populations are important, but they need habitat first • Once Watershed Inputs and FGPs are addressed, could address hatchery production to increase populations

						• Don't focus on the fish until they have a supporting environment / habitat • Habitat key priority because of all the changes to the rivers • Habitats impacted by upstream processes and logging, many opportunities for restoration that could be effective • Fertilizer and manure inputs are a threat in parts of the watershed • May be too many hatcheries here and the focus should be shifted to pollution and habitat restoration • Flood infrastructure a problem; improving access will help if water quality can be maintained/improved. Both of these things are key.
Lower Fraser River Approach **(n = 4)**	1.5	2.25	1.5	4.75	4.25	• Fish passage is a key concern • Water flows are also very important - making sure there is sufficient water (and of sufficient quality) for salmon - especially in light of increasing demands for drinking water (by Vancouver). • Key concerns around stormwater runoff and pollution.

						• While Biological Interactions are a high concern rated this low because the ability to affect change within the watershed is low. • Habitat rated highest because of the severe loss of habitats within the lower Fraser - culverts, agriculture, linear infrastructure, etc. • There are issues around contamination (due to agriculture) • Despite concerns about biological interactions, feel as if we need to tackle the other issues first • Logging effects big issue in upper areas • Issues with flow timing and amounts due to flow diversions • Flood infrastructure is a huge impact • Diked areas represent biggest potential for habitat improvements (breaching etc.) • Big pollution problems • Fluvial - surface ground water interactions totally messed up because of roads.

4.3 Exposure and Sensitivity Indicators

Given the key near term restoration priorities (i.e., Watershed Inputs, Fluvial Geomorphic Processes, and Habitat) for the LFFA Study Area identified across each of the Planning Areas we focused our efforts on the identification, compilation and/or derivation of indicators that could provide direct information on the condition of each of these three elements across the LFFA Study Area or, alternatively, indicators that could serve as indirect proxies of their potential condition. LLFA Planning Area representatives provided commentary on potential indicators during the webinars of Nov. 10-20 of 2020.

Final exposure indicators subsequently selected for development in regard to climate conditions and for each of the three priority functional tiers (i.e., Watershed Inputs, Fluvial Geomorphic Processes, and Habitat) in relation to the effects of land use impacts are presented in **Table 3.** Indicators that relate to habitat and fish population sensitivity to climate change are presented in **Table 4.** Note that additional indicators could be developed/incorporated in future iterations of the framework (as funding allows) to better reflect all exposure and sensitivity concerns as expressed by Planning Area representatives but this initial list was considered a solid suite of relevant indicators for use in initial development of a prioritization framework.

Existing datasets to inform these indicators were compiled and new datasets were developed for the Coastal Restoration and Climate Adapt Project study area based on recommendations from Planning Area representatives on the key data inputs needed to prioritize adaptation strategies. This included drawing upon the salmon habitat and population data layers already developed during Phases 1 and 2 of the Climate Adapt Project (Bears et al. 2019), as well as other relevant information obtained or generated by ESSA for the project using readily available, broad-scale GIS data layers. Analyses have also leveraged a selected subset of the existing watershed-scale habitat information for the Fraser Basin that has been developed recently by the province’s Cumulative Effects Framework and by the Pacific Salmon Foundation, as well as a Fraser Basin data layer developed recently by Riley Finn (UBC – Conservation Decisions Lab) to support new evaluations of fish habitat conditions in Lower Fraser stream reaches.

Table 3 Indicators compiled/developed by ESSA for evaluation of LFFA Study Area watershed ***exposure*** *in relation to climate changes and to each of the three near term priority functional process tiers affected by land use activities.*

Watershed Functional Process Tiers	Relevant Stressors Across the LFFA Study Area	Key Related Watershed-scale Indicators	Data Sources
Climate Change (all functional tiers affected to some extent)	all stressors affected to some extent	Projected future climate: • Average maximum summer (Jun-Aug) air temperature • Total spring (Mar-May) precipitation • Total summer (Jun-Aug) precipitation • Total fall (Sep-Nov) precipitation • Total winter (Dec-Feb) precipitation • Annual precipitation as snow (between August in previous year and July in current year)	ESSA Technologies Ltd. (derived from ClimateBC data)
LAND USE			
Watershed Inputs	• Fine sediment erosion into streams • Water extraction • Excess nutrients (fertilizer, manure)	• Roads • Roads on steep slopes • Linear disturbance (railways, pipelines) • Wastewater discharges	• Pacific Salmon Foundation (Lower Fraser Salmon Explorer) • BC Provincial Cumulative Effects Framework

		• Mineral mines • Extent agriculture • Urban development • Agricultural development • Rangeland	
Fluvial Geomorphic Processes	• Decreased summer flows • Increased peak flows • Accelerated run-off from residential areas • Changed seasonal hydrographs • Increased flooding • Stream channelization	• Equivalent Clear-cut Area (ECA) • Young second growth • Water diversions • Placer mining tenures	• Pacific Salmon Foundation (Lower Fraser Salmon Explorer) • BC Provincial Cumulative Effects Framework
Habitat	• Fish passage barriers (dams, culverts, flood gates, pumps) • Infilled and drained wetlands and sloughs • Limited mainstem holding areas	• Riparian disturbance (streams and lakes) • Known passage barriers • Stream/road crossings (potential passage barriers) • Major dams/barriers • Contaminated sites	• Pacific Salmon Foundation (Lower Fraser Salmon Explorer) • BC Provincial Cumulative Effects Framework • Zoetica Environmental Consulting Services

	• Increased water temperatures • Fine sediment deposition • Impacted or lost riparian zones • Impaired water quality (DO, etc.) • Invasive clogging plants • Footprint of urban development	• Total landcover alteration	(Lower Fraser Climate Adapt Project)

*Table 4 Watershed-scale indicators compiled/developed by ESSA for evaluation of **habitat and population sensitivity** to climate change impacts in the LFFA Study Area.*

Indicator Category	Indicator	Data Sources
Habitat Sensitivity	Landslide Risk	Zoetica Environmental Consulting Services
	Flood Risk	Zoetica Environmental Consulting Services
	Water storage (lakes & wetlands)	British Columbia Cumulative Effects Framework (BC CEF)
	Drainage density ruggedness (DDR)	British Columbia Cumulative Effects Framework (BC CEF)
	Glacier influence	ESSA Technologies Ltd.
Population Sensitivity	Salmon Conservation Unit status	Zoetica Environmental Consulting Services

4.4 Adaptive Capacity Indicators

As indicated earlier adaptive capacity refers to the ability to decrease exposure or reduce sensitivity of salmon habitats and/or populations to climate-induced stresses. As such, adaptive capacity is a function of both the responsiveness of humans to mitigate or avoid adverse consequences of climate change and the potential responsiveness of salmon habitats and/or populations to mitigative actions (i.e., ecological responsiveness). This responsiveness will affect both the **resistance**[8] and **resilience**[9] of LFFA habitats to the impacts of climate change. Indicators that relate to habitat and fish population adaptive capacity to respond to climate change impacts are presented in **Table 5.**

*Table 5 Watershed-scale indicators for evaluation of the **adaptive capacity of salmon populations and salmon habitats** to respond to climate change impacts in the LFFA Study Area.*

Indicator Category	Indicator	Data Sources
Salmon Population Adaptive Capacity	Salmon escapement/productivity rating	Zoetica Environmental Consulting Services
	Salmon distribution	Pacific Salmon Foundation

[8] **Resistance** is the ability of a habitat able to maintain its characteristic biological, chemical, and physical features in the face of a temporary or prolonged disturbance, where high resistance results in low levels of impact (Eno et al. 2013).

[9] **Resilience** is the ability of a habitat to recover (over some period of time) its characteristic biological, chemical, and physical features after disturbance (Eno et al. 2013).

Salmon Habitat Adaptive Capacity	Parks & Protected Areas	DataBC
	Habitat Quality Rating	R. Finn (UBC – Conservation Decisions Lab)

Despite an understanding of the importance of adaptive capacity in regard to potential human responsiveness to climate change it can be difficult to predict or measure. Information that would relate to the relative level of human community responsiveness to climate change issues include:

- Funding available
- Planning processes in place
- Property owner access, land use restrictions
- Available infrastructure
- Training, skillsets available
- Available technologies
- Climate change awareness, understanding

These are elements that while difficult to define as broad indicators for general mapping purposes could instead be captured and quantified at the time of particular project proposals as an element of adaptive capacity screening. For example, in areas where prior assessment of exposure and sensitivity to climate change has suggested should be priorities for adaptation actions the adaptive capacity potential of proposed projects could be assessed based on both broader ecosystem benefits and the anticipated human community responsiveness, with human responsiveness characterized by quantifiable indicators (and their associated relative benefit ratings). Further developing project/proposal-specific adaptive capacity indicators and the ratings/scores that should be applied for each proposed project could be a focus of continued discussions with Planning Area representatives within next iterations of development for the LFFA prioritization framework.

5. Analytical Methods

5.1 Exposure Indicators

5.1.1 Climate Change

Climate normals (1981-2010) and climate projections for 2050 in the lower Fraser Basin were obtained from ClimateBC[10] for select climate metrics (Wang et al 2016). The climate projection data for 2050 for the lower Fraser used the CanESM2 model, and followed RCP8.5, which models GHG emissions under a “business as usual” scenario, the likely scenario if strong efforts to reduce emissions are not made.

Nelitz (2012) identified a subset of key climate variables related to water temperatures and flows considered to have the greatest potential impact on freshwater habitat conditions influencing the success of key seasonal salmon life history events (e.g., migration, spawning, incubation, rearing). **Table 6** indicates the temperature and flow-related climate change indicators (based on rationales in Nelitz (2012)) that were derived for LFFA watersheds for the compared time periods (historical baseline vs. 2050).

Table 6 Climate exposure indicators, associated metrics for analysis, and data sources.

Climate Exposure Indicator	Metric (unit)	Data Source
Summer average maximum air temperature (baseline vs. 2050)	Absolute change in average max. summer air temperature (Jun-Aug) across watershed (%)	ESSA (ClimateBC / CanESM2)
Summer precipitation (baseline vs. 2050)	Absolute change in average total summer precipitation (Jun-Aug) across watershed (%)	ESSA (ClimateBC / CanESM2)
Spring precipitation (baseline vs. 2050)	Absolute change in average total spring precipitation (Mar-May) across watershed (%)	ESSA (ClimateBC / CanESM2)
Fall precipitation (baseline vs. 2050)	Absolute change in average total fall precipitation (Sept-Nov) across watershed (%)	ESSA (ClimateBC / CanESM2)
Winter precipitation (baseline to 2050)	Absolute change in average total winter precipitation (Dec-Feb) across watershed (%)	ESSA (ClimateBC / CanESM2)
Precipitation as snow (baseline vs. 2050)	Absolute change in average total annual precipitation[11] as snow across watershed (%)	ESSA (ClimateBC / CanESM2)

For each climate indicator, the percent change between historical climate normals and the 2050 predicted future scenario was calculated. To calculate percentile changes, we first transformed the data to the absolute value of the percent change, reasoning that a departure from the baseline represented a cause for concern. Percent change values were averaged across each watershed using the package "terra" (Hijmans et al. 2021) in the R statistical computing language

[10] ClimateBC website: http://climatebc.ca/

[11] Average annual precipitation as snow (PAS) as measured between August in previous year and July in current year

(R Development Core Team 2020). Across all watersheds, five percentile categories were calculated, in intervals of 20%.

High water temperatures can increase fish energy expenditures, create thermal blockages to migration, exacerbate the progression of diseases and parasites, and decrease fecundity of eggs (Carter 2005; Crossin et al. 2008). While provincial-scale climate models can only provide predicted changes in air temperature (which is not directly relevant for fish) there are well-accepted relationships between air and water temperatures (e.g., Stefan and Preud'homme 1993; Morrison et al. 2002; Voss et al. 2008), although the strength of this relationship is highly variable as stream thermal response to air temperature can depend on a suite of local influences (e.g., groundwater inputs, riparian type, hydrology, geomorphology, etc.) (Isaak et al. 2010). Recent multivariate analysis undertaken for the Fraser River basin, however, indicated that air temperature primarily controls water temperatures in the basin by capturing ~80% of its explained variance with secondary impacts through river discharge (Islam et al. 2019), consistent with general arguments presented in Pike et al. (2010). Air temperature has similarly been found to be the primary driver of water temperature differences in ongoing broad-scale water temperature modeling being developed for the Canadian Columbia River Basin (R. MacDonald, MacDonald Hydrology Consultants Ltd., pers. comm.). While the overall influence of air temperature on water temperature will undoubtedly vary locally within watersheds (e.g., due to groundwater inputs, etc.) it represents the primary driver of water temperature over broad scales.

The quantity, quality and connectivity (e.g., fish migration) of aquatic habitats are influenced by the amount of flow. Fish at different periods of their life cycles require adequate stream flows e.g., to provide unimpeded access to spawning areas, to provide oxygen to incubating eggs, to maintain suitable rearing conditions, etc. Low flows in particular (in combination with high water temperatures) can affect fish by increasing energy expenditures, create physical or thermal blockages to migration, exacerbate the progression of diseases and parasites, and decrease fecundity of eggs (Carter 2005; Crossin et al. 2008). While provincial-scale climate models can only provide predicted changes in precipitation stream flows are primarily driven by rainfall. Local factors such as groundwater upwelling, snowmelt, and glacier outflows can supplement and maintain seasonal flows but the key driver of stream flow patterns is expected to be driven by regional precipitation regimes (and the interplay of precipitation with air temperature) (Pike et al. 2010).

5.1.2 Land Use

Eng (2020) has suggested that areas that are more affected by human land use impacts will be relatively less resistant to the potential impacts of climate change. In general, methods for describing the cumulative exposure to land use impacts (i.e., the human footprint) involve (from Theobald 2013):

- Categorization of human land uses

- Mapping of the spatial extent of those land uses
- Estimating a "pressure" or "intensity" associated with each land use
- Combining the pressures for each land use into a single exposure index for an area

We have followed this approach, while sub-setting our selected land use exposure metrics into the three key functional process tiers identified of priority near-term concern in the LFFA Study Area. **Table 7** indicates the land use impact indicators (across watershed inputs, fluvial geomorphic processes, and habitat impact categories) that were compiled and/or derived for LFFA watersheds and their rationales for inclusion in the analyses.

Table 7 Land use exposure indicators, associated metrics for analysis, and data sources.

Land Use Impact Category	Indicator	Metric (unit)	Data Source	Rationale
WATERSHED INPUTS				
	Roads	Length of road divided by assessment watershed surface area (km/km^2)	BC CEF[12]	Roads may increase coarse and fine sediment delivery to streams depending on surficial geology and terrain stability.
	Roads on steep slopes	Length of road on slopes > 60% divided by assessment watershed surface area (km/km^2)	BC CEF	Roads on steep slopes (especially those coupled to streams) represent a greater potential for sediment delivery
	Railways and associated infrastructure	Area of rail lines (buffered), airport, and airstrip infrastructure divided by assessment watershed surface area (km^2 / km^2 as %)	BC CEF	Railway lines may cross streams having potential impacts including disruption of stream connectivity that prevents fish from feeding, spawning and accessing over-wintering areas. Railways near streams also present the potential for increased fine sediment inputs into habitats and contamination from leaks and spills that could poison fish or the food fish eat.
	Pipelines	Area of oil and gas pipelines, well facilities, and ancillary features (buffered) divided by assessment watershed surface area (km^2 / km^2 as %)	BC CEF	Pipelines near streams present the potential for contamination from leaks and spills that could poison fish or the food fish eat.
	Wastewater discharges	Number of wastewater discharge points within assessment watershed (count)	BC CEF	High levels of wastewater discharge can impact the water quality of aquatic habitats either through excessive nutrient enrichment or chemical contamination. Some industrial waste products can directly injure or kill aquatic life even at low concentration while excessive nutrient levels (eutrophication) can result in depletion of the dissolved oxygen in streams and lakes, starving fish and other aquatic life.

[12] BC CE: British Columbia Cumulative Effects Framework

	Aggregate & Mineral Mines	Number of mines within assessment watershed (count)	BC CEF	Mining development can potentially cause degradation of fish habitat or mortality of fish through the direct footprint of the mine site, tailings ponds and other infrastructure, or more indirectly through disruption of flows, alteration of stream beds, and inputs of fine sediment or other contaminants.
	Urban development	Area of Urban or Mixed (residential/agricultural), built up areas divided by assessment watershed surface area (km^2 / km^2 as %)	BC CEF	Extensive hard, impervious surfaces (e.g., paved roads, sidewalks, driveways, buildings, etc.) from urban development can decrease the ability of the ground to absorb water and the resultant increased volume and velocity of water flow over impervious surfaces erodes streambanks causing increased turbidity, degrading aquatic habitats, and filling streambeds with sediment. Urbanization is also associated with increased loading of nutrients and contaminants.
	Agricultural development	Area of agricultural areas and clearings divided by assessment watershed surface area (km^2 / km^2 as %)	BC CEF	Agriculture development can potentially affect aquatic habitats by causing channelization of streams, removing water from groundwater or surface water for irrigation, and introducing nutrients (via fertilizers), contaminants, or fine sediments that can affect water quality.
	Rangeland	Area of BTM Natural Rangelands - unimproved pasture and grasslands divided by assessment watershed surface area (km^2 / km^2 as %)	BC CEF	Range land development can potentially affect aquatic habitats by altering riparian zones and floodplains through livestock grazing, removing water from groundwater or surface water for livestock purposes, and introducing nutrients and pathogens (via manure), contaminants, or fine sediments that can affect water quality.
FLUVIAL GEOMORPHIC PROCESSES				

	Equivalent Clearcut Area (ECA) (describes second-growth blocks in terms of hydrological equivalent as clearcut)	Area of ECA divided by assessment watershed surface area - (km^2 / km^2 as %)	BC CEF	Recently logged forest can significantly affect peak flow in streams due to changes in canopy precipitation interception, evapotranspiration, snow melt dynamics and runoff. Effects on peak flows will diminish as the forest recovers.
	Points of diversion (PODs) (count of all Points of Diversion)	Number of points of diversion within watershed (count)	BC CEF	Withdrawal of surface and/or hydraulically connected subsurface water for human purposes can affect fish habitats at critical times of year by reducing instream flows to levels that could constrain physical access to spawning and rearing habitats or potentially dewater redds, while reductions in both surface water and ground water supplies can increase water temperatures with resultant impacts on all fish life stages.
	Second growth forest (forest < 60 years old)	Area of second growth forest divided by assessment watershed surface area (km^2 / km^2 or %)	PSF	There may be significant effect of regenerating forest on summer low flows (research suggests an effect beginning at about 20-25 years post-cutting, reaching maximum effect at about 50-60 years, and then diminishing by 75-80 years post-cutting (depending on tree species).
	Placer mining tenures	Number of placer mines within assessment watershed (centroid count)	PSF (DataBC – Placer Mining)	The primary impact of placer mining is displacement and increased delivery of sediment and altered hydrology. Other potential effects include increases in organic loading heavy metal release, potential for acid drainage, and footprint impacts on fish and other aquatic biota.
HABITAT	Stream riparian disturbance	Length of stream within 30m of total human disturbance (current and historical) or natural (fire and insect) disturbance (km/km^2)	BC CEF	Riparian areas are intimately connected with streams providing a wide variety of ecological services and functions. Riparian areas also influence water quality, provide shade, and are sources of food, nutrients, and large wood to aquatic ecosystems. The maintenance of these

				functions and services depends upon intact riparian areas. When riparian vegetation is lost, stream channels are weakened due to the lack of root structures, and intensified surface erosion and mass-wasting are common outcomes.
	Lake riparian disturbance	Area of the riparian buffer with total human (current and historical) or natural (fire and insect) disturbance divided by assessment watershed surface area (km^2 / km^2 or %)	BC CEF	Riparian areas are intimately connected with streams providing a wide variety of ecological services and functions. Riparian areas also influence water quality, provide shade, and are sources of food, nutrients, and large wood to aquatic ecosystems. The maintenance of these functions and services depends upon intact riparian areas. When riparian vegetation is lost, stream channels are weakened due to the lack of root structures, and intensified surface erosion and mass-wasting are common outcomes.
	Major dams (Number of dams)	Number of dams within assessment watershed (count)	BC CEF	Dams (natural or man-made) and their impoundments can affect volume and timing of downstream flows, alter water quality, simplify channel morphology, and create barriers or impediments to fish movement. Restricted access to spawning streams and/or lakes can have consequent impacts to fish survival and productivity and impact overall population connectivity.
	Road/Stream crossings	Number of road-stream intersections within assessment watershed (count)	BC CEF	Stream crossings can (dependent on the type of crossing structure) create fish passage problems by interfering with or blocking access to upstream habitats that include spawning or rearing areas and reduce the total amount of available fish habitat in a watershed. Stream crossings can also influence the efficiency of water delivery to the stream network, increasing peak flows and becoming a chronic source of

				fine sediment or other contaminant delivery to streams.
	Passage barriers	Number of identified barriers/watershed (count)	Zoetica	Known fish passage barriers block access to upstream habitats that include spawning or rearing areas and reduce the total amount of available fish habitat in a watershed.
	Total land cover disturbance	Area that has been affected by human, fire, or insect disturbance divided by assessment watershed area (km^2 / km^2 as %)	BC CEF	Total disturbance represents potential changes in cumulative watershed processes such as altered hydrologic flows, sediment generation, contaminants, etc. that can affect downstream spawning and rearing habitats. Multiple elements of landscape disturbance (changes in land cover composition, configuration, and connectivity of impervious areas) will have interacting and often unpredictable effects on the biophysical environment.
	Contaminated sites	Number of contaminated sites/watershed (count)	Zoetica	Heavy metals and other contaminants that may enter streams through human activities or disturbances (e.g., mines, pipelines, urban runoff, etc.) can have lethal or sub-lethal effects on different fish life history stages.

5.2 Sensitivity Indicators

As noted earlier "sensitivity" relates to the likelihood and nature of response when exposed to the effects of climate change and can be considered as a relative measure of the potential habitat and population resilience in the face of impacts. **Table 8** indicates the sensitivity indicators (across habitat and population sensitivity categories) that were compiled and/or derived for LFFA watersheds and their rationales for inclusion in the analyses. As glacier influence was a new, requested indicator relating to habitat sensitivity developed by ESSA for this project we describe its derivation below in some detail. Within the time frame of our analyses (i.e., historical vs. 2050) it was considered that glacier-fed watersheds would have greater buffering capacity (i.e., less sensitive to climate change impacts) than watersheds not fed by glaciers. It is recognized however that these benefits will only be important in the short term and if glaciers ultimately recede these benefits will disappear, and such streams (if historically dependent on glacier runoff) may become even more sensitive to the effects of climate change.

Table 8 Sensitivity indicators, associated metrics for analysis, and data sources.

Sensitivity Category	Indicator	Metric (unit)	Data Source	Rationale
HABITAT SENSITIVITY				
	Lakes and wetlands	Surface area of lakes and wetlands within each assessment watershed (km^2 / km^2 as %)	BC CEF	Within the constraints of local climate and geology watersheds will react differently to hydrologic disturbance, at least partly because of differences in watershed storage capacity. Watersheds with large storage capacity, as represented by lakes, can better buffer against run off from land clearing and the potential effects of climate change (e.g., disrupted flows, water heating). Larger lakes and wetlands provide greater buffer capacity. Lakes also can provide key rearing and/or refuge habitats for fish.
	Drainage density ruggedness (DDR)	km of streams / km^2 of reporting unit) * (reporting unit relief m)) (dimensionless)	BC CEF	DDR is measured as the dimensionless product of drainage density (stream length per unit area) and total elevation relief (the difference between the highest and lowest points in the watershed). Drainage density ruggedness reflects how quickly hillslope and stream runoff could be transported downslope or downstream through a watershed, thereby reflecting the potential for flash-floods events. The greater the stream density in a catchment, the less distance there will be for hillslope runoff to travel before reaching a stream, where water velocities are much greater. Likewise the greater the elevation relief in a basin the greater the average stream gradient and streamflow velocity. Both these factors reduce the time of concentration for precipitation to reach lower channel reaches and increase the sensitivity of the basin to elevated peak flows.
	Landslide Risk	Surface area within each assessment watershed where slope > 30% (km^2 / km^2 as %)	Zoetica	Landslides and other debris flow events that enter watercourses can introduce sediment and smother fish and eggs or create barriers to fish movement. Landslides may also affect fish habitat quality by stripping away important streamside vegetation. Watersheds prone to

				greater frequency and intensity of debris flows could significantly damage fish habitats.
	Flood Risk	Area of each assessment watershed flooded at any depth in a 500-year flood, assuming 0.5m sea level rise (km^2 / km^2 as %)	Zoetica	Flood scenarios developed for the lower Fraser predict that climate change will increase flood risk in the lower Fraser, due to an increase in both spring (freshet) flooding and winter (coastal) flooding in a region that is already vulnerable.
	Glacier influence	Area of upstream glacier / total upstream drainage area (km^2 / km^2 as %)[13]	ESSA	Glacier runoff can be a vital component of surface flows in glaciated drainage basins of British Columbia, especially during summer when water demand is high. Glaciers represent natural reservoirs that can yield the most water during the driest periods of later summer. Streams with glacier sources may be expected (in the near-term, while glaciers persist) to be more resilient to climate change, such as increased temperatures in the summer, because of their cooler water inputs. As glaciers retreat the size of the reservoir shrinks and so does the available runoff to support sufficient flows and water temperatures that maintain fish habitat.
POPULATION SENSITIVITY				
	Salmon Conservation Unit (CU) status	**All Species:** # of CUs (among all species) with Extirpated, At Risk, Depleted, or other designations of conservation concern/watershed (count) **By Species:** # of CUs (by species) Extirpated, At Risk, Depleted, or other designations of conservation concern/watershed (count)	Zoetica	Salmon CUs that have already reached levels of conservation concern warranting formal status designations are relatively more at risk from the climate change effects and land use impacts within a watershed.

[13] The derivation of upstream glacier area breaks down slightly in the lower / middle Chilliwack because the American watersheds are mapped at a different scale as the Canadian watersheds. The data currently mis-calculates the upstream glacier area for a few small upstream watersheds at the CAN/US border in the lower & middle Chilliwack watersheds.

Glacier influence derivation. Within each LFFA Planning Area (Harrison Watershed - Mid Reach Fraser River, Lower Fraser River Approach, Fraser Canyon, Chilliwack), we summarized the coverage of glaciers within the drainage catchment of each individual stream reach. Using a stream network index table, we then calculated the total upstream area, and upstream glacier coverage (%) for each individual stream reach segment.

This approach works for headwater streams but ignores upstream segments of rivers that originate outside of each LFFA watershed study area (that is to say, the analysis for the Lower Fraser correctly determines the total upstream glacier coverage for the Pitt river, which starts and ends in the Lower Fraser; but the analysis cannot accurately determine the total upstream glacier coverage for the Fraser River because the analysis excludes data upstream of the Lower Fraser LFFA watershed study area[14]). For this reason, it was necessary to supplement the analysis by calculating the amount of upstream drainage area and upstream glacier area for each stream segment extending outside of each LFFA watershed (including watersheds in the USA). Then, we modified all downstream values by adding the upstream values (upstream drainage area & upstream glacier area) and re-calculating upstream glacier percentage. Stream network and watersheds data were obtained from DataBC (Government of British Columbia 2021) and the USGS (USGS 2018), while glacier coverage was obtained from DataBC (Government of British Columbia 2021) and the Global Land Ice Measurements from Space (GLIMS) database (GLIMS and NSIDC 2018).

5.3 Adaptive Capacity Indicators

Adaptive capacity is a measure of the ability of a system to decrease exposure or reduce sensitivity to climate induced stresses and is based on both ecological responsiveness (i.e., how well can habitats and salmon populations respond to climate or land use impacts (i.e., bounce back)) and human responsiveness (i.e., how will human communities attempt to mitigate or avoid some of the adverse consequences of climate change). For example, the adaptive capacity of a watershed to cope with climate changes will be enhanced by connectivity of habitats and maintenance of floodplain, wetland and other landscape features in their natural conditions to support natural hydrology and sediment supply (EPA 2021). Within our analyses we have quantified various measures of ecological responsiveness but have not done so for human responsiveness, which are more difficult not capture and map at broad scales. Additional work will need to be developed in subsequent stages working with LFFA Planning Area participants to incorporate this human responsiveness element into assessment of adaptive capacity. Section 4.4 identified some of the human adaptive capacity elements that could be brought into an

[14] We could not calculate glacier coverage for the entire Fraser River for two reasons. The first is that the method is extremely computationally intensive and would have exceeded our resources. The second is that we needed to include data from watersheds on the USA side of the border, which required additional processing, as described in the text above.

analysis, either at the time of individual project proposal scoping or ultimately as part of broader scale inventory. **Table 9** indicates the ecological adaptive capacity indicators (across salmon population and habitat categories) that were compiled and/or derived for LFFA watersheds.

Table 9 Adaptive capacity indicators, associated metrics for analysis, and data sources.

Adaptive Capacity Category	Indicator	Metric (unit)	Data Source	Rationale
POPULATION				
	Salmon escapement/productivity	**All Species.** Maximum salmon productivity among all reaches within watershed, regardless of species (Ranked) **By Species.** Maximum salmon productivity among all reaches within watershed, within species (Ranked).	Zoetica	Historical escapement (number of spawners observed) provides a measure of the relative importance of a watershed in supporting salmon production. While escapement numbers may have declined in many systems, historic escapement averages provide a measure of the intrinsic productivity of these watersheds, and their presumed potential to respond to restoration efforts.
	Salmon distribution	**All Species.** Total number of spawning locations per watershed among all species (count) **By Species.** Total number of spawning locations per watershed by species (count)	PSF	The number of known salmon spawning sites in a watershed provides an indication of the watershed's potential resilience in supporting salmon production (i.e., multiple areas where salmon spawning/rearing could occur).
HABITAT				
	Parks and protected areas	Area of parks and protected areas divided by assessment watershed surface area (km^2 / km^2 as %)	DataBC	Areas that are currently protected from human development and are relatively pristine with a mix of available habitats for fish may provide additional refugia from future climate changes. It should be noted that historically, protected areas have largely been established to conserve particular geological, biological, and cultural resources in a given place, rather than a focus on mitigating the dynamic impacts of climate change on fish biodiversity.

	Habitat Quality Rating	Mean habitat quality (ranked from 0 (lowest) to 4 (highest)) among stream reaches within watershed, normalized by length. (Ranked)	Riley Finn (UBC Conservation Decisions Lab)	Differences in local stream-scale intrinsic habitat quality can determine watersheds that may be most resistant/resilient of climate change impacts and that will likely be most responsive to restoration projects that improve fish access or provide other improvements to fish habitat conditions.

5.4 Overall Sensitivity, Exposure, and Adaptive Capacity Scoring

5.4.1 Indicator Benchmarks

Metric values for each indicator were summarized within each LLFA Study Area watershed[15]. Analyses were conducted using the R statistical computing language (R Development Core Team 2020) packages "terra" (Hijmans et al. 2021), "sf" (Pebesma 2018), and "raster" (van Etten 2020). Each metric was split into five percentiles[16] (quintiles) , representing the bottom fifth, the next fifth, and so on, up to the top fifth of values within the area of interest; values were coded with a score of 1 representing the lowest percentile category for an indicator, and a 5 representing the highest percentile category for an indicator. The meaning of a high percentile category varies dependent on the indicator type; for example, a score of 5 could represent relatively high exposure, high sensitivity, or high adaptive capacity. The method is flexible for defining relative benchmarks for comparing the status of indicators across the entire LFFA Study Area or for undertaking relative comparisons only within each of the four LFFA Planning Areas (i.e., Harrison Watershed - Mid Reach Fraser River, Chilliwack, Fraser Canyon, or Lower Fraser River Approach). The results in this regard should be used in a **comparative** sense: a watershed's rating for an indicator indicates how it scored when compared to all other watersheds within the geographic area of comparison. The ranking scores are not, by themselves, an indication of whether a watershed's overall health is "good" or "bad," or meets certain thresholds. Rather, the results are best used as a broad-level screening tool to compare watersheds to one another within a defined geographic area of analysis and targeting appropriate locations for monitoring and management actions. A similar "relative" ranking approach has been adopted by the US EPA for assessing and comparing watershed vulnerability within their Healthy Watersheds Protection Program (https://www.epa.gov/hwp/developing-watershed-vulnerability-index).

5.4.2 Indicator Roll-ups / Index Development

Scored indicators were aggregated/combined into more easily interpretable **indices**[17] for each of the indicator categories for use within the prioritization framework. For index development individual indicators were summarized within each of the indicator categories (Exposure, Sensitivity, and Adaptive Capacity), sub-categories (e.g., Habitat Sensitivity), and sub-sub-categories (e.g. Watershed Inputs, etc.) (see **Table 10**). Within each sub-category (or sub-sub-category), the value of the metrics used for each indicator were averaged to determine an overall

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[15] FWA Assessment Watersheds used for analyses are watershed aggregations that are consistently between 2,000 and 10,000 ha

[16] For certain metrics, a sixth "zero" category was added for zero values (e.g., watersheds with no urban land use). For mines and dams, percentile benchmarks were not calculated; the count of dams and mines within each watershed was utilized instead.

[17] An **index** is a single rating/score made by combining several ratings/scores (for indicators), sometimes by straightforward addition but often in more complex ways, in order to represent some given variable.

sub-category (or sub-sub-category) value. Finally, within each category, the values of sub-categories were then summed to produce an overall final scored index value for Sensitivity, Exposure and (Ecological) Adaptive Capacity within each LFFA watershed.

Additional summaries specific to individual salmon species were also calculated by substituting the overall salmon escapement within a watershed with escapements for each species; the overall number of designated salmon CUs within a watershed for all salmon species with the number of designated CUs within a watershed for each individual salmon species; and the overall number of salmon spawning sites in a watershed with the number of species-specific spawning sites in a watershed.

Table 10 Methods for calculating Overall, Exposure, Sensitivity, and (Ecological) Adaptive Capacity Scores.

Categories / Indicators	Derivation
EXPOSURE	
Watershed Input (WI) score	Average of Watershed Input indicator scores (Roads, Roads on steep slopes (>60%), Railways, Pipelines, Wastewater discharges, Mines, Urban development, Agriculture, Rangeland)
Fluvial Geomorphic Processes (FGP) score	Average of FGP indicator scores (ECA, PODs, Young 2nd Growth Forest, Placer Mining Tenures)
Habitat (H) score	Average of Habitat indicator scores (Stream Riparian disturbance, Lake Riparian disturbance, Major dams, Road/stream crossings, Known Passage Barriers, Total Land Cover Disturbance, Contaminated Sites)
Land Use score	Average of WI, FGP, and H indicator scores
Climate Change score	Average of Climate Change indicator scores (Summer Temperature - delta, Summer rain - delta, Spring rain - delta, Autumn rain - delta, Winter rain - delta, Precipitation as snow - delta)
Overall Exposure Index (no species-specific information)	Sum of average Land Use + average Climate Change exposure scores
SENSITIVITY	
Habitat Sensitivity score	Average of Habitat Sensitivity indicator scores (Lakes & wetlands, DDR, Landslide Risk, Flood Risk (2050s), Glacier Influence)
Population Sensitivity score (all species / by species)	Equivalent to number of Designated CUs (all species / by species)
Overall Sensitivity Index (all species / by species)	Sum of average Habitat Sensitivity + Population Sensitivity indicator scores (all species / by species)
(ECOLOGICAL) ADAPTIVE CAPACITY	
Population Adaptive Capacity score (all species / by species)	Average of Salmon Population Adaptive Capacity indicator scores (Salmon Productivity, Salmon Distribution) (all species / by species)
Habitat Adaptive Capacity score	Average of Habitat Adaptive Capacity indicator scores (Protected Areas, Habitat Quality Rating)
Overall (Ecological) Adaptive Capacity Index (all species / by species)	Sum of Population + Habitat Adaptive Capacity indicator scores (all species / by species)

5.4.3 Watershed Prioritization

Derived final index scores for each of the three elements representing climate change vulnerability (i.e., Exposure, Sensitivity, and (Ecological) Adaptive Capacity) could now be used to identify/filter priority watersheds for potential adaptation/restoration actions. A R-coded Watershed Vulnerability Tool was developed for a process that first filters all watersheds according to their Exposure score. Watersheds above a user-defined Exposure threshold value (e.g., the 50th percentile, which corresponds with a specific Exposure score) are passed through for further evaluation, and the remainder of watersheds are filtered out. Next, within the watersheds that are retained, those that are above a user-defined Sensitivity threshold value are passed through, and the remainder are filtered out. Finally, the remaining watersheds above a user-defined Adaptive Capacity threshold value are then selected as the priority watersheds for restoration or adaptation actions. See **Figure 9** for a conceptualization (A) of the watershed filtering/prioritization process within the Tool and a visualization (B) of GIS-based outputs generated using the Tool.

This filtering mechanism in the Tool is flexible and can be utilized or modified by users of R. Indicator category threshold values can easily be adjusted, as can the order of prioritization operations (e.g., Sensitivity or Adaptive Capacity could be the first filter if desired). Similar screening level tools are used in other jurisdictions for identifying and prioritizing vulnerable watersheds for protection and/or restoration. For example, the Wisconsin Department of Natural Resources uses similar overlays of derived index values to identify watersheds that are considered (relatively) the most healthy but also most vulnerable to future habitat degradation from climate change or other impacts (which become the focus of watershed protection priorities) and those that are considered (relatively) less healthy but not as vulnerable to future habitat degradation (which then become the focus of watershed restoration priorities) https://dnr.wisconsin.gov/topic/Watersheds/HWA.html. The particular types of protection or restoration that might be most appropriate for each priority watershed can be then explored in more detail by viewing the individual indicator/metric scores for the watersheds, which will help identify what the specific problem issues may be. This broad watershed-scale screening-level exercise need to be supported/vetted by discussions with local experts who are familiar with the actual land uses and on-the-ground conditions of each watershed.

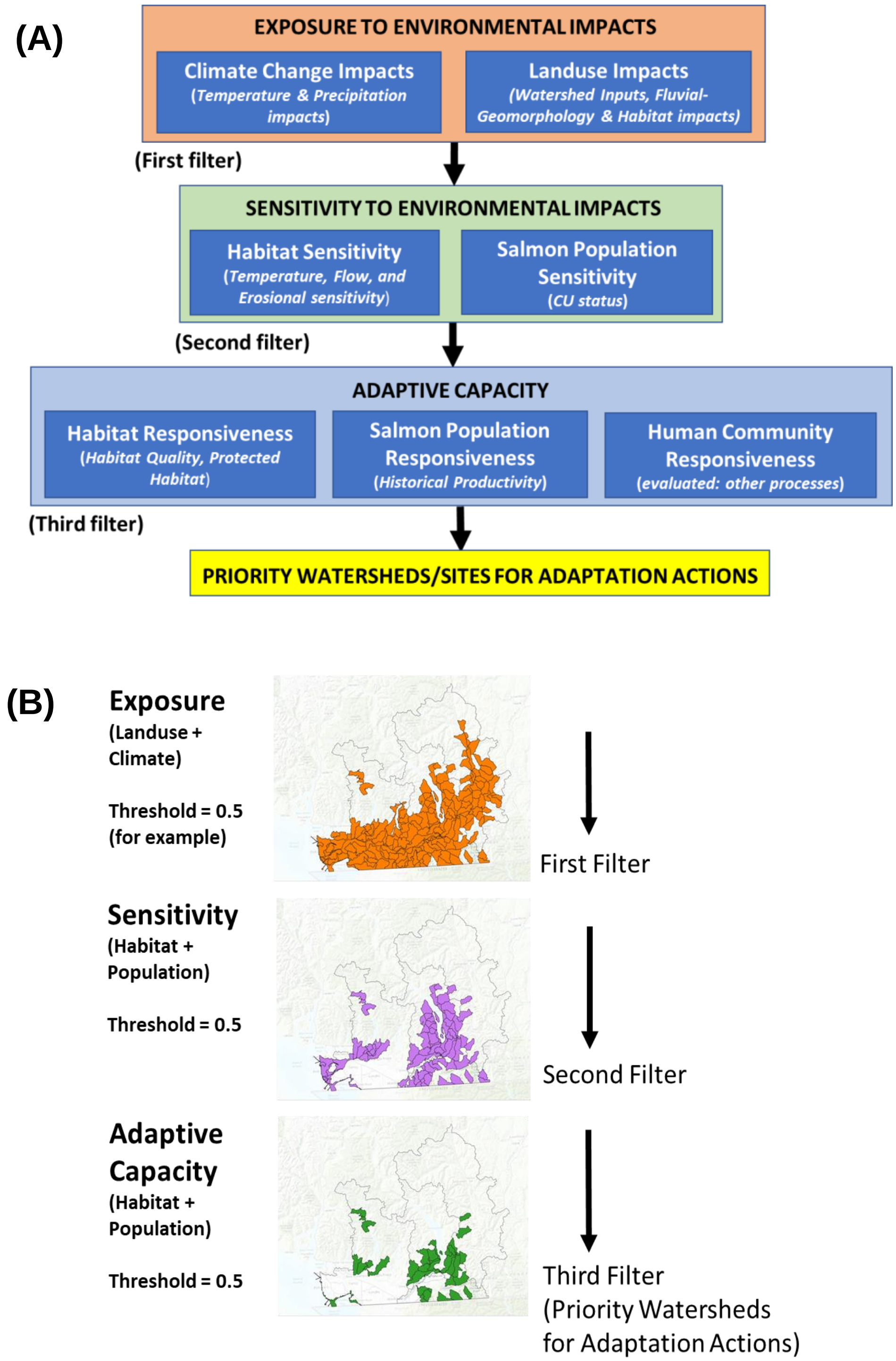

(A)
EXPOSURE TO ENVIRONMENTAL IMPACTS
Climate Change Impacts
(Temperature & Precipitation impacts)
Landuse Impacts
(Watershed Inputs, Fluvial-Geomorphology & Habitat impacts)
(First filter)
SENSITIVITY TO ENVIRONMENTAL IMPACTS
Habitat Sensitivity
(Temperature, Flow, and Erosional sensitivity)
Salmon Population Sensitivity
(CU status)
(Second filter)
ADAPTIVE CAPACITY
Habitat Responsiveness
(Habitat Quality, Protected Habitat)
Salmon Population Responsiveness
(Historical Productivity)
Human Community Responsiveness
(evaluated: other processes)
(Third filter)
PRIORITY WATERSHEDS/SITES FOR ADAPTATION ACTIONS
(B)
Exposure
(Landuse + Climate)
Threshold = 0.5
(for example)
First Filter
Sensitivity
(Habitat + Population)
Threshold = 0.5
Second Filter
Adaptive Capacity
(Habitat + Population)
Threshold = 0.5
Third Filter
(Priority Watersheds for Adaptation Actions)

Figure 9 Upper (A): Conceptual model of filtering system to identify priority areas for adaptation actions. The first filter are areas most exposed to environmental risks; the second are areas with the most sensitive habitats or populations; and the third are areas with the highest adaptive capacity for restoration. Lower (B): Hypothetical example of filtering system to identify a subset of priority watersheds for restoration using indicator data from the LFFA Study Area.

5.5 Sites of Local Concern

In addition to the development of broad-scale indicators and associated indices within the framework for defining the vulnerability status of LFFA Study Area watersheds the locations of specific local areas of concern have been summarized from discussions with Planning Area representatives (see Locations of key concern in Appendix C) and mapped as precisely as possible within each watershed. These sites were identified as potential sites of concern with regards to fish habitat issues within each of the LFFA Planning Areas. These provide a next level of information for adaptation/restoration prioritization (i.e., identifying areas within priority watersheds that could become the focus for implementing targeted restoration actions to address limiting factors and improve local resistance/resilience to climate change impacts). Mapping of local issues of concern includes points, lines, and polygons as identified by LFFA members. Specific local concerns identified included such issues as fish passage blockage locations, localized fish habitat impairment, invasive species hotspots, streams prone to low flows, pollution inputs, and local sedimentation issues. As a final analytical step in the prioritization process the locations of issues of local concern can be overlaid with priority watersheds identified from the watershed-level indicator evaluations/filtering to identify particular sites/areas within watersheds to target/concentrate mitigation or restoration efforts and help inform the specific actions that could be considered to best restore habitat functioning and promote adaptation to climate change impacts (see **Figure 10**).

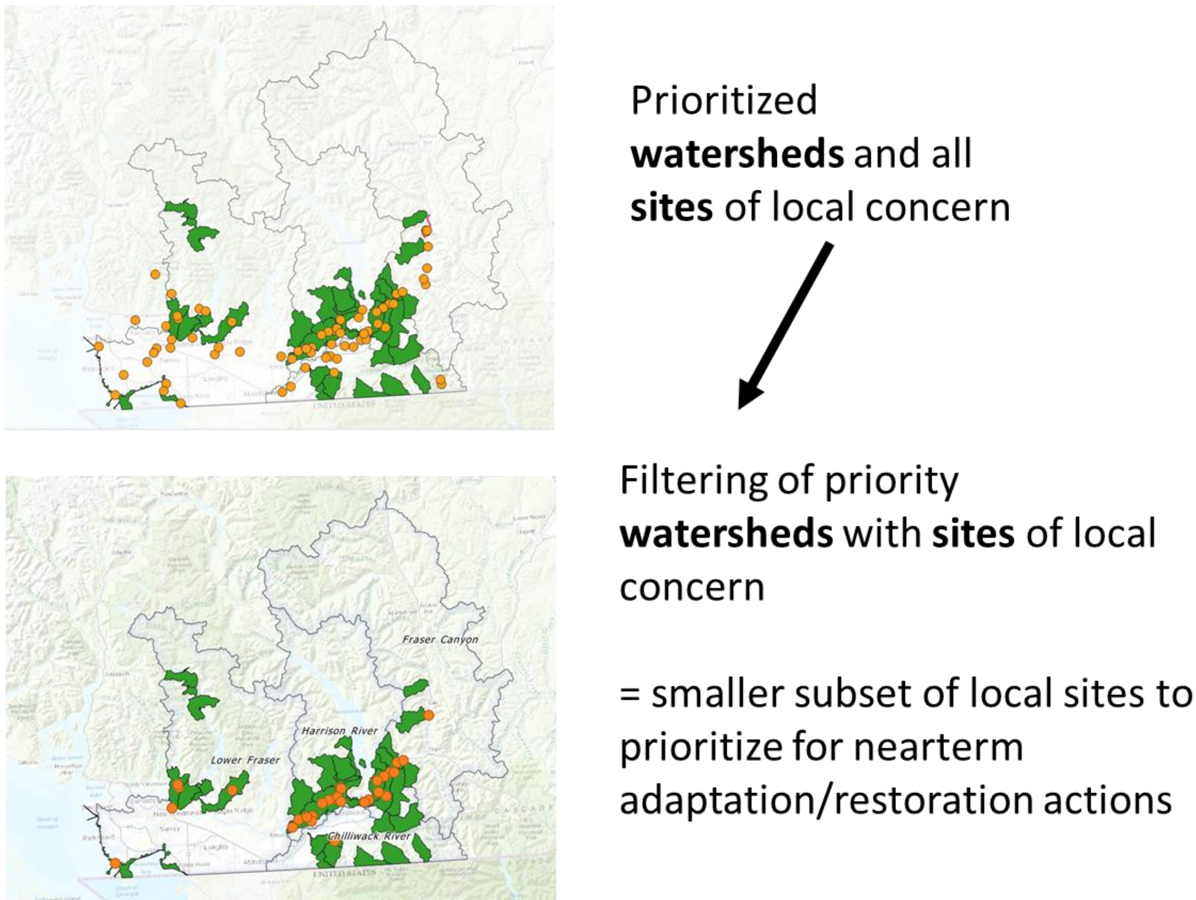


Figure 10 Filtering process (hypothetical example) for identifying key sites of local concern to consider targeting for implementation of restoration/adaptation projects within priority watersheds as identified through exposure, sensitivity, and adaptive capacity indicator analyses. Sites of local concern are indicated by yellow circles and priority watersheds are indicated in green.

6. Analytical Results

All derived scores for exposure, sensitivity, and (ecological) adaptive capacity indicators are provided for each of the 293 FWA watersheds defined for the LFFA Study Area in an accompanying Excel spreadsheet (**Indicator Data Analysis - 2021-04-23.xlsx).** This spreadsheet should be referred to for evaluation of specific results, as the volume of derived information precludes easy inclusion as an appendix in this report. For the most part, indicators are scored on an increasing relative scale of 1-5 by quintile (i.e., bottom 20%, second 20%, and so on) with an additional category for values of zero - a few indicators are scored differently and this is detailed in the Excel spreadsheet). Scoring for indicators are presented in the spreadsheet in separate worksheets in relation to 1) a whole LFFA Study comparison, and 2) individual LFFA Planning Areas (i.e., separate relative comparisons of indicator values within each of the Chilliwack, Fraser Canyon, Harrison Watershed - Mid Reach Fraser River, and Lower Fraser River approach Planning Areas).

In addition to individual indicator scores the worksheets include rollups (summaries) of overall Exposure, Sensitivity, and (Ecological) Adaptive Capacity scoring, which are calculated for *all species*, as well as for *specific salmon species* (indicated by blue (Chinook), gray (Chum), yellow (Coho), light blue (Pink), and green (Sockeye) highlighting in the worksheets)). These worksheets also provide the filtering/thresholds results (these are at the right-hand side of each worksheet, in various shades of pink highlighting). Indicator benchmarks were also calculated for *all species combined*, as well as for *specific salmon species*. Indicator summaries (benchmarking, rollups, and user-defined filtering thresholds) were calculated separately for each LFFA Planning Area and for the LFFA Study Area as a whole. This allows relative comparisons for identifying highest priority watersheds to be made based on all the watersheds in the Study Area or only with the smaller number of watersheds within each Planning Area (i.e., **across** Study Area prioritization or **within** Planning Area prioritization options).

Indicator scores as represented in this Excel spreadsheet are generated and manipulated within an accompanying R code package developed for the project: "**2_EN2639_CompileScores.r".** This R package generates the indicator benchmarking, roll-up, and prioritization processes. The required input for the r-code comes from an accompanying **" Data_Compiled_NoScores"** GIS layer (see below); and when run, will produce the remaining layers within accompanying **"Data_Compiled_Scores_All"** and **"Data_Compiled_Scores_[*watershed*]"** files (see below). These files are for representation of the whole LFFA Study Area and individual LFFA Planning Areas, respectively. The code within this R package can be modified as desired by the user (i.e., benchmarking methods employed; calculation of roll-ups; thresholds to use for prioritization; order of indicator category prioritization).

Input and output data for the R program is contained in an accompanying **"Output.gpkg"** file in geoPackage format. Within the geopackage there are six GIS layers. The geometry of each of the six layers correspond to FWA Assessment Watersheds. Fields in each dataset indicate the value for each indicator, and roll-up values:

- **"Data_Compiled_NoScores"** - this layer includes the average or total *raw* indicator score per watershed (e.g., summer air temperature, road density, etc.).
- **"Data_Compiled_Scores_All" / "Data_Compiled_Scores_[*watershed*]".** These datasets contain the same data as the excel spreadsheet detailed above, but are linked (spatially) with the FWA polygons, so they can be opened in a GIS application of the user's choice.

Mapped representations of indicator results from this processing are presented in the sections below for each of the different indicator categories (Exposure, Sensitivity, and (Ecological) Adaptive Capacity). Differences in map colour shading intensity indicates ranked category differences in the relative scoring for each indicator across LFFA Study Area watersheds. Mapping examples of relative indicator scoring/ranking are presented here for the whole LFFA Study Area comparison. As indicated the Tool can also run relative scoring comparisons within each of the LFFA Planning Areas with results that may be more relevant to local planning decisions (i.e. what are the best or worst scored watersheds relative to the other watersheds within my Planning Area). For the interest of space we have only shown one example here of results for a relative indicator value comparison specific to a Planning Area (i.e., Overall Exposure, Sensitivity, and Adaptive Capacity scores/ranking in the Harrison Watershed - Mid Reach Fraser River Planning Area). Within a GIS application the suite of potential comparisons can be explored fully and visualized through map representations. PSF's Lower Fraser Salmon Explorer online interactive mapping tool provides a powerful application that could be considered for display and interrogation of this derived indicator information (along with other supporting datasets) for future LFFA restoration planning purposes.

In addition to watershed indicator information the locations (sites, stream segments, or broader areas) of key issues of local concern have been identified by LFFA Planning Area representatives and mapped across the LFFA Study Area. At each mapped location of concern the type of issue present (both in terms of general category of concern and specific problem) has been documented as well as the primary functional process tier effected (i.e., Watershed Inputs, Fluvial Geomorphic Processes, Habitat, or Biological Interactions). In addition, a proposed type of (primary) restoration response is identified in relation to the issue at that location. This assembled information is provided in an accompanying geopackage **("LFFA_Sites.gpkg")** containing point, line, and polygon GIS layers for the local sites of concern information, allowing for overlays with watershed-level indicator scoring representations (such as illustrated in hypothetical example in Figure 10).

Maps in Section 6.1 – 6.4 (**Figures 11 – 21**) illustrate indicator results (relative scoring) across the LFFA Study Area generated from the Watershed Vulnerability Tool for individual indicators within each of the vulnerability categories (i.e., Exposure (6.1), Sensitivity (6.2), and (Ecological) Adaptive Capacity (6.3). In addition, maps are shown of the final cumulative overall score across LFFA Study Area watersheds for each of the three vulnerability categories. Section 6.4 presents maps **(Figure 22)** for final overall scores for the vulnerability categories across A) all LFFA Study Area watersheds, and B) across watersheds within the Harrison Watershed - Mid Reach Fraser River Planning Area (as a comparative example of how relative overall scoring/rating of watersheds would change if the geographic extent of comparison changes). Section 6.5 provides maps (**Figures 23 - 25**) of the locations of local issues of key concern within LFFA Planning Areas, with locations categorized by primary functional process effected, the general issues of concern, and the proposed adaptation/restoration action to consider undertaking at the location.

6.1 Exposure Indicators

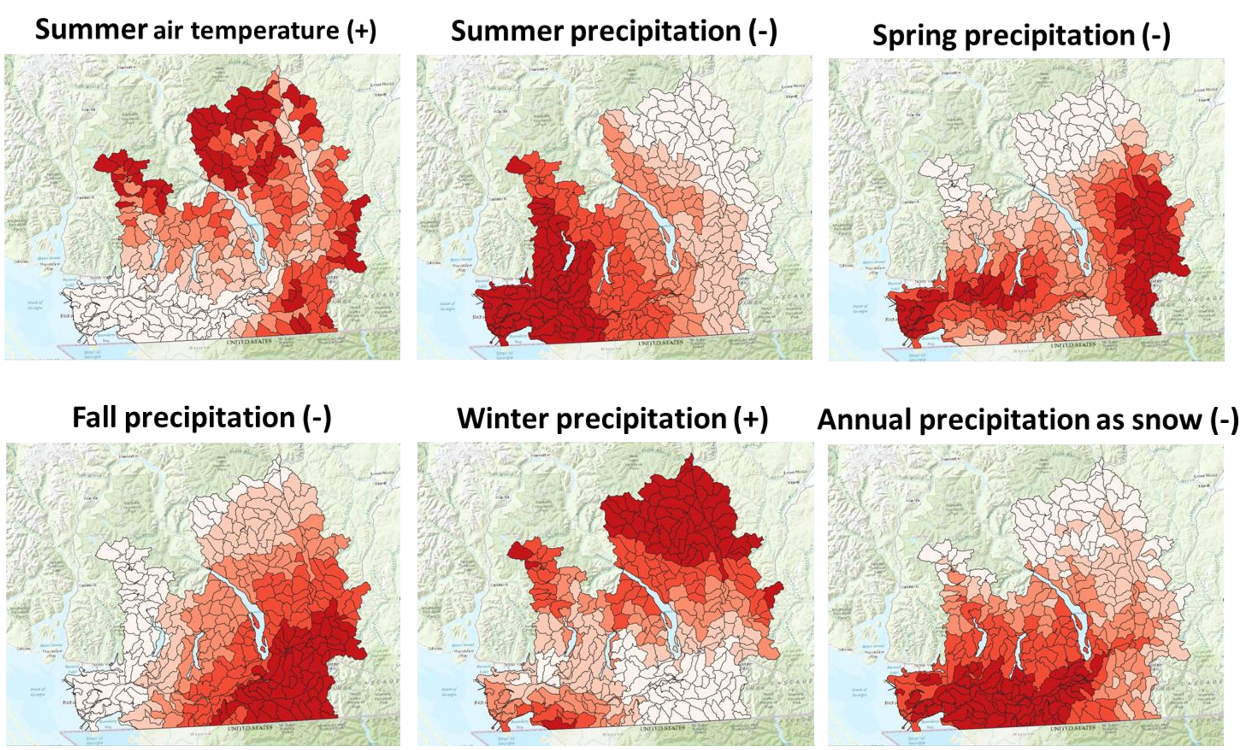


Figure 11 Predicted change (historical baseline vs. 2050) in climate change indicators across all watersheds in the LFFA Study Area. Darker colours indicate greater relative amount of predicted change (positive (+) or negative (-) dependent on the particular indicator evaluated (ClimateBC modeling) based on a quintile split of values across LFFA Study Area watersheds for each indicator/metric).

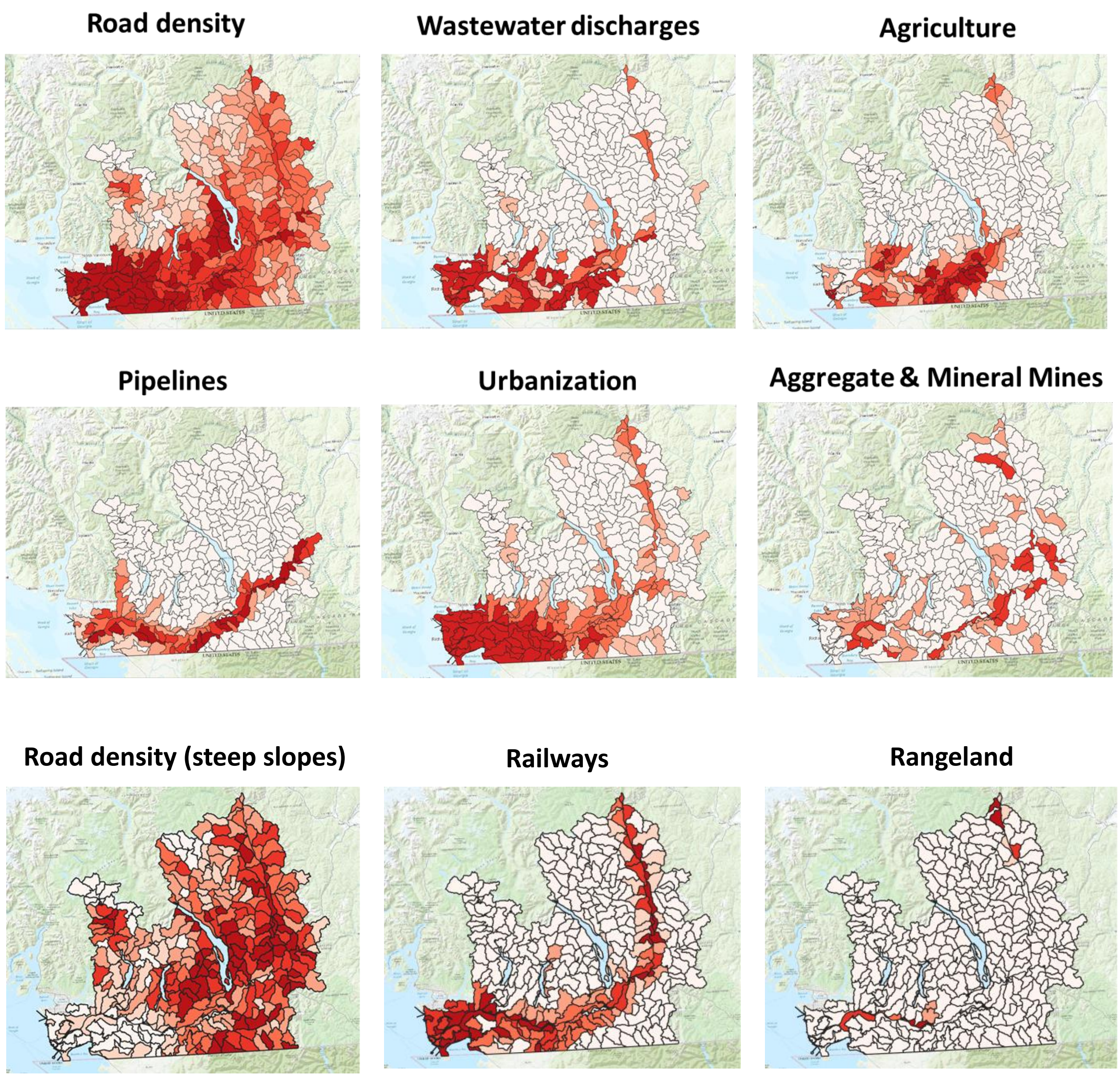


*Figure 12 Intensity of current land use impacts (principally affecting Watershed Inputs) across all watersheds in the LFFA Study Area. Darker colours indicate greater **relative** amount/extent of land use disturbance (based on a quintile split or count of values across LFFA Study Area watersheds for each indicator/metric).*

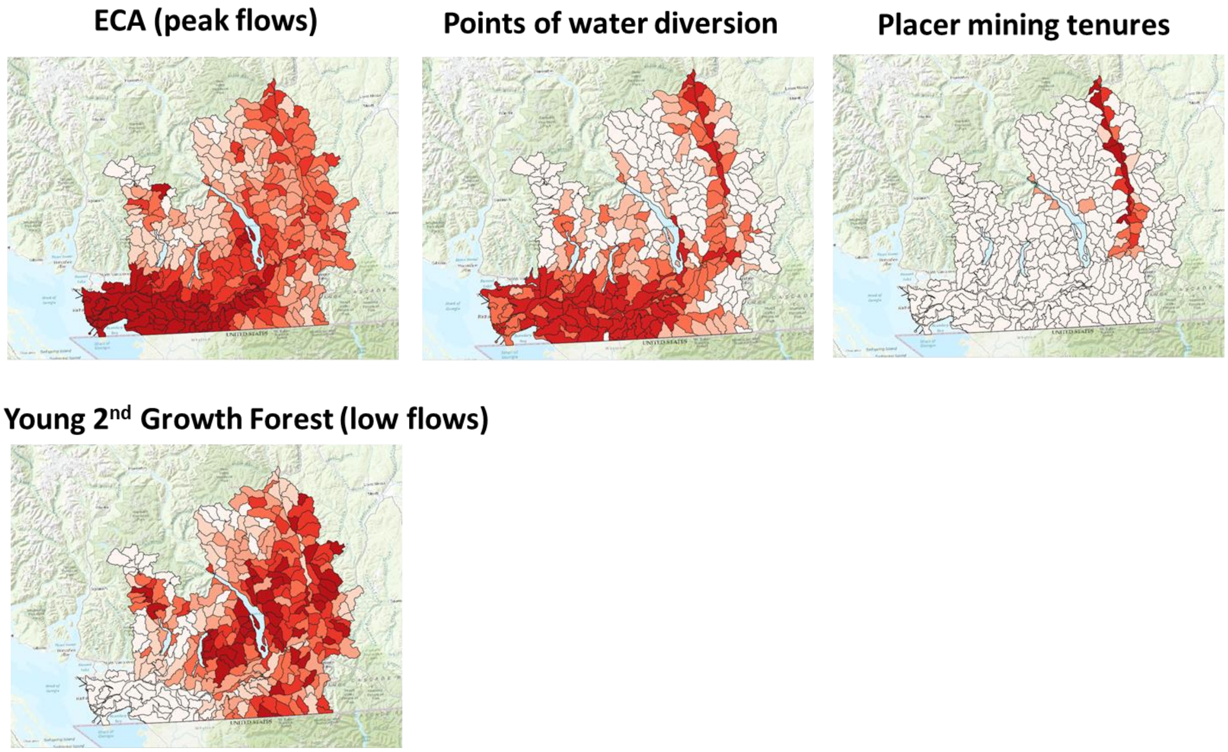


*Figure 13 Intensity of current land use impacts (principally affecting Fluvial Geomorphic Processes) across all watersheds in the LFFA Study Area. Darker colours indicate greater **relative** amount/extent of land use disturbance (based on a quintile split or count of values across LFFA Study Area watersheds for each indicator/metric).*

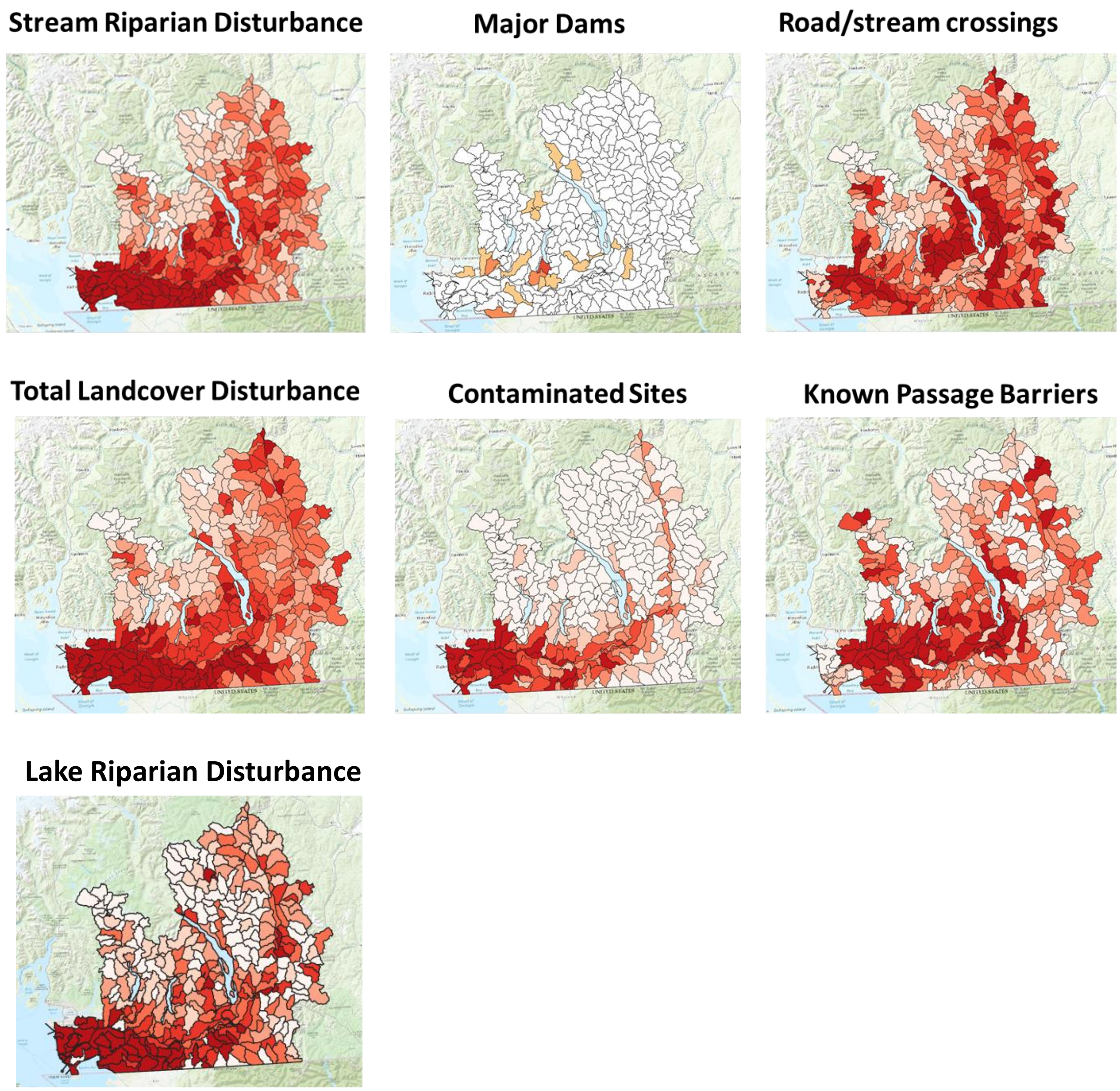


Figure 14 *Intensity of current land use impacts (principally affecting Habitat) across all watersheds in the LFFA Study Area. Darker colours indicate greater **relative** amount/extent of land use disturbance (based on a quintile split or count of values across LFFA Study Area watersheds for each indicator/metric).*

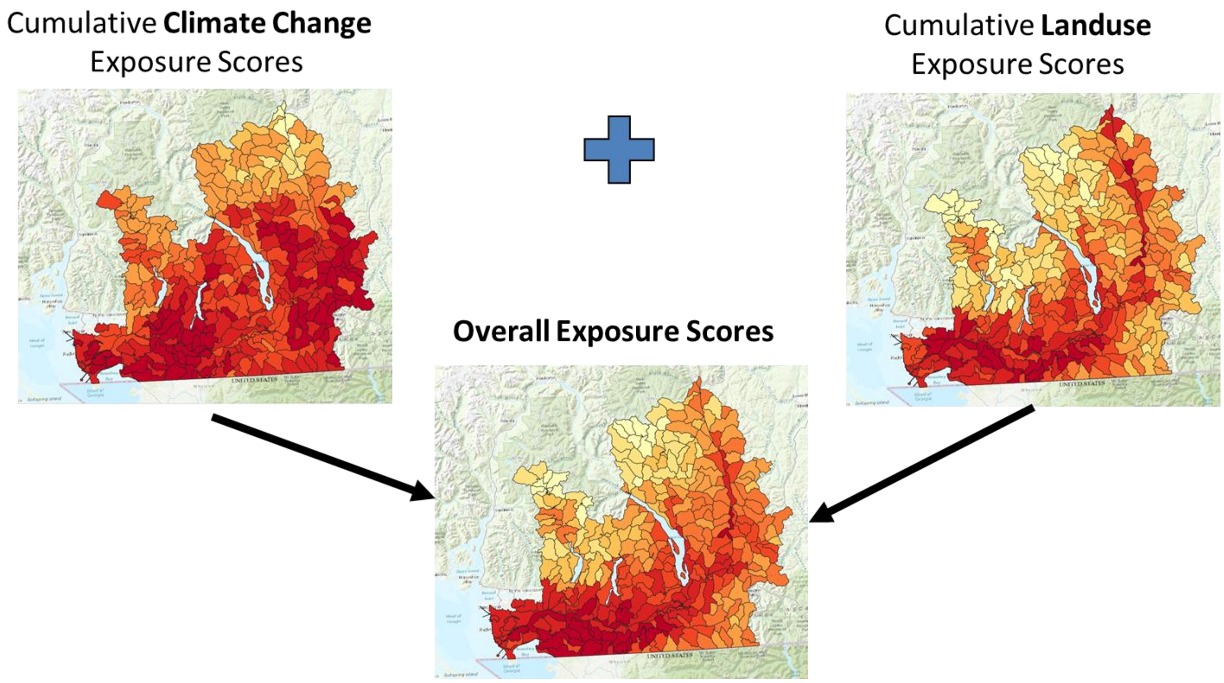


Figure 15 Scoring summation of overall Exposure (climate use + land use impacts scores) across all watersheds in the LFFA Study Area. Darker colours indicate watersheds with higher relative scoring for overall Exposure.

6.2 Sensitivity Indicators

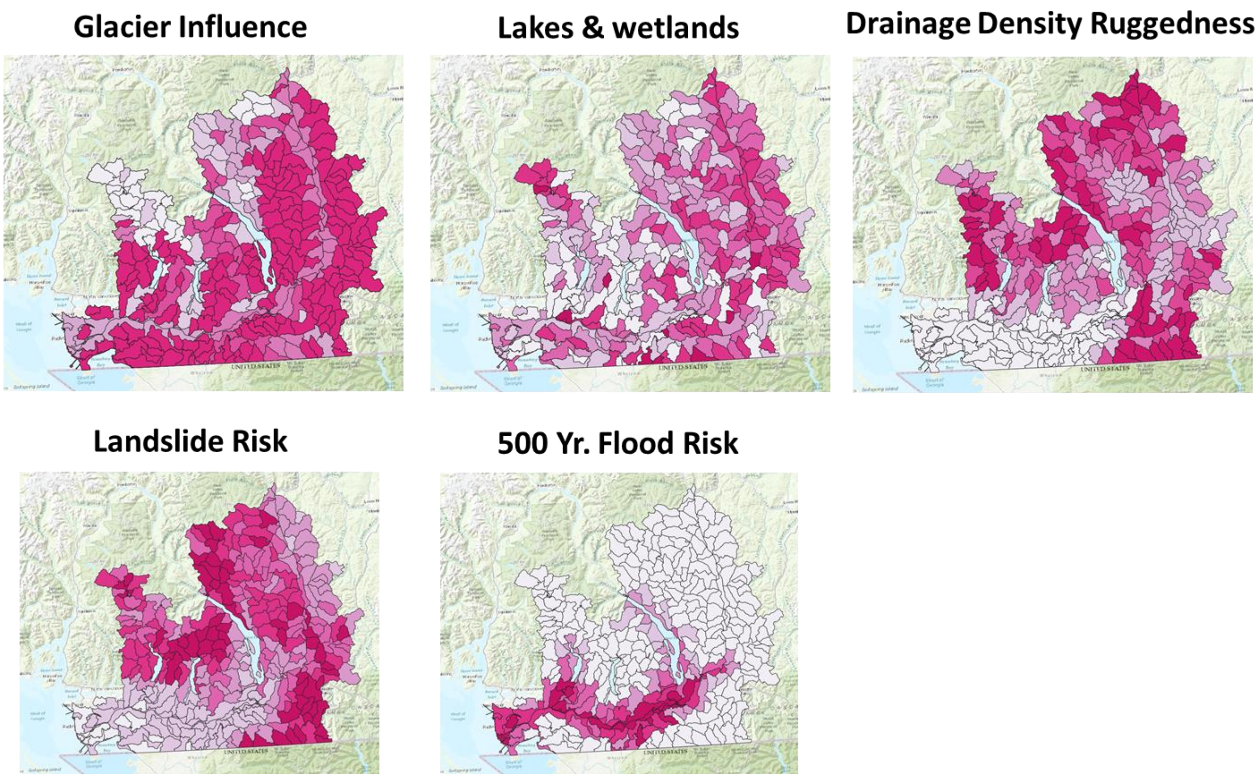


Figure 16 ***Habitat*** *sensitivity to exposure across all watersheds in the LFFA Study Area. Darker colours indicate greater* ***relative*** *sensitivity to exposure (based on a quintile split of values across LFFA Study Area watersheds for each indicator/metric).*

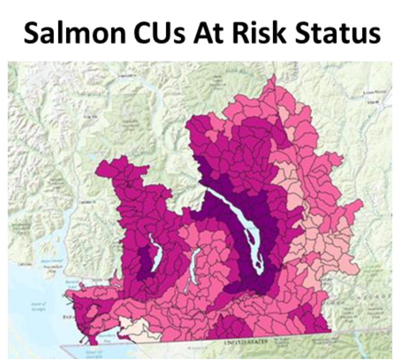


Figure 17 ***Population*** *sensitivity to exposure across all watersheds in the LFFA Study Area. Darker colours indicate greater* ***relative*** *sensitivity to exposure (based on a quintile split of values across Study Area watersheds for the indicator/metric).*

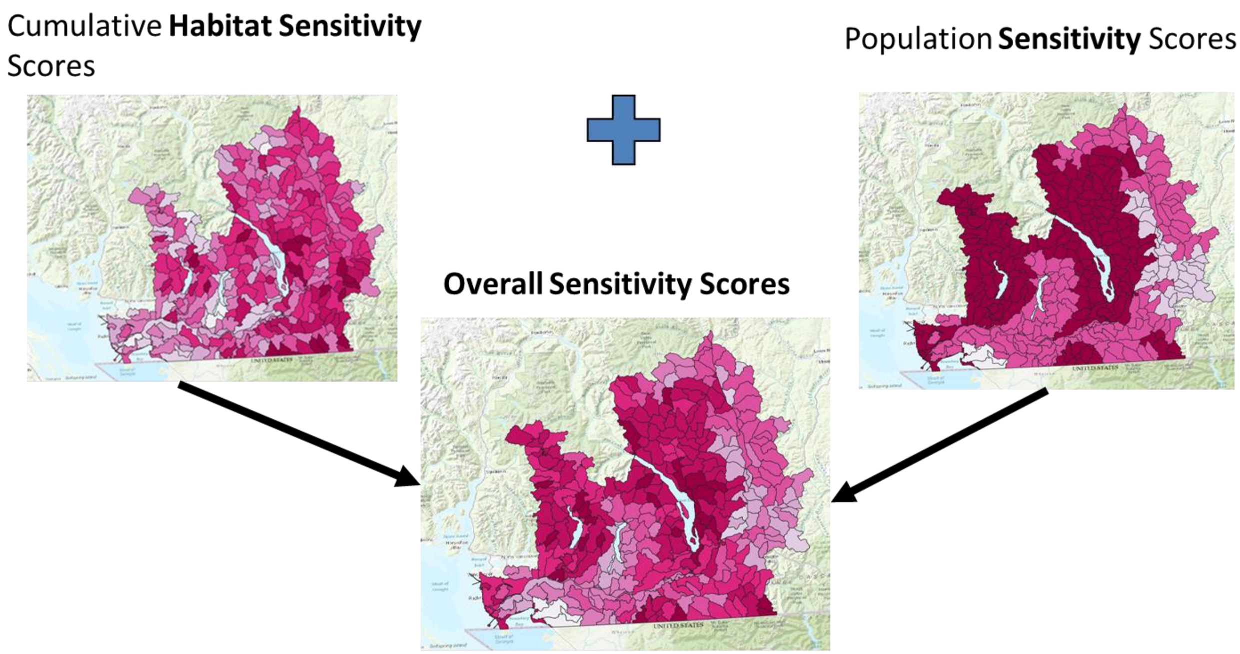


*Figure 18 Scoring summation of overall Sensitivity (habitat + population sensitivity scores) across all watersheds in the LFFA Study Area. Darker colours indicate watersheds with higher **relative** scoring for overall Sensitivity.*

6.3 Adaptive Capacity Indicators

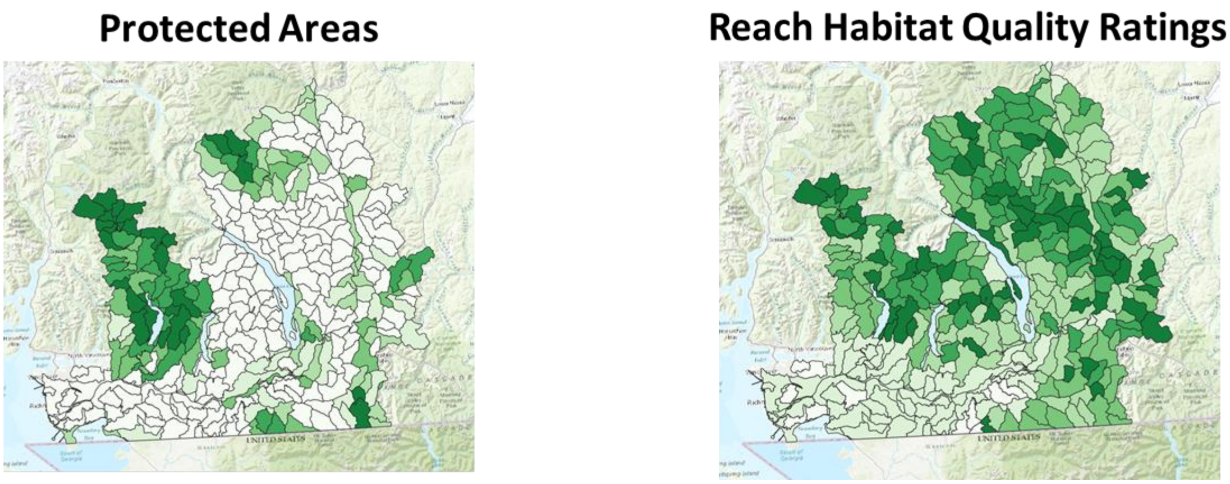


*Figure 19 **Habitat** adaptive capacity across all watersheds in the LFFA Study Area. Darker colours indicate greater **relative** habitat adaptive capacity to respond to impacts (based on a quintile split of values across LFFA Study Area watersheds for each indicator/metric).*

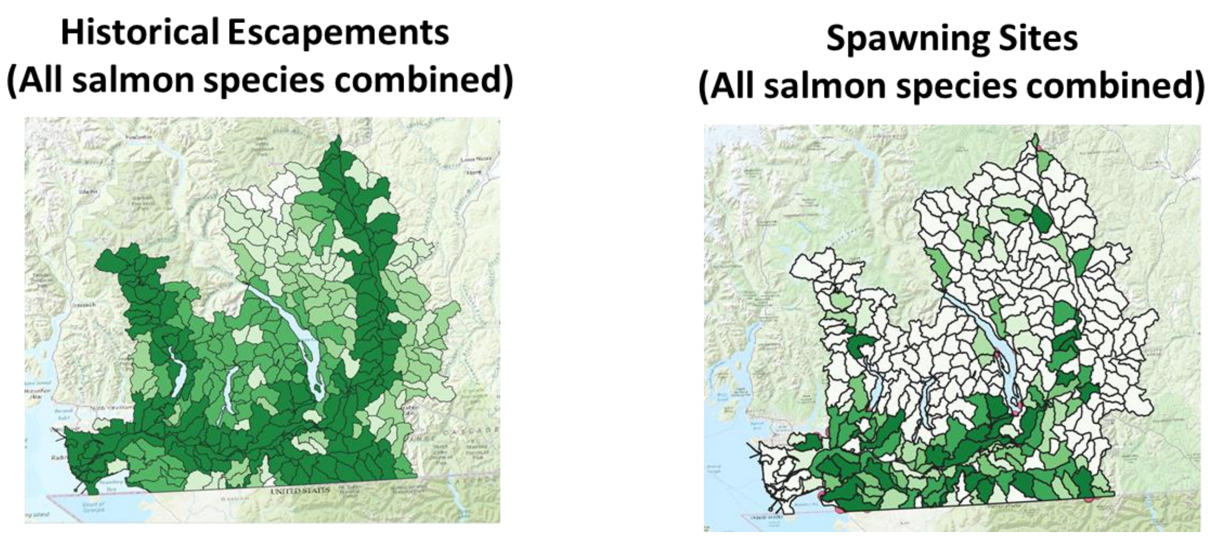


*Figure 20 **Population** adaptive capacity across all watersheds in the LFFA Study Area. Darker colours indicate greater **relative** population adaptive capacity to respond to impacts (based on a quintile split of values across LFFA Study Area watersheds for each indicator/metric).*

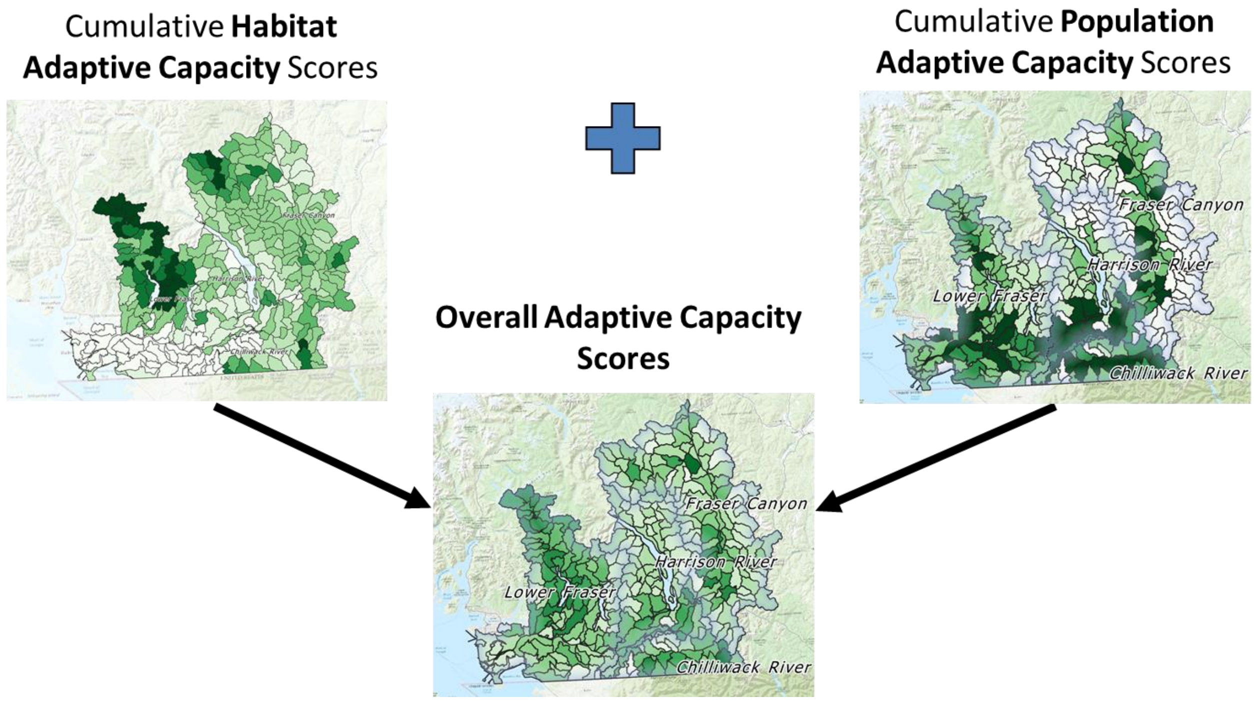
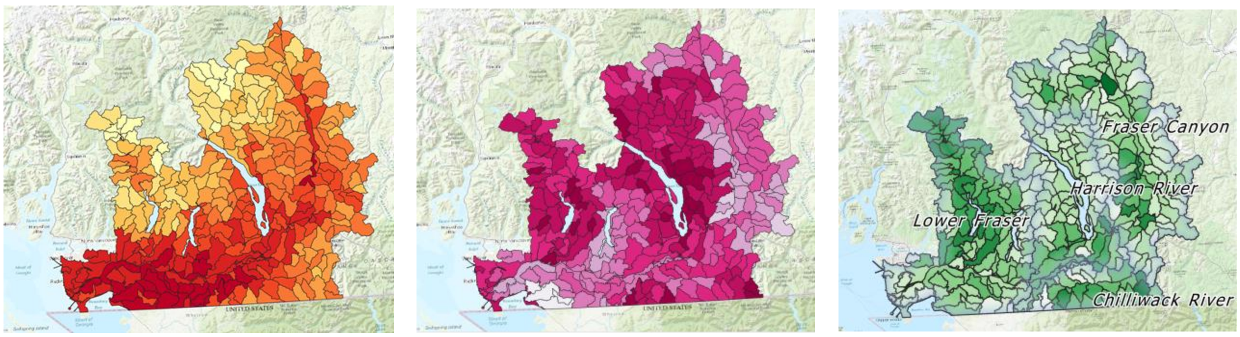


*Figure 21 Scoring summation of overall (Ecological) Adaptive Capacity (habitat + population adaptive capacity scores) across all watersheds in the LFFA Study Area. Darker colours indicate watersheds with higher **relative** scoring for overall (Ecological) Adaptive Capacity.*

6.4 Final Summations Across Indicator Categories

(A) Entire LFFA Study Area

Overall **Exposure** Scores | Overall **Sensitivity** Scores | Overall **Adaptive Capacity** Scores



(B) Harrison Planning Area

Overall **Exposure** Scores | Overall **Sensitivity** Scores | Overall **Adaptive Capacity** Scores

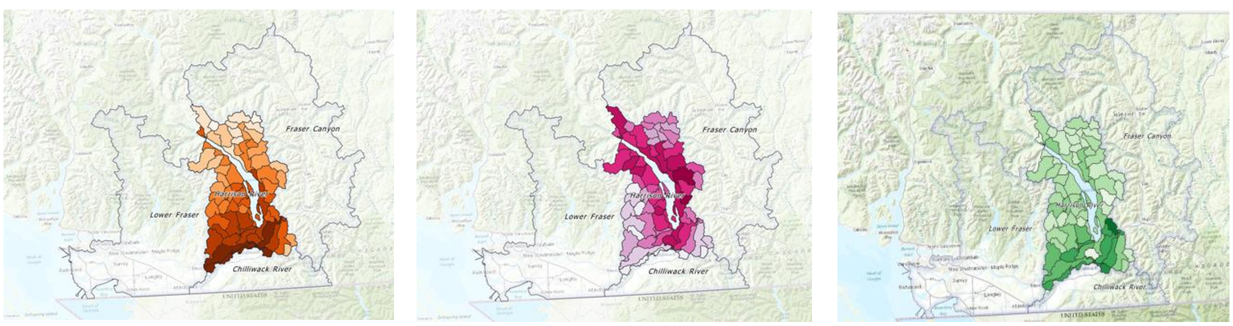


*Figure 22 Scoring summations of **relative** overall Exposure, Sensitivity, and (Ecological) Adaptive Capacity for watersheds across the entire LFFA Study Area (A), and within an individual LFFA Planning Area (Harrison Watershed - Mid Reach Fraser River (B), presented as an example of how relative scoring/ranking will differ if based only on watershed values within an individual Planning Area. Darker colours indicate watersheds with higher **relative** scoring within an indicator category (i.e., greater exposure, greater sensitivity, better adaptive capacity).*

6.5 Local Issues of Concern

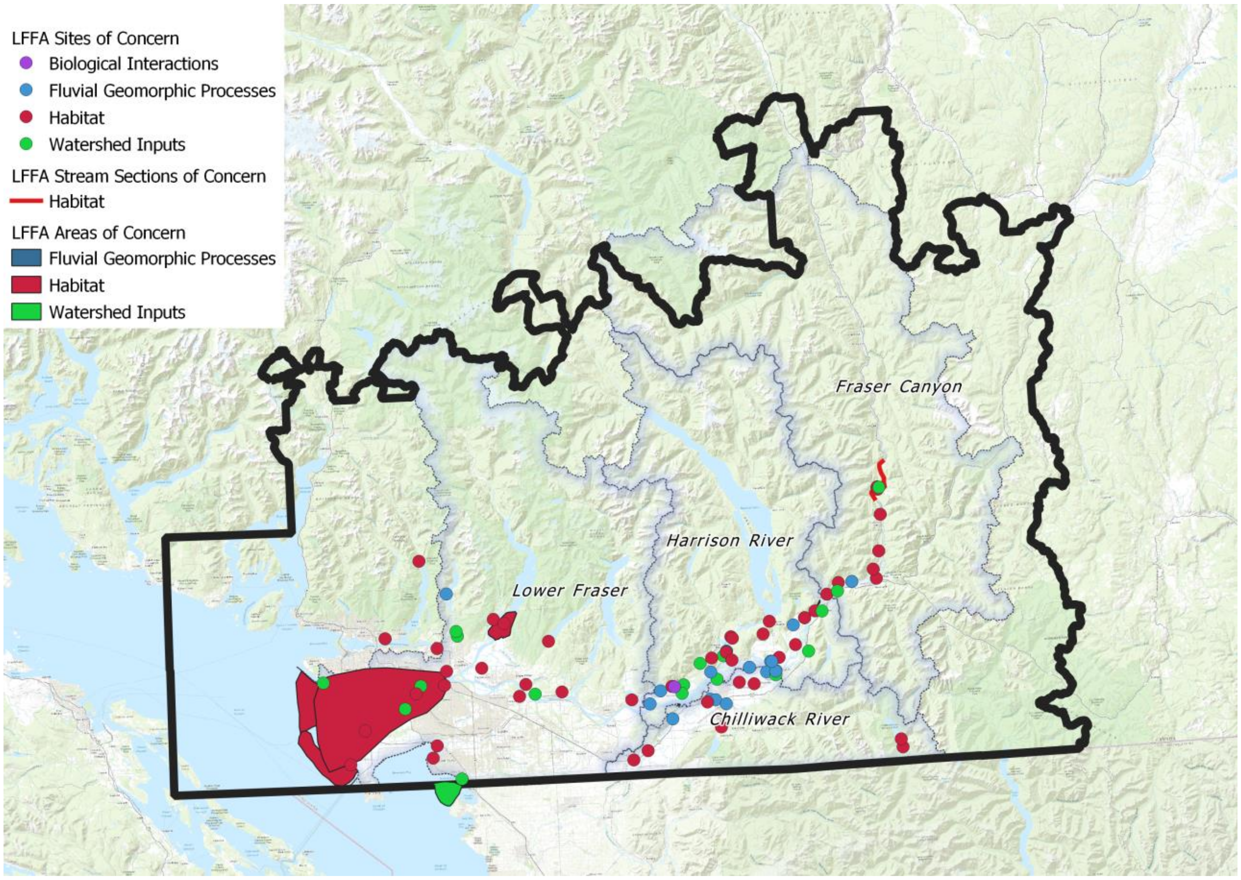


*Figure 23 Locations of local issues of concern within the LFFA Study Area identified by Planning Area representatives, classified here by the **key functional process tier impaired** at the location (i.e., Watershed Inputs, Fluvial Geomorphic Processes, Habitat, or Biological Interactions). Mapping of local issues are represented here as specific sites (points), stream segments (lines), or broader areas (polygons) of concern.*

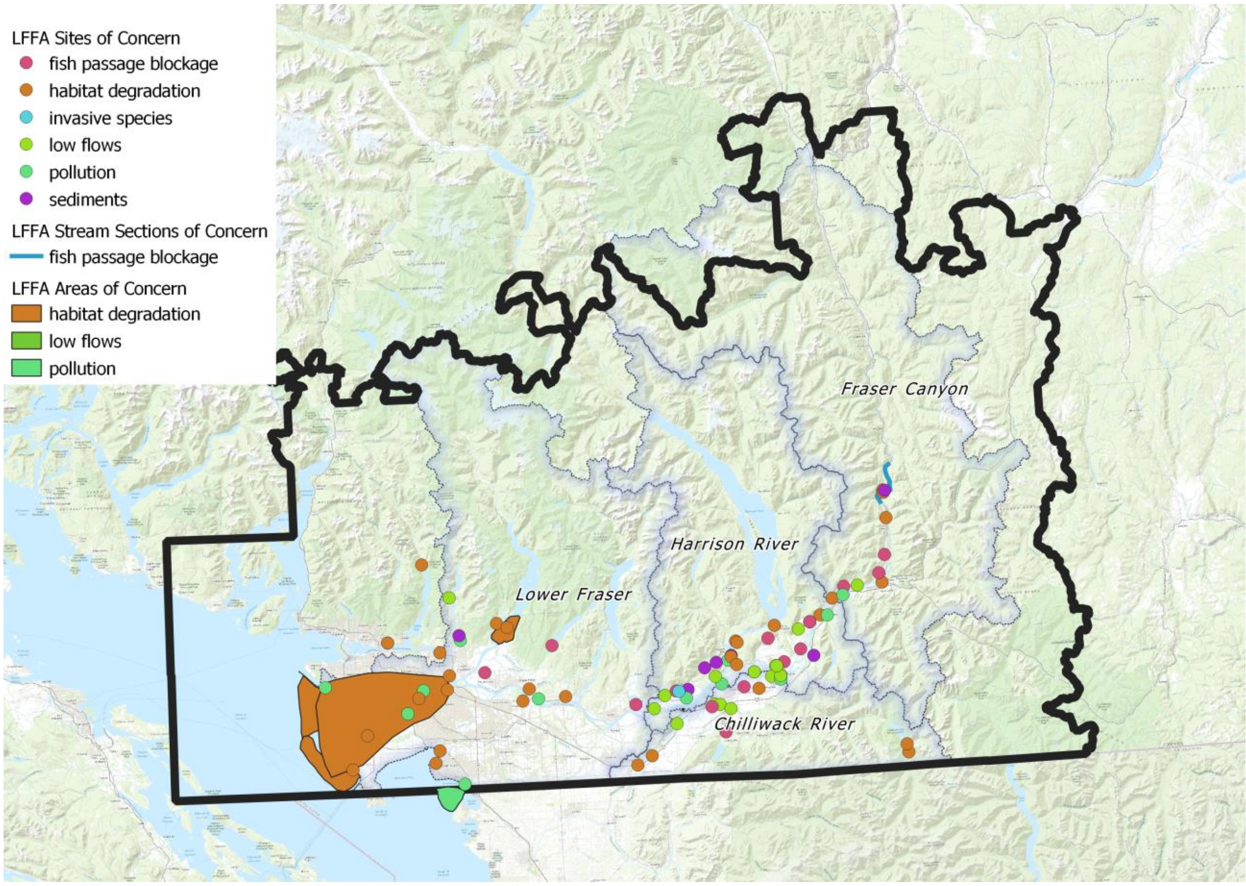


Figure 24 Locations of local issues of concern within the LFFA Study Area identified by Planning Area representatives, classified here by the ***key type of general concern*** *at the location. Mapping of local issues are represented here as specific sites (points), stream segments (lines), or broader areas (polygons) of concern.*

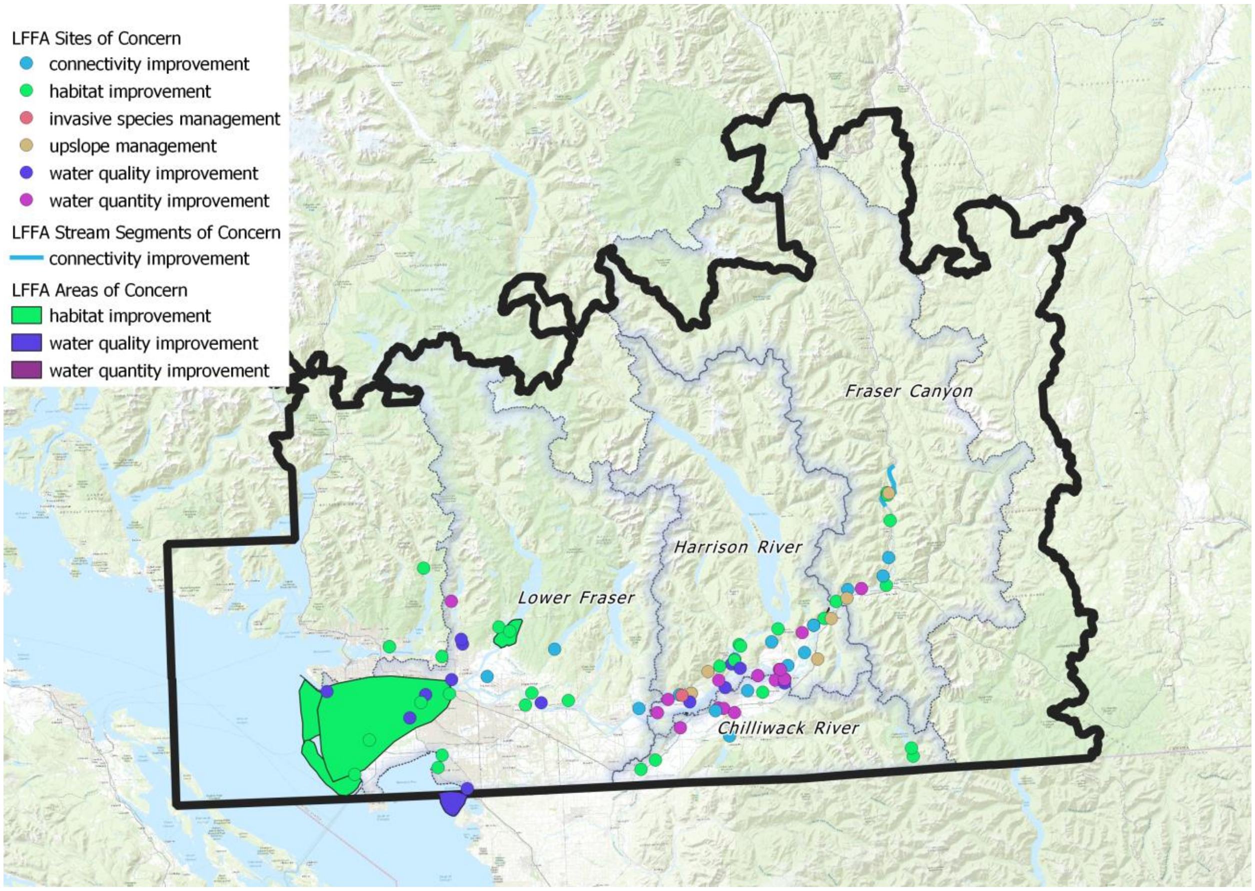


*Figure 25 Locations of local issues of concern within the LFFA Study Area identified by Planning Area representatives, classified here by the **proposed key adaptation actions to undertake** at the location in response to concerns. Mapping of local issues are represented here as specific sites (points), stream segments (lines), or broader areas (polygons) of concern.*

6.6 Selection of Priority Sites for Adaptation/Restoration Actions

For initial prioritization efforts using the Watershed Vulnerability Tool we used general defaults in our scoring of Sensitivity and Adaptive Capacity indicators, in that we used the pooled scoring across all salmon species combined. The Vulnerability Tool also has the ability to generate species-specific indicator scoring for Sensitivity and Adaptive Capacity indicators if the desire is to focus on key species of concern for adaptation/restoration efforts. Within each LFFA Planning Area we progressively adjusted indicator category scoring thresholds for selecting priority watersheds until we ultimately determined a percentile threshold to use that captured at least 5 identified sites of local concern (as previously identified by LFFA representatives) across the high priority watersheds defined within each of the four LFFA Planning Areas. This meant that different thresholds for prioritization might be used in each Planning Area, although the same percentile threshold was used for the Exposure, Sensitivity, Adaptive Capacity indicator categories in a particular Planning Area (e.g., 0.5 for Lower Fraser Approach, 0.2 for Fraser

Canyon, etc.). The scoring percentile thresholds used for the indicator categories within each LFFA Planning Area are provided in **Table 11**. If a greater number of watersheds (and associated greater number of intersecting local sites of concern) would like to be considered for identifying potential adaptation/restoration actions the prioritization thresholds can be adjusted as desired to be less restrictive. **Table 11** shows the subset of priority local issues (generally and specifically) identified within each LFFA Planning Area through this current exercise and the watershed process functional tier affected. Associated mapping embedded within the table shows the locations of the selected priority watersheds and the sites of key concern within those selected watersheds.

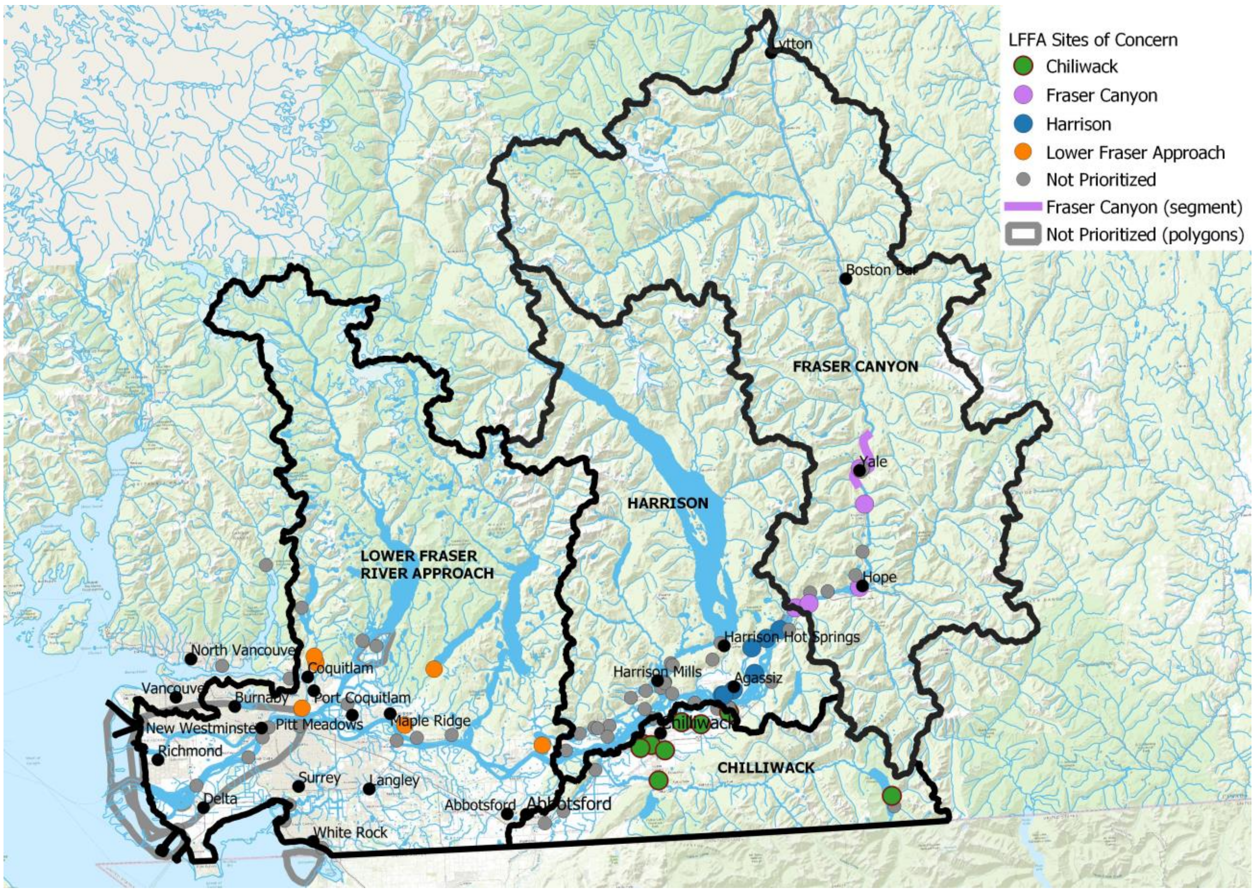
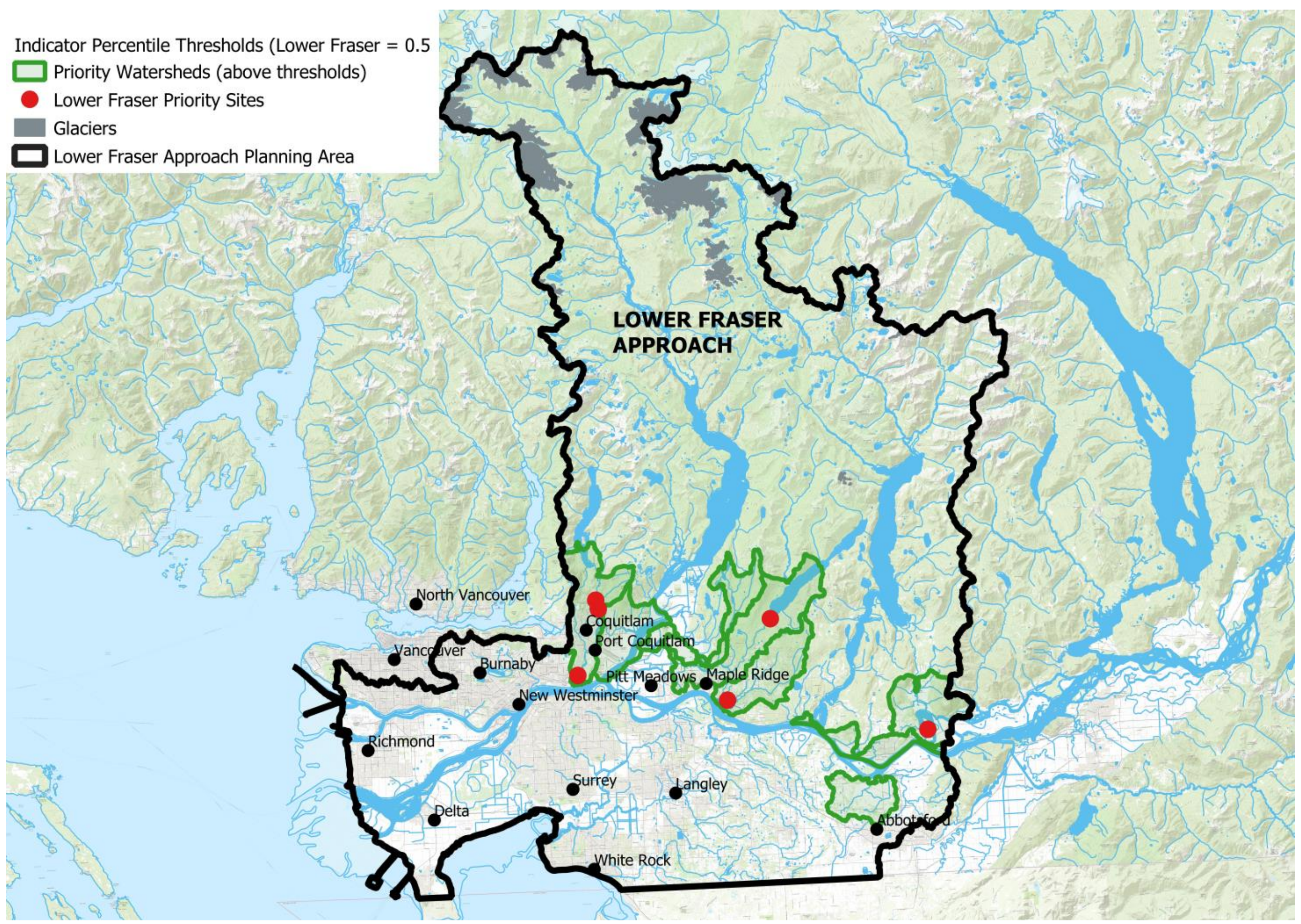


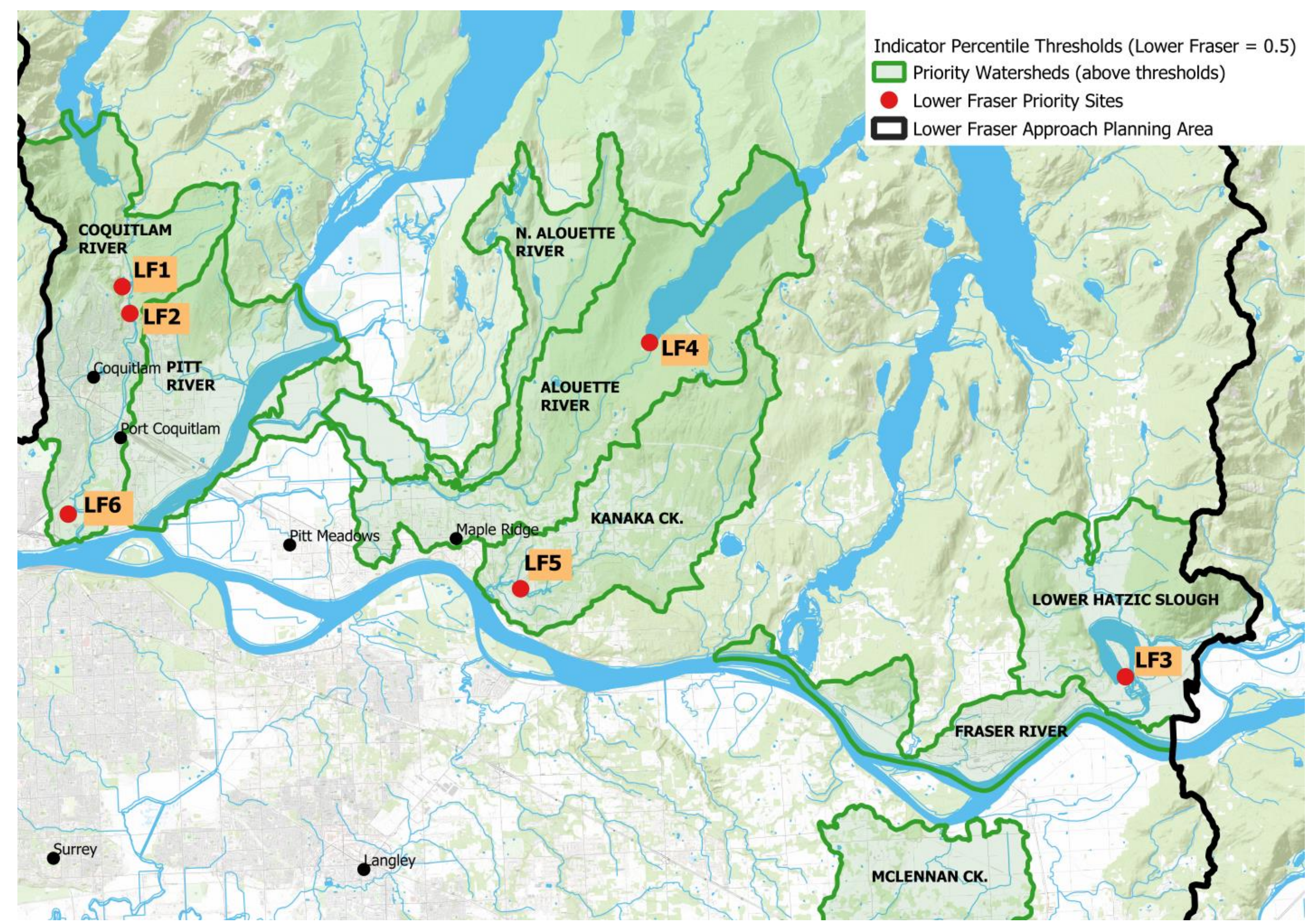
Figure 26 shows the locations of all local issues of concern identified by LFFA Planning Area representatives, including those that were or were not prioritized through filtering using the Watershed Vulnerability Tool.

Table 11 Priority locations for adaptation/restoration actions in LFFA Planning Areas (A – Lower Fraser Approach, B – Harrison Watershed/Mid Reach Fraser River, C – Fraser Canyon, and D – Chilliwack). Mapping of prioritized watersheds and sites of concern within each Planning Area provided with each table.

(A) Lower Fraser Approach Planning Area (indicator categories scoring percentile threshold used = 0.5)

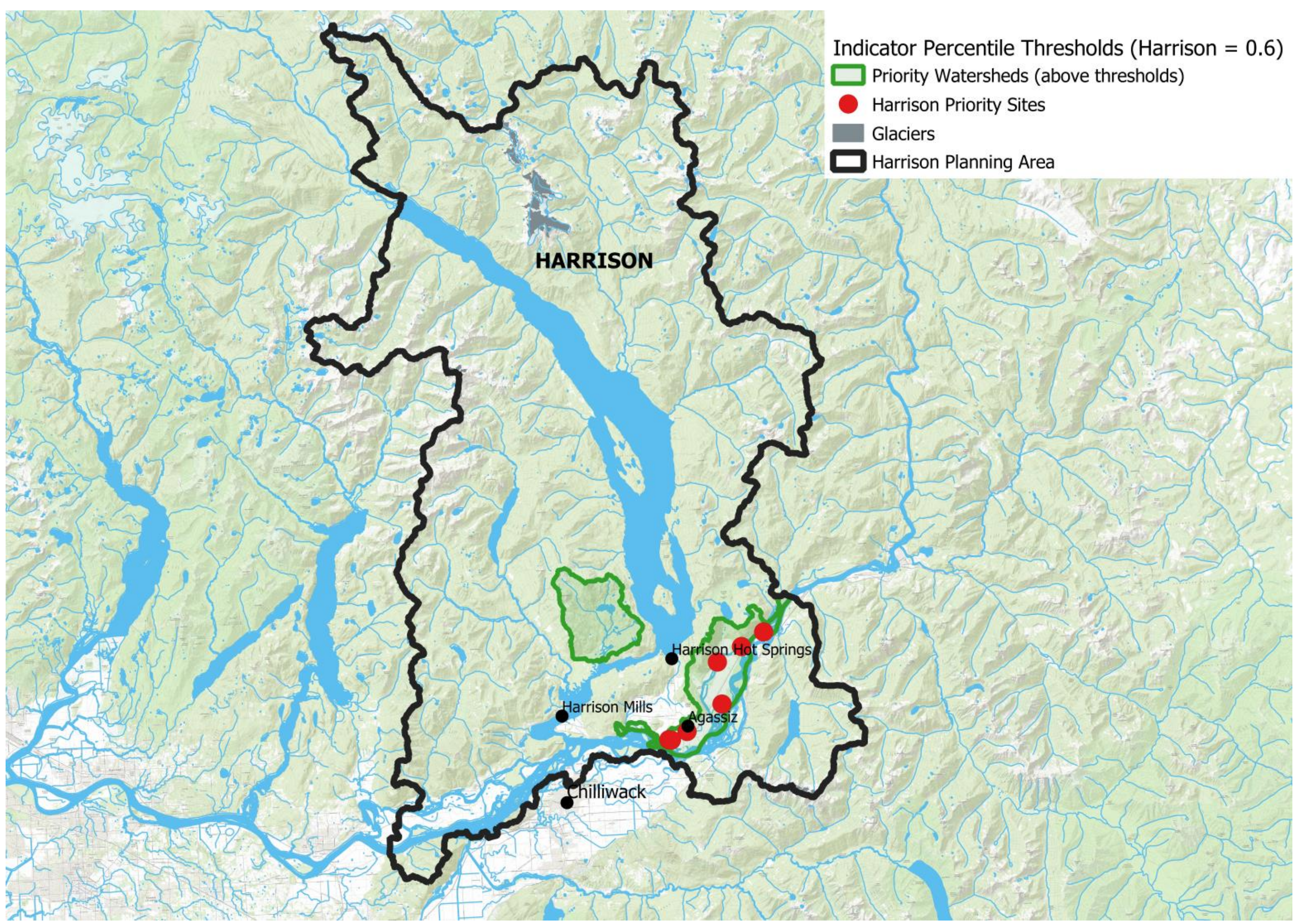
Issue Location	Site ID	Watershed	Functional Tier Affected	Issue (general)	Issue (specific)	Restoration Response Category	Watershed Group Code
Upper Coquitlam sites	LF1	Coquitlam R.	Watershed Inputs	sediments	Gravel mines in upper Coquitlam watershed (silt inputs)	water quality improvement	LFRA
Coquitlam R.	LF2	Coquitlam R.	Watershed Inputs	pollution	Increased siltation of Coquitlam river due to gravel quarries, industrial and residential development	water quality improvement	LFRA
Hatzic Lake/Hatzic Slough	LF3	Lower Hatzic Slough	Habitat	fish passage blockage	Invasive plants and fish, stagnant water, blocked fish passage due to current lake management practices	connectivity improvement	LFRA
Alouette Dam	LF4	Alouette R.	Habitat	fish passage blockage	Alouette Dam blocks Sockeye access to Alouette Lake (currently trucked)	connectivity improvement	LFRA
Kanaka Ck.	LF5	Kanaka Ck.	Habitat	habitat degradation	Riparian areas on Salmon River, Whonnock Ck. and Kanaka Ck. impacted by farming; need for improving riparian buffering	habitat improvement	LFRA
Wilson Farm	LF6	Coquitlam R.	Habitat	habitat degradation	Wilson Farm project (water temperature issues)	water quality improvement	LFRA

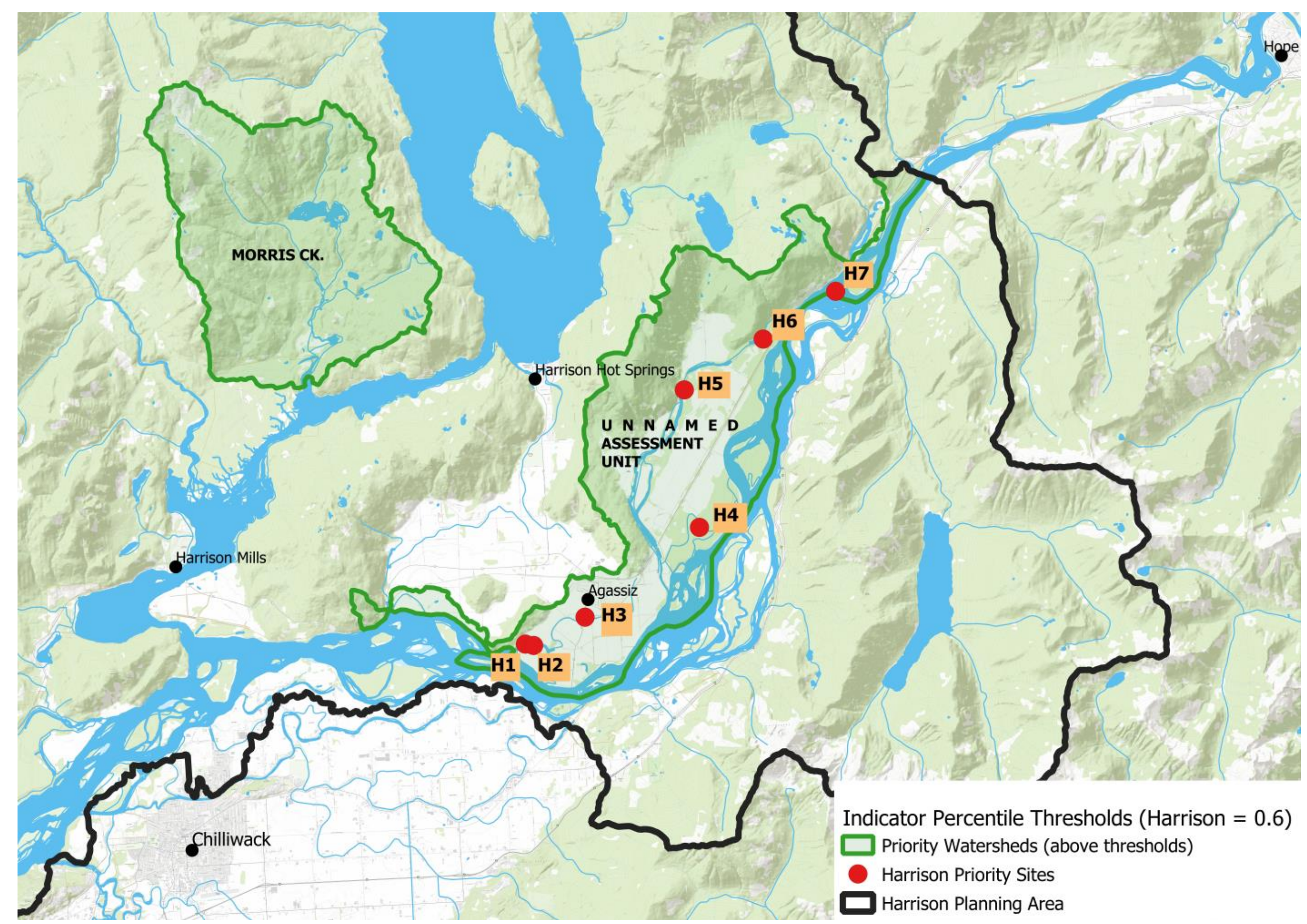




(B) Harrison Watershed - Mid Reach Fraser River Planning Area (indicator categories scoring percentile threshold used = 0.6)

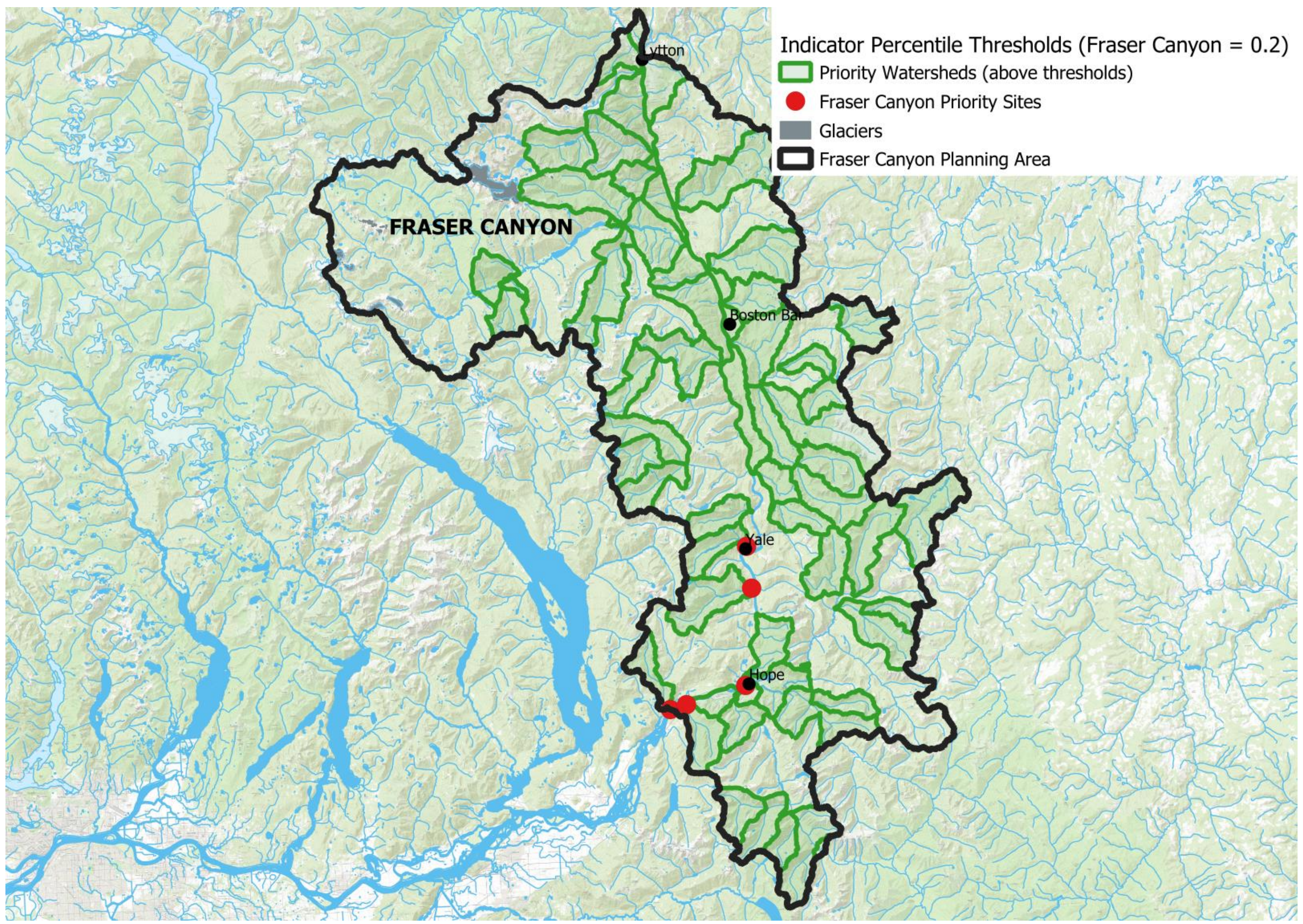
Issue Location	Site ID	Watershed	Functional Tier Affected	Issue (general)	Issue (specific)	Restoration Response Category	Watershed Group Code
Cheam Slough	H1	Unnamed Assessment Unit	Fluvial Geomorphic Processes	low flows	Old channels where there is no water, need floodgates	water quantity improvement	HARR
Cheam Slough	H2	Unnamed Assessment Unit	Fluvial Geomorphic Processes	low flows	Limited flows into Thompson Slough, Cheam Slough (engineering flows through the dikes with flood gates should be considered)	water quantity improvement	HARR
Agassiz Slough	H3	Unnamed Assessment Unit	Habitat	fish passage blockage	Agassiz Slough used to join Maria Channel at Seabird Island but now filled in by roads (likely used to be important spawning area, now closed off)	connectivity improvement	HARR
Seabird Island	H4	Unnamed Assessment Unit	Habitat	fish passage blockage	Blocked channel on Seabird Island that could be restored	connectivity improvement	HARR
Hicks Creek	H5	Unnamed Assessment Unit	Fluvial Geomorphic Processes	low flows	Generally concerned about low water levels in summer	water quantity improvement	HARR
Maria Slough	H6	Unnamed Assessment Unit	Habitat	fish passage blockage	access closed off by CP rail tracks (also many invasive plants)	connectivity improvement	HARR
Power Line bar	H7	Unnamed Assessment Unit	Habitat	habitat degradation	Power line bar at Cheam already has restored Coho (800m) spawning habitat, and then want to restore another part for Chum spawning. There are fresh water springs in there. Want to remove gravel.	habitat improvement	HARR

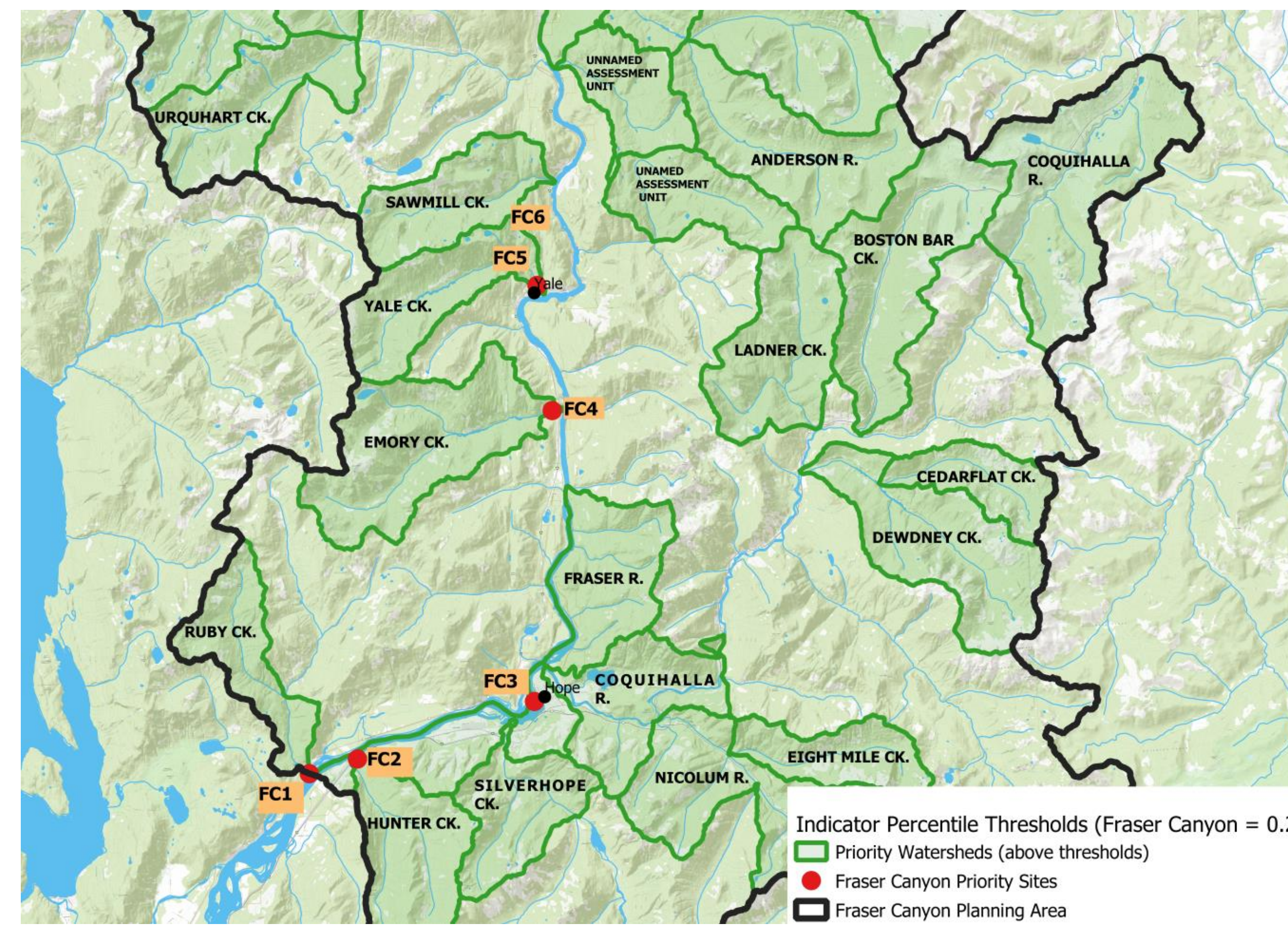




(C) Fraser Canyon Planning Area (indicator categories scoring percentile threshold used = 0.2)

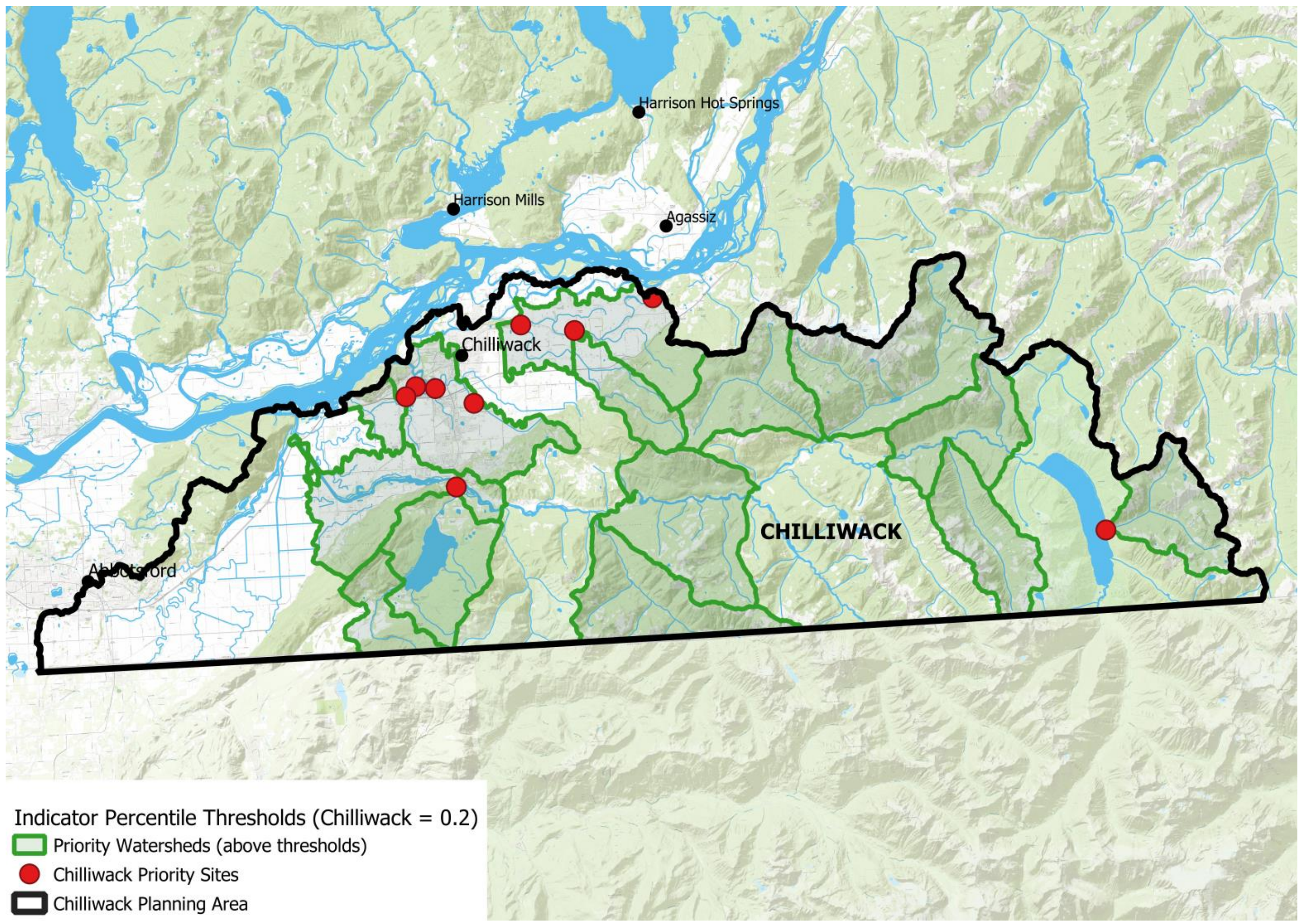
Issue Location	Site ID	Watershed	Functional Tier Affected	Issue (general)	Issue (specific)	Restoration Response Category	Watershed Group Code
Ruby Ck.	FC1	Ruby Ck.	Habitat	habitat degradation	dike impairments	habitat improvement	FRCN
Hunter Ck.	FC2	Hunter Ck.	Watershed Inputs	pollution	High sediment loads from logging in Hunter Creek	upslope management	FRCN
area below Hope Bridge	FC3	Fraser R.	Habitat	habitat degradation	Riparian areas impacted by past heavy windstorms (loss of trees, extensive erosion)	habitat improvement	FRCN
Emory Ck.	FC4	Emory Ck.	Habitat	habitat degradation	habitat degradation (Coho & Pink present - multiple kms of useable habitat)	habitat improvement	FRCN
Yale Ck.	FC5	Yale Ck.	Habitat	habitat degradation	habitat degradation (Coho & Pink present - but only short length of useable habitat)	habitat improvement	FRCN
Creeks west of highway (multiple sites/reaches)	FC6	Fraser R.	Habitat	fish passage blockage	upstream logging has caused debris blockages at stream culverts	connectivity improvement	FRCN

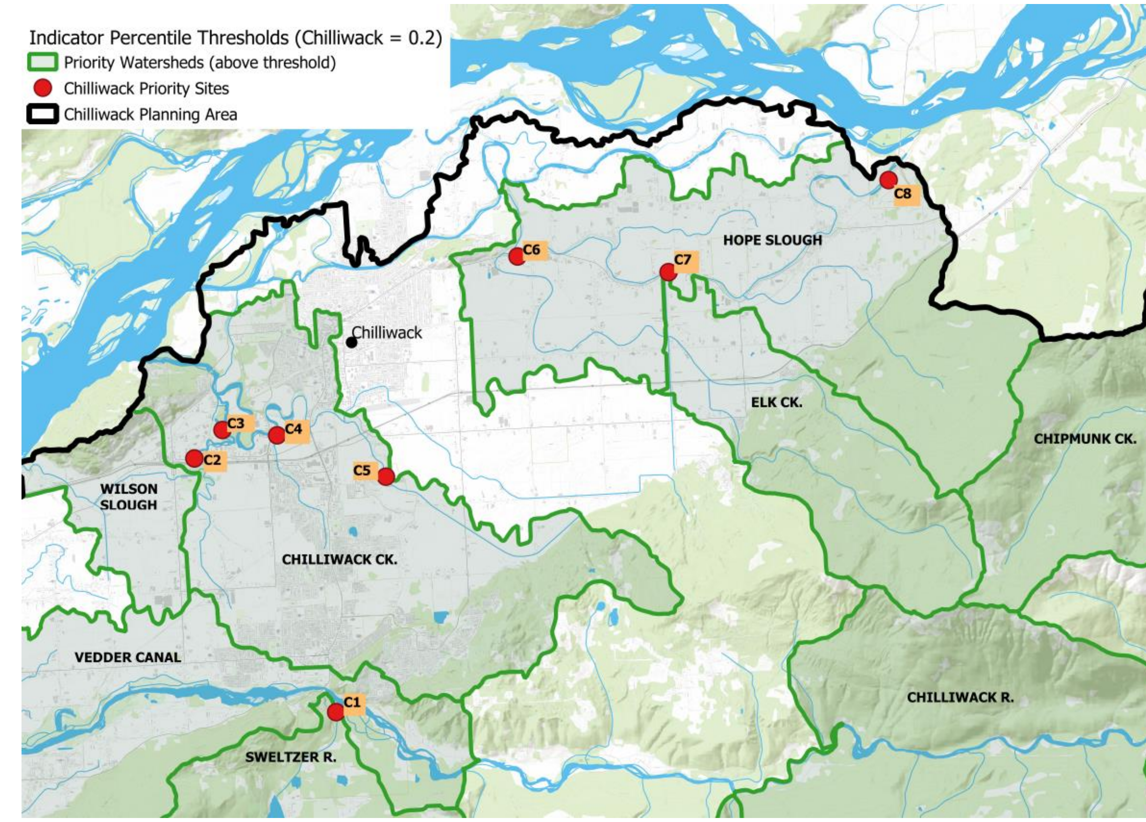


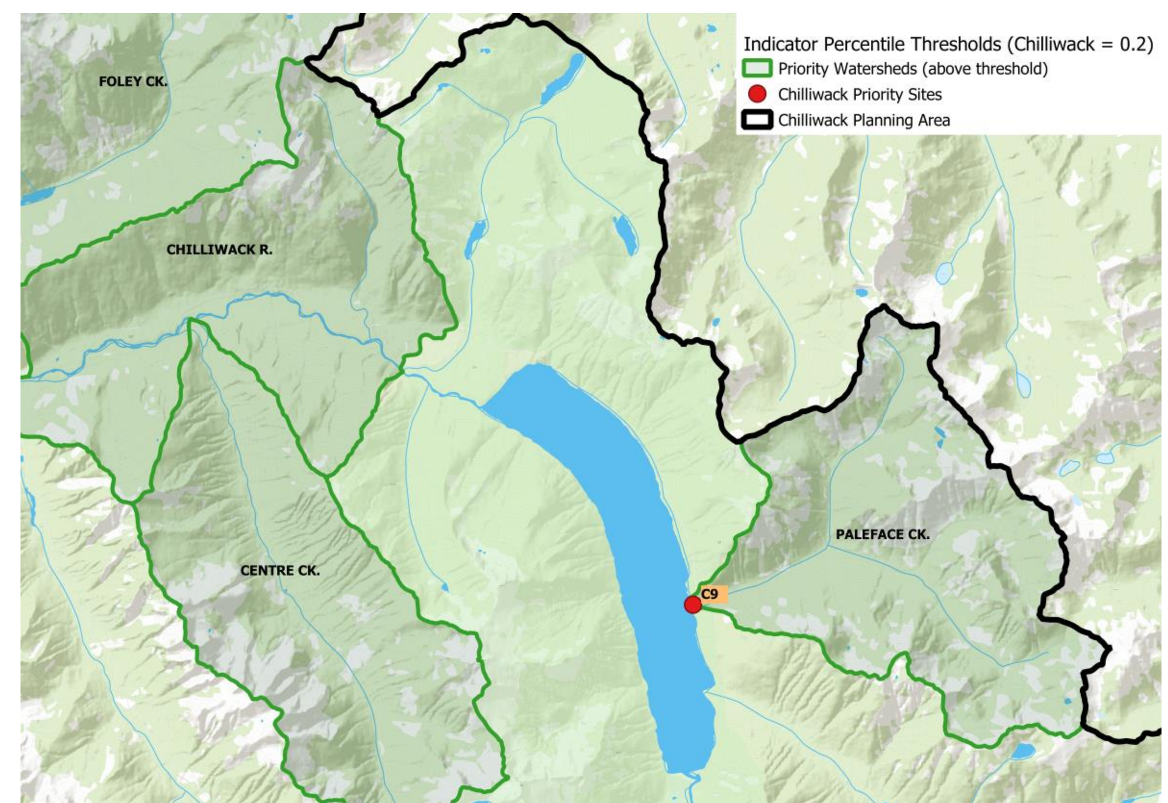


(D) Chilliwack Planning Area (indicator categories scoring percentile threshold used = 0.2)

Issue Location	Site ID	Watershed	Functional Tier Affected	Issue (general)	Issue (specific)	Restoration Response Category	Watershed Group Code
Sweltzer Ck.	C1	Sweltzer R.	Habitat	fish passage blockage	Fish access to Sweltzer Creek blocked in recent years (Chinook and Chum used to spawn there)	connectivity improvement	CHWK
Aitchelitiz Ck.	C2	Chilliwack Ck.	Habitat	fish passage blockage	Channels to Atchelitz Ck. historically used by Pink and Chum now blocked by Yale Road, new freeway	connectivity improvement	CHWK
Atchelitz Ck.	C3	Chilliwack Ck.	Fluvial Geomorphic Processes	low flows	Aitchelitz, Luckacuk, and Little Chilliwack River are drying up and have become shorter due to aquifer extractions for drinking water	water quantity improvement	CHWK
Luckacuk Ck.	C4	Chilliwack Ck.	Fluvial Geomorphic Processes	low flows	Aitchelitz, Luckacuk, and Little Chilliwack River are drying up and have become shorter due to aquifer extractions for drinking water	water quantity improvement	CHWK
Little Chilliwack River	C5	Chilliwack Ck.	Fluvial Geomorphic Processes	low flows	Aitchelitz, Luckacuk, and Little Chilliwack River are drying up and have become shorter due to aquifer extractions for drinking water	water quantity improvement	CHWK
Hope Slough	C6	Hope Slough	Habitat	fish passage blockage	fish access into slough blocked	connectivity improvement	CHWK
Elk Ck.	C7	Elk Ck.	Habitat	habitat degradation	Elk Ck. has been turned into agricultural ditches rather than a functioning waterway, no longer salmon habitat	habitat improvement	CHWK
Cheam landfill	C8	Hope Slough	Habitat	pollution	Potential river contamination from landfills around Skyway, Cheam, and Kwantlen FN lands	Water quality improvement	CHWK
Paleface Ck.	C9	Paleface Ck.	Habitat	habitat degradation	Concerns for habitat condition of tributaries to Chilliwack Lake relating to extensive logging on the east side of the lake	habitat improvement	CHWK


Harrison Hot Springs
Harrison Mills
Agassiz
Chilliwack
CHILLIWACK
Abbotsford
Indicator Percentile Thresholds (Chilliwack = 0.2)
Priority Watersheds (above thresholds)
Chilliwack Priority Sites
Chilliwack Planning Area


Indicator Percentile Thresholds (Chilliwack = 0.2)
Priority Watersheds (above threshold)
Chilliwack Priority Sites
Chilliwack Planning Area
C8
HOPE SLOUGH
C6
C7
Chilliwack
ELK CK.
C3
C4
C2
C5
CHIPMUNK CK.
WILSON SLOUGH
CHILLIWACK CK.
VEDDER CANAL
CHILLIWACK R.
C1
SWELTZER R.


FOLEY CK.
Indicator Percentile Thresholds (Chilliwack = 0.2)
Priority Watersheds (above threshold)
Chilliwack Priority Sites
Chilliwack Planning Area
CHILLIWACK R.
PALEFACE CK.
CENTRE CK.
C9

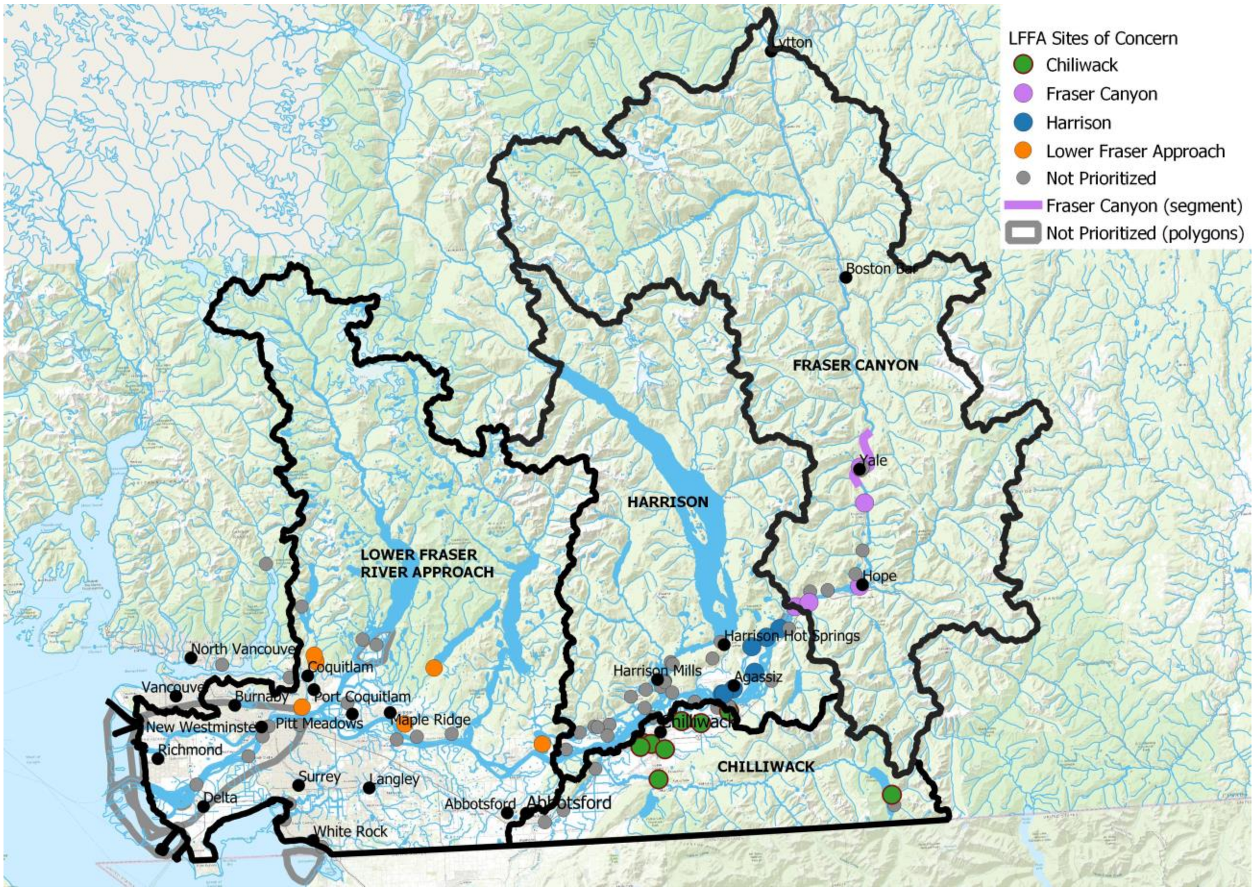


Figure 26 Locations of all issues of local concern in the Study Area identified to date by LFFA Planning Area representatives. Gray coloured sites points/lines/polygons are locations that were not prioritized in the current exercise. The brighter colored site locations (orange, blue, green, and purple) are those that were prioritized in the current exercise for consideration for habitat adaptation/restoration actions within each LFFA Planning Area.

While the Climate Adapt Phase 3 process to date has helped select priority watersheds of concern within each LFFA Planning Area and identify the known issues of key concern within these watersheds determining the specific types of adaptation/restoration projects to undertake to address these concerns will require additional considerations. Restoration projects are planned and executed with the hope that improving freshwater rearing, spawning, and migrating habitat will enhance survivorship of threatened salmonids and offset some of the sources of fish mortality (as represented earlier in **Figure 4**). For any identified habitat issue different adaptation/restoration alternatives may potentially exist to remedy the problem. Alternatives to be considered for a particular project may include one approach or combinations of techniques that address different components of the issue. Any or all alternatives may be potentially valid to employ to some extent.

7. Next Steps – Implementation of the Prioritization Framework

The results of climate change vulnerability assessments generated through use of the Watershed Vulnerability Tool developed within this project can be used to inform prioritization of watersheds for targeted adaptation efforts to protect or restore key functional processes and address threats across the LFFA Study Area and within individual Planning Areas. Principally, Tool outputs can help determine where adaptation/restoration actions may be most needed. While various initial scoring defaults are in place within the Watershed Vulnerability Tool it is designed to be flexible to various user-defined inputs to consider in overall vulnerability scoring of LFFA watersheds across the three indicator components (i.e. Exposure, Sensitivity, and (Ecological) Adaptive Capacity) and allows adjustment of:

- input indicators to use as desired to target key local concerns,
- benchmarks to use for scoring levels of relative concern for each indicator
- different geographic areas/spatial boundaries to use for undertaking relative vulnerability comparisons,
- evaluation of sensitivity and adaptive capacity measures for all salmon species combined (as a composite indicator) or for each individual salmon species (Chum, Coho, Sockeye, Chinook, and Pink)
- threshold levels to be used for defining subsets of watersheds to consider targeting for adaptation/restoration actions prioritization (e.g., top 25% of watersheds scored most exposed to cumulative exposure & then top 50% of those watersheds scored most sensitive to exposure, etc.), and
- the desired ordering of indicator categories for sequentially prioritizing watersheds for potential adaptation/restoration actions (e.g., Exposure issues evaluated first, Sensitivity issues evaluated second, etc.).

Before implementing the Tool for targeting restoration priorities it will be useful to further explore/vet analytical outputs with LFFA Planning Area representatives. The locations and types of issues of local concern as identified by LFFA representatives can be used to determine if watershed-level impacts as identified/predicted through indicator analyses are consistent with the types of local on-the-ground habitat problems that we would expect to be identified within each Planning Area. Once elements of the Watershed Vulnerability Tool are finalized and acceptable for use by LFFA the Tool could help inform annual watershed planning exercises. Vulnerability assessment results from the Tool could be used in conjunction with field observations of aquatic ecosystem conditions to identify priority watersheds for adaptation/restoration within and across LFFA Planning Areas and determine appropriate management actions. In addition to identifying currently vulnerable watersheds, results from the Tool could also be used to target watersheds for field monitoring as data from key, representative watersheds could be used to track potentially broader watershed health issues that might affect conditions across all LFFA watersheds and help pinpoint specific causes of habitat degradation. Ultimately, monitoring and evaluating changes in the different vulnerability metrics and associated processes over time (at different spatial scales) will be useful for tracking progress and determining whether any directed management/restoration actions have been successful. Vulnerability assessment results could potentially also be used as part of efforts to inform and the public on the general status of habitats and salmon populations in their local watersheds relative to other watersheds the lower Fraser, and to help encourage action to protect or improve their watersheds (through protective zoning at the local level, for example).

Improvements in a next iteration of the Tool could include the ability to provide user-defined weightings for particular indicators. Currently all indicators within an indicator category are weighted equally within overall scoring. Weighting would allow greater importance to be placed on certain factors as desired (e.g., if mines were considered an issue of greater concern than roads, for example). Incorporating weighting would also allow the ability to explore the sensitivity of final results to alternative indicator weightings. The current Watershed Vulnerability Tool (coded in R) would also benefit from additional efforts to improve ease of use, such as developing a user interface (UI), to allow easier implementability across potential user groups.

Additional vulnerability indicators/associated metrics could be included in next iterations of the Tool as data availability and modeling efforts allow, and could expand/improve initial representations of watershed vulnerability. Examples of additional watershed-scale indicators to consider in this regard include:

- extent of lake eutrophication within watersheds (i.e., based on phosphorus and chlorophyll a levels).
- Vulnerability of watersheds to aquatic invasive species establishment (could be quantified according to a watershed's proximity to existing aquatic invasive populations and other watershed characteristics (as suggested in EPA 2014)).
- projected percent change in fish species distributions within watersheds under modeled climate shifts (i.e., changes in stream temperature patterns (as in Nelitz et al. 2010; Porter et al. 2017)
- evaluation of the broader range of potential air temperature and precipitation changes across LFFA watersheds based on outputs from multiple global climate models (GCM) (climate predictions in the Tool are currently based on a single "business as usual" GCM projection only).

Additionally, while the best currently available, broad-scale data has been assembled for the exercise there remains a need to continue to develop improved information on salmon populations and their habitats across LFFA Planning Areas to better inform different elements of the vulnerability assessment. Much work was done in Phase 2 of this project to fill known information gaps, and additional agency and academic-based data sources were accessed in Phase 3 to develop additional indicators for use in the Tool. However some of the data gaps identified previously by Zoetica (2019) for Phase 2 of this project still apply, and could be the focus of additional data gathering efforts in the future. Some examples of data gaps/deficiencies to focus on for future improvements in quantitative vulnerability assessments in the LFFA Study Area include:

- improved mapping of rearing, migration, and spawning habitat locations
- Identification of invasive species hotspots
- Identification of areas of high restoration potential (e.g., based on LiDAR-based mapping of buried sloughs, etc.)
- Improved mapping of terrain stability
- improved fish passage barrier information
- improved numeration of spawner abundance across a greater number of watercourses
- more extensive information on water quality (particularly seasonal water temperatures and dissolved oxygen)

7.1 Project Prioritizations

Section 4.4 briefly discussed indicators that could be developed for evaluating (Human) Adaptive Capacity. As yet we have not yet been able to incorporate information of this type into the Watershed Vulnerability Tool. Efforts to acquire this information broadly across the Study Area, while difficult, could become a focus of next efforts by LFFA. Alternatively in the near-term, as we have suggested in Section 4.4, information on the potential degree of human responsiveness could be collected, evaluated, and scored at the time of specific project proposals and this information then integrated with the outputs from the Tool as an additional adaptive capacity element for rating project prioritizations.

Effective project prioritization frameworks can provide a systematic, repeatable, and transparent rationale for making restoration decisions given limited funding, capacity, and time (Beechie et al. 2008, Roni et al. 2013). Prioritization in this sense refers to the process of scoring or ranking of potential restoration actions to determine the most beneficial sequencing to inform funding and implementation decisions, and to begin to logically group the top-tier of priority restoration actions into a coherent set of restoration packages or overall restoration strategies. Structured prioritization frameworks help to clarify the decision-making process for funding agencies, proposal reviewers, project proponents, and other stakeholders that will be affected by these decisions and facilitate reprioritization on a regular basis as projects are completed, new opportunities are identified, and new information becomes available. Prioritization can take place at the level of the basin, watershed, sub-watersheds, or reaches, or alternatively by habitat type, but prioritization at smaller scales needs to be consistent with a basin-wide restoration strategy. Initiatives at a regional scale may take a multi-level approach involving prioritization across watersheds within a basin-wide strategy, followed by prioritization of projects within watersheds (Beechie et al. 2008, Roni et al. 2013).

Many approaches to project prioritization are possible depending on restoration objectives, spatial scale, and level of information available; each approach has pros and cons (Roni et al. 2013; Roni et al. 2017; **Table 12**). Beechie et al. (2008) provide an overview of river restoration prioritization approaches and suggest that there are six different general approaches that can be used. These approaches are project type, refugia, decision support systems, single-species analysis, multispecies analysis, and cost effectiveness. They specify that the prioritization approach chosen will depend on the amount of information available and each will have different strengths and weaknesses. They identify the first three approaches as “logic” approaches because they are based on simple logic tools rather than on detailed information about the changes in watershed processes and habitats. The first is project type in which techniques that have a high probability of success, relatively quick response time, and long duration should be implemented before other techniques. The second approach is refugia, which is based on protecting sites in the best condition first and then expanding outward from those areas. This strategy may be most appropriate if at least one species is at high risk of extinction. The third logic approach is decision support systems which uses qualitative or semi-quantitative tools (such as Multi-criteria Decision Analysis (MCDA)) to weigh information and set priorities. Groups can rank and score projects based on common evaluation criteria and compare them based on total scores or component scores. The final three approaches (i.e., single-species analysis, multispecies analysis, and cost effectiveness (e.g., Walsh et al. 2020) are categorized by Beechie et al. (2008) as “analytical” because they are based on analyses of habitat loss or degradation, changes in watershed processes, and importance of specific habitat losses to one or multiple species.

Table 12 Common approaches for prioritizing restoration (ESSA 2018, adapted from Beechie et al. 2008, Roni et al. 2013, Roni et al. 2017).

Approach	Description	Pros	Cons
Logic-Based Approaches			
Project Type & Effectiveness	Ranks projects based on general understanding of effectiveness from literature review.	Helpful interim approach if no or limited data available on physical habitat conditions.	Ignores influence of local contexts on effectiveness of a given project type. Also does not account for other elements that could inform decision.
Refugia	Prioritizes protecting refugia first, and then restoration near refugia.	Useful approach for single species dependent on a specific habitat type.	Challenging to implement for multiple species with different habitat requirements. Does not encourage rehabilitation of process and function in highly degraded environments.
Decision Support: Multi-criteria Decision Analysis (MCDA)	Also known as multi-criteria scoring. A rubric where projects or watersheds are scored on multiple criteria (e.g., effectiveness, cost, extent) to determine overall rank, and then combining projects into a coherent restoration strategy.	Widely used, transparent and easy to document, incorporates multiple information types, and adaptable to varying spatial scales and data availability.	Scales and weightings used for criteria imply some level of subjectivity in prioritization. Priorities may be influenced by 'who' is asked to participate in the scoring.
Analytical Approaches			
Scale of Effect	Ranks projects by area restored and/or projected increase in fish production	Based on habitat-abundance relationships derived from empirical data.	Data may be unavailable in all regions, challenging to predict benefit to fish populations for specific projects with much certainty.
Capacity or Life-Cycle Computer Models	Estimates population benefits at each life stage to predict overall population benefit from a given project. Other types of computer models use statistical approaches to predict restoration outcomes.	Based on empirical data for specific life stages, and species, can handle complex data types.	Complex, time consuming, requires detailed habitat and fish population data by life stage, and difficult to draw conclusions at the project scale. Often many assumptions with rankings sensitive to these assumptions. One of the least transparent approaches for some stakeholders.
Cost-Benefit	A strictly cost or cost-benefit approach to ranking projects.	Provides a common currency for comparing across projects.	Many benefits are hard to translate into economic terms. Costing data difficult to obtain or compare across project types, and economic benefits of restoration challenging to estimate, omits other factors contributing to project effectiveness.

Multi-criteria scoring approaches are widely used in many restoration programs across agencies and institutions for prioritizing habitat restoration actions for funding and implementation (e.g., NRC 1992; OWEB 2005; Griebling et al. 2006; Thom et al. 2011; LCREP 2011; USDE 2003; NMFS 2014; Goodman and Reid 2015; ELI 2013, MDEP 2017). Multi-criteria scoring approaches Have the benefit of being transparent, and highly adaptable, being based on a set of criteria associated with simple scales and weighting systems (Roni et al. 2013).

Applying multi-criteria scoring involves the following key steps:

1. selection of criteria to score,
2. identifying the scoring and weighting method/algorithms,
3. data collection and inventory analysis as needed to assist with scoring,
4. scoring and ranking of projects; and
5. discussion and further synthesis of the results into a coherent restoration strategy.

We recommend that the LFFA develop a multi-criterion scoring approach (also referred to as multi-criteria decision analysis (MCDA) framework) to supplement and extend the indicator-based watershed prioritization process developed through the Watershed Vulnerability Tool. A proposed adaptation/restoration project scoring tool to employ for ranking/prioritizing potential adaptation/restoration projects within LFFA Planning Areas is presented in an accompanying Excel spreadsheet tool (**LFFA Project Prioritization Rubric.xlsx**). The suggested structure/criteria for scoring of proposed projects within this prioritization tool are presented in **Appendix D**. The proposed prioritization rubric represents a derived synthesis of project prioritization categories and associated rating criteria employed across multiple agencies for various restoration programs in Canada and the U.S., customized for application by the LFFA. The project ranking or prioritization scores resulting from use of this tool are **not** intended to be definitive final decisions but can provide a logical starting point to help structure unbiased stakeholder discussions. Such prioritization systems should be a framework to inform a rational, neutral dialogue amongst rating committee members and interested participants, and not a computer formula which replaces human decision-making. It is therefore very important that all these steps in any prioritization decisions are documented so that funding partners, those reviewing restoration projects, and those proposing the projects can easily understand the process and the process can be consistently repeated periodically.

8. References

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Appendix A: Lower Fraser Fisheries Alliance First Nation representatives (summary from April 30, 2020 LFFA Forum)

Region	First Nation
Mouth of Fraser River to Port Mann Bridge	Kwikwetlem
	Musqueam
	Semiahmoo
	Tsawwassen
	Tsleil-Waututh
Port Mann Bridge to Mission	Kwantlen
	Katzie
	Matsqui
Mission to Hope Bridge	Aitchelitz
	Leq'á:mel
	Popkum
	Shxwha:y
	Skowkale
	Squiala
	Tzeachten
	Yakweakwioose
	Cheam
	Kwakwa'apilt
	Scowlitz
	Seabird
	Shxw'ow'hamel
	Soowahlie
	Sts'ailes
	Peters
	Sumas
	Skwah
	Skawahlook
Hope Bridge to Saw Mill Creek	Chawathil
	Union Bar
	Yale

Appendix B(a): List of information providers (Phase 2 interviews SurveyMonkey questionnaire, and/or first series of Phase 3 webinars)

Last Name	First Name	Nation	Watershed	Information Source
Florence	Norm	Chawathil	Fraser Canyon	SurveyMonkey/Webinar
Hendrickson	Amy	Chawathil	Fraser Canyon	SurveyMonkey/Webinar
Hope	Dominic	Yale	Fraser Canyon	Webinar
Garner	Kevin	Union Bar	Fraser Canyon	Interview
Pearson	Mike	Invited expert	Fraser Canyon	Webinar
Staley	Mike	Invited expert	Fraser Canyon	Interview
Moore	Dave	Sts'ailes	Harrison	SurveyMonkey/Webinar/Interview
Charlie	Kim	Sts'ailes	Harrison	Interview
Sherwood	Phil	Leq'a:mel	Harrison	Webinar/Interview
McNeil	Tyrone	Seabird	Harrison	Webinar
Hope	Sally	Shxw'ow'hamel	Harrison	Webinar/Interview
Leggat	Bonnie	Shxw'ow'hamel	Harrison	Webinar/Interview
Louie	Ray	Shxw'ow'hamel	Harrison	Interview
McHalsie	Sonny	Invited expert	Harrison	Webinar
Mussell	Lester	Skwah	Harrison	Interview
Staley	Mike	Invited expert	Harrison	Webinar
Bailey	Angie	Aitchelitz	Chilliwack	Webinar/Interview
Archie	James	Skowkale	Chilliwack	Webinar/Interview
Malloway	Ken	Tzeachten/Kwakwa'apilt	Chilliwack	Webinar/interview
Jimmie	Al	Squiala	Chilliwack	Interview
Commodore	Gary	Soowahlie	Chilliwack	Interview
Mussell	Lester	Skwah	Chilliwack	Interview
Douglas	Bruce	Cheam	Chilliwack	Interview
Staley	Mike	Invited expert	Chilliwack	Interview
McHalsie	Sonny	Invited expert	Chilliwack	Webinar
Orr	Craig	Kwikwetlem	Lower Fraser	Webinar/Interview

Chappell	Harley	Semiahmoo	Lower Fraser	Webinar/Interview
Thomas	Carleen	Tseil-Waututh	Lower Fraser	Webinar/Interview
Antone	Les	Kwantlen	Lower Fraser	Webinar/Interview
Timothy	Tanner	Kwantlen	Lower Fraser	Webinar/Interview
Morgan	Brenda	Matsqui	Lower Fraser	Webinar
Louis	Martin	Musqueam	Lower Fraser	Interview
Lockert	Krystal	Tswwassen	Lower Fraser	Interview/SurveyMonkey
Bailey	Rick	Katzie	Lower Fraser	Interview
Ned	Murray	Sumas	Lower Fraser	Interview
Victor	Ernie	Sto:lo Nation	Lower Fraser	SurveyMonkey
Silver	Dalton	Semath	Lower Fraser	SurveyMonkey
Staley	Mike	Invited expert	Lower Fraser	Interview
Spremberg	Uwe	Invited expert	Lower Fraser	Webinar

Appendix B(b): List of information providers (second series of Phase 3 webinars)

Last Name	First Name	Nation	Watershed	Information Source
Florence	Norm	Chawathil	Fraser Canyon	Webinar
Hendrickson	Amy	Chawathil	Fraser Canyon	Webinar
Hope	Dominic	Yale	Fraser Canyon	Webinar
Orstad	Lynn	Skawahlook	Fraser Canyon	Webinar
Pehl	Dave	Invited expert (DFO)	Fraser Canyon	Webinar
Pearson	Mike	Invited expert	Fraser Canyon	Webinar
McHalsie	Sonny	Invited expert	Harrison	Webinar
Moore	Dave	Sts'ailes	Harrison	Webinar
Pearson	Mike	Invited expert	Harrison	Webinar
Sherwood	Phil	Leq'a:mel	Harrison	Webinar
McNeil	Tyrone	Seabird	Harrison	Webinar
Victor	Ernie	Sto:lo Nation/Cheam	Harrison	Webinar
McHalsie	Sonny	Invited expert	Harrison	Webinar
Bailey	Angie	Aitchelitz	Chilliwack	Webinar
Gladstone	Robert	Shxwhay	Chilliwack	Webinar
Archie	James	Skowkale	Chilliwack	Webinar
Malloway	Ken	Tzeachten/Kwakwa'apilt	Chilliwack	Webinar
Victor	Ernie	Sto:lo Nation/Cheam	Chilliwack	Webinar
Kierstan	Dolata	Sto:lo Nation	Chilliwack	Webinar
Ardell	Keri	Ts'elxwéyeqw	Chilliwack	Webinar
Point	Mark	Skowkale	Chilliwack	Webinar
Pearson	Mike	Invited expert	Chilliwack	Webinar
McHalsie	Sonny	Invited expert	Chilliwack	Webinar
Orr	Craig	Kwikwetlem	Lower Fraser	Webinar
McHalsie	Sonny	Invited expert	Lower Fraser	Webinar
Malloway	Ken	Tzeachten/Kwakwa'apilt	Lower Fraser	Webinar
Pearson	Mike	Invited expert	Lower Fraser	Webinar

Appendix C: Responses from LFFA representatives to key questions/themes for defining the required context and scope of the prioritization framework.

Theme	Climate Adapt Project Planning Areas			
	Fraser Canyon	Harrison Watershed-Mid Reach Fraser River	Chilliwack Watershed	Lower Fraser River Approach
Salmon species	• Currently present in Fraser mainstem and tributaries: Coho, Pink, Chum • Not present in tributaries, migration through Fraser mainstem: Sockeye, Chinook	• Currently present: Chum, Pink, Coho, Chinook, Sockeye • Extirpated: Chehalis Lake Sockeye, Blackhead Chum (Dec. run), summer Chinook	• Currently present: Chum, Pink, Coho, Chinook, Sockeye	• Currently present: Chum, Pink, Coho, Chinook, Sockeye • Salmon populations have been extirpated locally from many streams in Lower Fraser (e.g., see DFO map of lost creeks)
Salmon populations or life history stages / associated habitats of key concern	• Habitats for rearing Coho (wetlands, tributaries) • Return of Chum Fraser Canyon CU to harvestable levels	• Chum: maintaining genetic diversity within spawn timing groups (Sep, Oct, Dec) that have been damaged due to past hatchery management strategies (historical bimodal spawning peaks now compressed into a single peak) • Pink: early vs. late runs • Coho: hatchery vs. wild populations; seasonal run timing groups (e.g., Dec. Coho run in the Nicomen) • Chinook: note remnants of wild red summer Chinook • Sockeye: note lost populations of Chehalis Lake	• No salmon of any species in the Hope slough because it is currently blocked off from access	• Chum: spawn up to Yale; most are hatchery fish. Larger wild Chum (called "blackheads") have faced population decline and are now listed species. While some head straight to the ocean after emergence others hang out in the estuaries before moving to the ocean. • Pink: Spawning gravels for Pink Salmon in the mainstem Fraser River are at risk from emergency management measures to take them down to prevent flooding. Few streams have had stock assessment for Pink, so unsure what's happening with them. • Many creeks in the Lower Fraser Valley are Coho creeks, and many are unprotected. Can use Coho habitat needs (i.e., shade, clean running water, food) as a basis to protect multiple species habitat - they are so general. Interior Fraser Coho have more protections than Lower Fraser Coho. • Chinook: are mostly interior fish (other than Chilliwack hatchery). However, there is known to be some limited spawning in Lower Fraser sloughs. Out-migrating Chinook smolts may also spend time in the sloughs and side channels of lower Fraser Islands, sit in (often unnoticed) micro-estuaries before heading to the ocean. • Sockeye: populations having the hardest struggle as they must migrate long routes

				through the Fraser, facing hard banks and dikes with limited resting areas. Currently Sockeye are having the additional trouble getting through Big Bar. Fraser populations currently facing possibly catastrophic decline. Juvenile usage of Fraser estuary and outmigration a concern; potentially very vulnerable to climate change though out their migrations, need good water levels in the river. There is also a need for collaboration between Fraser and Coastal FNs regarding risk to Fraser Sockeye from sea lice near coastal fish farms. • Major concern is protecting the condition of the Fraser Estuary. Lynchpin that can either secure or detract from salmon run health.
Associated First Nation Values of key concern	• Salmon harvest opportunities (no Chum harvest in the canyon currently as CU is too fragile, but would like to restart managed harvest if numbers were high enough) • Cultural heritage of salmon as critical to FN identity • Contribute to assisting/maintaining full life cycle of salmon	• Salmon life history diversity • Increased spawner density • Reconnection and/or restoration of lost habitats (e.g., wetlands, sloughs) • Stewardship of salmon and salmon habitat diversity • Increased resilience and adaptability of wild salmon populations	• Abundance of salmon (FNs are paying the price for current scarcity. Unlikely to achieve historical abundance that Nations once depended on for a long time, even if trends can be reversed) • Access to fish as a food, but also as a connection to the land for cultural events • Seek to protect the river from being further channelized or diked (want to maintain a natural system that "regularly changes its banks" as it did historically)	• Socio-economically, the communities have been hit hard - not just with food security - but with the cost of salmon harvesting - it has gotten more difficult and expensive to get out there and fish lately. • Food security is important – but it's not just about food - it's about 'sustenance of our spirit' • Indigenous perspectives and practices need to be acknowledged and incorporated in all development within our lands/territories. This would be consistent with Govt commitment to UNDRIP. • Comprehensive decision-making processes that ensure that when you use a resource you leave it like it is or leave it better. All things are connected at all stages of salmon life cycles so can development somehow restore or enhance salmon habitat? • Ecosystem based management and implementation of indigenous perspectives • We need to encourage long term planning for the lower Fraser - and more holistically. The

				short-term initiatives simply do not accomplish enough.
<u>Key *Current*</u> stressors for salmon and salmon habitats	• Beaver dam barriers and culverts restricting fish access to tributaries • Limited wetland habitat in tributaries • Decreasing stream flows in tributaries, some dry up in summer, reasons unknown (may relate to upslope land use, possible climate change effects) • High winter flows in tributaries related to legacy of upstream logging, scouring spawning (gravel) areas • Erosion into tributaries and build up of fine sediment at creek mouths • Limited holding areas in creek mouths for upriver Fraser migrating salmon (issue in large freshet periods when salmon struggling to move upriver against high flows); could also be a problem for out-migrating juveniles • Water extraction (e.g., Nestle)	• Chum: slough and wetland habitats are infilled by silt (by-product of decreasing salmon escapement; not enough spawners to clean out the streams). Presence of competing invasive fish species. Catch and release of Chum – additional physiological stressor • Coho: limited habitat availability (lack of healthy streams un-impacted by development/agriculture) • Chinook: limited habitat availability (lack of healthy streams un-impacted by development/agriculture) • Sockeye: high water temperatures • Pink: specific limiting factors uncertain • Habitat stressors on salmon are particularly acute where agriculture and rural development pressures are closest to salmon habitats. Extensive habitats behind dikes are disconnected, lack flows, have minimal riparian buffering, and are suffering at times from water quality issues from too much nutrient input (e.g., fertilizers, manure) and consequent low oxygen. • Predatory invasive fish species are a threat to salmon eggs/fry in the sloughs	• Predators of Fraser-origin salmon in coastal waters (e.g., seals and sea lions, whales) • Overfishing in the ocean from commercial fishing, impacting Chilliwack bound fish • Restricted availably of returning salmon for FNs as DFO is perceived to prioritize recreational fishery in the watershed over FN access to the salmon • Altered flows in river and creeks (river used like an irrigation system) • Long/straight banks of Vedder Canal limit any resting spots for migrating salmon while the open nature of the Canal without protective, overhanging trees results in increased water temperatures • Fine sediment erosion/infilling of streams from landslides due to logging activities and forest fires • Improperly designed culverts and sometimes beaver dams blocking fish access to streams • Effluents from farms affecting water quality • Slough channels clogged by extensive milfoil growth • Historical draining of Sumas Lake a massive past impact with long lasting effects on availability and condition of salmon habitats • Water flow issues at Chilliwack Lake and Cultus Lake are affecting spawning habitat there for Sockeye: spawning areas limited so predators (e.g., bears, cougars, eagles) can easily target Sockeye spawners, with resultant high pre-spawn mortality.	• Slough blockages (e.g., floodgates, pump, and dikes) preventing access to available spawning and rearing habitats • Altered flows in tributaries due to diking • Many flood gates and pumps are also blocking juvenile Coho from returning to the oceans during freshet. • Reduced spawning habitats in the mainstem and tributaries • Competition with hatchery fish (Chum) • Lack of resting areas for salmon while migrating to spawning areas due to fast flowing water, and no back eddies due to dredging and dikes. • High water temperatures (in summer currently up to 75% of tributaries and sloughs are too warm for Coho so they have to ascend higher in the systems where they may become confined in small areas where they become vulnerable to predators). • Water quality impairment (dissolved oxygen, pH, fecal coliform) from agricultural runoff, industrial effluent, sewage • Accelerated water runoff from residential areas • Loss of riparian zones from development, over industrialization • Decreased stream productivity due to diminished returns of marine nutrients from salmon carcasses (resulting from low escapements and restricted access to spawning areas) • Predation from seals/seal lions and invasive fish species (e.g., small mouth bass)

				• Lack of flow and low dissolved oxygen in sloughs impacting spawning areas and the ability to sustain eggs to hatch • Impact to streams from forestry, roadways, general development (both in the lower Fraser and upriver) • Aggradation of estuary refugia due to projects like Roberts Bank Terminal 2 Project impacting out-migrating smolts
<u>Key</u> anticipated *<u>Future</u>* stressors for salmon and salmon habitats under changing future climate conditions	• Restricted fish access to tributaries (due to increased debris blockages from high flows) • Increased water temperatures • Changing seasonal flows/hydrograph in tributaries • Increased incidence of fish disease • Increased physiological stress • Change in accessibility to habitats • Change in suitability of habitats • Change in growth rates • Increased frequency & magnitude of peak flows / flooding • Increased frequency and magnitude of low flow periods • Increased fine sediment concentrations • Inconsistent spring freshets • Increased scouring of salmon redds	• Increased incidence of fish disease • Increased physiological stress • Increased scouring of redds due to increased frequency and magnitude of peak flows (example of threat: massive Nov. flood in 2004 washed out much of Chum spawning in the Harrison that year) • Increased timing mismatches leading to changes in predation, competition, or food availability • Increased frequency and magnitude of low flow periods • Increased water temperatures • Decrease in dissolved oxygen • Altered nutrient concentrations • Increased fine sediment concentrations	• Decreases in dissolved oxygen (stagnant water) • Reduced stream flows (creeks running dry) • Increased physiological stress • Increased scouring of redds • Increased incidence of disease • Earlier timing in spring peak flows • Increased frequency and magnitude of peak flows / flooding • Increased water temperatures • Restricted fish access to tributaries due to lower flows	• Increased frequency and magnitude of low flow periods • Increased water temperatures • Increased physiological stress • Altered nutrient concentrations • Increased fine sediment concentrations • Increased incidents of disease • Increased scouring of redds • Increased stranding of juveniles • Change in run timing • Change in age/time of outmigration • Increased timing mismatches leading to changes in predation, competition, or food availability • Change in accessibility to habitats • Change in habitat suitability • Changes in rates of fish growth • Increased abundance of invasive species • Change in food resources • Earlier timing of spring peak flows • Increased frequency and magnitude of peak flows / flooding
Key suggested climate change adaptation strategies/actions to pursue	**<u>Hard Infrastructure</u>** • Transplant salmon stocks or species	**<u>Hard Infrastructure</u>**	**<u>Hard Infrastructure</u>**	**<u>Hard Infrastructure</u>** • Improve fish passage/connectivity

	• Reintroduce salmon to extirpated areas • Introduce salmon to new areas • Improve fish passage through culvert improvements and removal of beaver dams • Consider development of local salmon hatchery to supplement populations (past trout hatchery operated in area, no longer functioning, but some existing infrastructure there) • Create slower flow, resting areas in mainstem Fraser for migrating salmon (dredging a possibility?) • Restore wetlands • Conserve pristine habitats • Implement low impact irrigation practices • Install water meters • Decrease surface water runoff • Manipulate surface water / groundwater interactions • Enhance instream habitat • Restore habitat connectivity • Upslope restoration to improve slope stability and reduce fine sediment erosion inputs • Restore riparian ecosystems **Soft Infrastructure** • Coordinate / implement improved planning frameworks (particularly to improve integrated management of Fraser Chum stocks; need better understanding of Chum abundance, run timing) • Improve collaboration between the Nations, DFO, other govt. organizations to minimize any jurisdictional/property issues and ensure successful Coho passage to newly created wetlands • Improve/implement prescription-based habitat management • Designate environmental aspects for special management consideration	• Open up old slough beds, dikes, creeks, and waterways so that the freshet can enter more areas and create accessible spawning and rearing habitats. Such 'cleaning out" of infilled tributaries will both create new spawning areas and reduce flood risks (e.g., as has been done in Puget Sound). Restoring habitat connectivity likely most effective thing that could be done to help restore salmon populations. High-res LiDAR is providing a broad scale method for detecting extinct infilled sloughs that can be re-wetted • Develop targeted incubation box program in conjunction with hatchery staff to re-establish diversity of Chum run timing groups • Reintroduce salmon to extirpated areas • Implement low impact grazing practices • Plant riparian vegetation to help reduce stream temperatures • Build new hatcheries to supplement salmon populations, co-managed by FNs • Manage gravel extraction in the mainstem Fraser River to avoid overextraction that will affect spawning Chum and Sturgeon. **Soft Infrastructure** • Ensure protection of critical habitats • Improve partnerships around water / habitat stewardship (the impact of farming is considerable – need coordination with DFO, the Province, other agencies and landowners to get access to lost wetlands and sloughs in the area to study or mitigate habitat issues). Real opportunities for habitat restoration are currently restricted primarily to reserve lands. There is a need to move beyond the simple prescriptions of the Fisheries Act to achieve real benefits. • Improve/implement prescription-based habitat management (would like to see current 10-m riparian buffer zone protections increased to 20-m and enforced)	• Develop holding ponds to keep water available through longer seasons and put water back into the aquifer. • Add/improve spawning gravels in tributary streams • Expand current salmon hatcheries in the watershed and develop new FN-managed hatcheries (Skwha have put in a current proposal in this regard). Would like to see more Chinook, Coho, Sockeye, Chum, Pink, Steelhead produced – believe the habitat is there to support them. • Re-engineer Vedder Canal to provide more natural river conditions for salmon • Transplant stocks or species • Reintroduce salmon to extirpated areas • Introduce salmon to new areas • Conserve pristine habitats • Enrich streams / lakes with nutrients • Implement low impact irrigation practices • Improve fish passage • Recycle water in industry • Install water meters • Release cold water • Enhance instream habitat • Enhance production with hatcheries • Create off-channel habitat • Restore habitat connectivity • Restore riparian ecosystems • Move dikes back from rivers • Create deep pools **Soft Infrastructure**	• Build fish ladder for Alouette Lake (as alternative to current BC Hydro Trap & Truck Sockeye program). Figure out a way to get Sockeye juveniles out of the reservoir. • Expand Allco hatchery to supplement salmon populations, co-managed by FNs • Transplant stocks or species • Reintroduce salmon to extirpated areas • Introduce salmon to new areas • Conserve pristine habitats • Restore habitat connectivity • Implement low impact irrigation practices • Determine how to remove Fraser River gravel for flood mitigation and emergency management purposes but still retain spawning habitat for Pink, Chum, and Sturgeon (Cheam FN has undertaken a successful pilot project in this regard with DFO and the Province just above Cheam bridge at Powerline/Strawberry Island). • Enhance instream habitat • Restore riparian ecosystems • Improve slope stability • Engineer streams • Move dikes back from river • Create off-channel habitat • Create deep pools • Enrich streams/lakes with nutrients • Clean spawning gravels • Recycle water in industry • Install water meters (something that is currently being pushed for in Coquitlam) • Build and manage additional water storage capacity

	• Ensure protection of critical habitats	• Develop a Heritage Policy and Resource Management Plan to create a foundation for incorporating TEK into referrals • Develop a mid-Fraser flood response strategy based on the concept of water storage (with First Nation concerns around salmon as a central element - water storage needs to include consideration of spawning and rearing habitats). Opened tributaries have immense capacity to absorb floods, which is good for river flood attenuation. • Anchor LFFA restoration planning in existing processes (e.g., COSEWIC) that have indigenous advisory mechanisms	• Improve storm drainage management plans (which are currently designed to get rid of water quicker) so as to achieve a more natural state • Encourage local champions in the community to protect seasonal creeks in key drainages (e.g., Hope Slough, Camp Slough) • Require effective operating licenses for water management • Implement prescription-based management • Implement results-based management • Adjust fisheries management practices • Compensate for unavoidable / non-mitigated impacts • Designate environmental features for special management consideration • Coordinate / implement improved planning frameworks • Ensure protection of critical habitats • Encourage partnerships for water / habitat stewardship • Develop a regional water budget • Entrench ecosystem rights to water	• Divert water from other locations • Decrease surface water runoff • Release cold water • Manipulate surface water / groundwater interactions • Implement low impact forestry practices **Soft Infrastructure** • Adjust fisheries management practices (e.g., non-lethal test fisheries – sonar, fish wheels; more tagging) • Develop a Lower Fraser foreshore plan • Encourage partnerships for water / habitat stewardship • Develop a regional water budget (water use Plan has been in place in Coquitlam since 2005) • Compensate for unavoidable / non-mitigated impacts • Implement results-based management • Designate environmental aspects for special management consideration • Ensure protection of critical habitats • Entrench ecosystem rights to water • Expand project effectiveness monitoring • Frame salmon habitat restoration efforts as a reconciliation activity; communities are looking for reconciliation-related projects. • Link dredging and cleaning gravel projects with the work that FBC does in their flood mitigation plan so the Nations can work collaboratively with FBC on shared objectives • Increase support for improving internal FN capacity/expertise for evaluating and mitigating impacts on salmon/salmon habitats

Relevant scales of information for climate change vulnerability assessments	• Site scale (e.g., culvert condition) • Reach scale (e.g., stream specific condition) • Multi-watershed (e.g., better information on Chum run timing, abundance, genetics to differentiate Canyon Chum from lower river Harrison/Chilliwack Chum run groups, at different points lower in the river, to effectively manage any Chum harvest opportunities in the Canyon. Currently a large Chum harvest downstream of Yale).	• Watershed scale (e.g., extent of disconnected wetlands and streams, extent of Infilling, extent of riparian disturbance) – would relate to questions such as: How much salmon habitat can we connect in the watershed (speculate that it could be 100s of km)? Where could we feasibly restore historic sloughs (given need for landowner permissions)? What volume of habitat could we create? What could be the impacts to flood control? • Reach scale (e.g., local assessments done of conditions in sloughs) • Site scale (e.g., sub-surface culverts put in for highways and railways (20-30 years ago) that are impacting salmon access to habitats) • Assessments across stream, watershed, and multi-watershed scales will best highlight the opportunities to make progress		• All suggested spatial scales of information potentially important for framing vulnerability assessments; support multi-scaled tiered thinking for framing this
Locations of key concern	• Initial habitat restoration priorities should focus on streams that have been identified as having Coho and Pink present (then expand to other streams) e.g., Yale CK (but only short length of useable habitat; Emory Creek (multiple kms of useable habitat) • Creeks west of highway where upstream logging causes debris blockages • Dike impairments at Yale town site and Ruby Creek • Slope restoration of Mary Anne Ck. beside Yale Ck. • Puckatholetchin Creek (Chum spawning site) – clogged with debris and logs. • Hope Slough – fish access blocked • Riparian areas below Hope bridge have been impacted by past heavy windstorms (loss of trees, extensive erosion) • Beaver dams at culverts near the highway and right of way on Schkam (IR2) of Chawathil. Potential to create serious habitat degradation issues during freshet.	• Maria slough – access closed off by CP rail tracks, also many invasive plants. • Salmon habitat in the Miami River is seriously degraded (difficult to get landowners on board, salmon are near extirpation from stream) • Fish passage blockages near Agassiz mountain due to culverts and beaver dams • Flows currently restricted into Nicomen Slough (focus of current restoration efforts – e.g., building culverts to allow water entry) • High sediment loads, low flows in Derouche Ck. have reduced stream size • Hatzic Lake/Hatzic Slough: invasive plants and fish, stagnant water, blocked fish passage due to current lake management practices • Potential river contamination from landfills around Skway, Cheam, and Kwantlen FN lands • Sediment loads (due to logging) in Jones/Wahleach Ck. as well as eutrophication, low oxygen levels from local dairy farming impacts in lower end of creek.	• Hope slough – blocked fish passage and impaired water flow • Fish access to Sweltzer Creek blocked in recent years (Chinook and Chum used to spawn there) • Catermole Ck. – used to be a large, deep eddy there used by Sockeye and Sturgeon that has become infilled by silted up in the last couple of decades • Aitchelitz, Luckacuk, and Little Chilliwack River are drying up and have become shorter due to aquifer extractions for drinking water • Limited flows into Camp Slough (engineering flows through the dikes with flood gates should be considered) • Channels to Atchelitz Ck. historically used by Pink and Chum now blocked by Yale Road, new freeway • Elk Ck. has been turned into agricultural ditches rather than a functioning waterway, no longer salmon habitat	• Alouette Dam blocks Sockeye access to Alouette Lake (currently trucked) • Widgeon Creek channel is narrowed due to invasive Reed Canary Grass • Buntzen Lake Dam is of little current use for electricity but diverts a significant amount of water from Coquitlam Lake; dam decommissioning would increase the flow into the lake. • Habitat impacts from port expansion at Roberts Bank Terminal • Old log storage areas in Indian Arm, Maplewood Mudflats and Port Moody • Water quality contamination (warm water discharges, fecal contamination) of Little Campbell River • Patullo Bridge: Noise, contaminants from shipping, impacts from construction and decommissioning of old bridge

	• Straightening, piping of tributary flows has degraded salmon habitat in streams near residential areas in the watershed	• High sediment loads from logging in Hunter Creek • Restricted flows entering Johnson and Maria sloughs; limited water available for rearing juveniles • Agassiz Slough used to join Maria Channel at Seabird Island but now filled in by roads (likely used to be important spawning area but now closed off) • Blocked channel on Seabird Island that could be restored • High erosion into streams from landslides near Herrling Island • Big historical eddy (very deep) in Fraser river at Catermole now silted up • Impaired water flow into Ferry Island below Cheam bridge due to blockages from rip rap • Water flow into Green Island impeded by a road to the island and rip rap embedded in the riverbed • Limited flows into Deroche Slough, Maria Slough, Thompson Slough, Cheam Slough (engineering flows through the dikes with flood gates should be considered) • Agricultural infilling of Duncan and Bates sloughs • Chehalis estuary impacted by dike • Harrison wetlands and sloughs impacted by diking • Norrish creek - a lot of water withdrawals so it runs dry in late summer. • Nicomen Island area and Harrison Mills - nutrients and agricultural pollution and flood infrastructure are major impacts • A lot of introduced fish species like bass in Nicomen slough • Harrison Bay - it is filling in with silt • Lake Errock - gravel pit and development • Hicks Ck. - generally concerned about low water levels in summer	• Sheffield Slough - conditions in slough have changed due to nitrate input (farms), among other land use changes • Depot Ck. and Paleface Ck. - concerns for habitat condition of tributaries to Chilliwack Lake relating to extensive logging on the east side of the lake • Nicomen Slough, Chwathill Slough, and Katzie Slough are plugged with silt • Flow at Ferry Island below Cheam bridge impaired; need to open up culvert to improve flow • Power line bar – Cheam has already restored Coho (800m) spawning habitat, and then want to restore another part for Chum spawning. There are fresh water springs in there. Need to remove gravel. • Green Island flow is blocked by a road to the island and rip rap embedded in the river bed. • Derouche Slough, Thompson Slough, Cheam Slough, Camp Slough, Maria Slough: old channels where there is no water, need floodgates • Blockage of flows from Barrowtown pumphouse to Sumas Lake • Sedimentation at Marshall Lonzo creek. Every year, city of Abbotsford dredges it and this affects fish habitat. • Culvert on Sumas Mountain Road - blew out and flooded because of old mining shafts that blew out new culvert.	• Airport jet fuel line from Alex Fraser to Sea Island. Concerned about impacts on fish movement, leaks, impacts of construction. • Increased siltation of Coquitlam river due to gravel quarries, industrial and residential development. • North Vancouver eel grass beds becoming submerged, failing to establish, because of hard waterfront edges, associated unnaturally deep shoreline waters • Riparian areas on Salmon River, Whonnock Ck. and Kanaka Ck. impacted by farming; need for improving riparian buffering • Canoe Pass: salmon refuge areas reduced due to infilling of side channels with fine sediment • Diking impacts at south end of Pitt Lake (considered one of the biggest restoration opportunities in Planning Area) • Wilson Farm project (water temperature issues) • Gravel mines in upper Coquitlam watershed (silt inputs) • Old Waputo Harvest Area: now contaminated marsh land. Mainly silted up and turned into ditches. • Bonacord Ck: once a productive creek • Surrey docks: heavy traffic of container ships. • Sewage treatment plant expansion in Musqueam land • Serpentine R. and Nicomekl R.: would like Cumulative Impacts assessments done and then restorative measures • Massey tunnel project. • Semiahmoo Bay is high priority for the Semiamhoo FN. No one has done

		• Bateson Slough - poor drainage, perched culverts and filled-in stream channels currently provide limited seasonal habitat for salmon juveniles • Sq'ewlets Slough - Traditional Ecological Knowledge suggests that water quality degraded significantly with the dike and CPR railway line • Sts'ailes sloughs - silt deposition, invasive vegetation and the loss of gravel-clearing spawning activity have led to the decline of these habitats.		environmental assessments of the Bay, need water quality testing • Sturgeon Bank: the area where the plants are is receding and they don't know what is causing it • Tsawwassen Port: flow blocked. Grasses and kelp has changed there because of shipping • Lower Fraser sloughs near the mouth of the Fraser R. and associated islands are being dredged out - not habitable for juvenile salmon
Hopes for the Coastal Restoration and Climate Adapt Project	• Vision of what things might look like in the Canyon with changing climate and how any impacts might be managed. There are current challenges for salmon as they run past Canyon reserves. Determine how current concerns about heavy flows in tributaries after big rain events, erosion events, might increase in the future under changing weather patterns and how would that affect salmon populations.	• Help build more effective working relationships between biologists and regional drainage program managers so that drainage engineers/managers can ensure sufficient water storage/flood control AND protect salmon habitat. • Restoring fish numbers locally and regionally, both for human use and for the whole ecosystem (eagles, bears, etc.). Would like to see more restoration actions happening.	• To help increase abundance of salmon in the watershed	• Encourage people living in the Lower Fraser to learn to enjoy the values that come from salmon and watersheds and make the area wild and natural in the long term • Decrease in destructive practices in resource management and better protection of all wildlife • An inventory of previous salmon habitat usage and preference as well as sites for potential repair or upgrading. • More green space and more clean water for public enjoyment, while also helping salmon. • Encouraging redesign of old developments and promoting standards for new developments • Creating a sense of ownership so that people will look after these habitats • A consensus strategy that many can come together under to effect change in the Lower Fraser • Process for helping coordinate and bridge gaps between governments (federal/provincial/Fraser Basin Council/FNs) to develop regional goals for restoring salmon habitats and populations

Appendix D: Suggested rubric for prioritizing proposed LFFA adaptation/restoration projects. Projects can be scored for these categories in a supporting "LFFA Project Prioritization Rubric" Excel-based tool.

PROJECT DESCRIPTION:

	Scoring Category	Criteria	Rating	Score (0-5)	Weight (user defined, 1-5) (default = 1)	Total
ECOLOGICAL CONSIDERATIONS						
1)	Ability of proposed restoration project to target/address key watershed impairment issues identified from earlier Climate Adapt and Coastal Restoration Project analyses	Directly targets many key issues	5			
		Directly targets some key issues	4			
		Directly targets 1 key issue	3			
		Indirectly helps addresses more than 1 key issue	2			
		Indirectly helps address 1 key issue	1			
		Unknown / Not provided	0			
2)	Number of salmon species expected to directly benefit from the proposed restoration project	**5 species of salmon** could benefit	5			
		4 species of salmon could benefit	4			
		3 species of salmon could benefit	3			
		2 species of salmon could benefit	2			
		1 species of salmon could benefit	1			
		Unknown / Not provided	0			
3)	Number of listed salmon CUs (i.e., Depleted, At Risk, Amber/Green, Amber, or Red status) overlapping spatially with the location the proposed restoration project	**5 or more listed salmon CUs** overlap with restoration location	5			
		4 listed salmon CUs overlap with restoration location	4			
		3 listed salmon CUs overlap with restoration location	3			
		2 listed salmon CUs overlap with restoration location	2			
		1 listed salmon CU overlaps with restoration location	1			
		None	0			
4)	Spatial scale of anticipated restoration action benefits	Planning Area scale benefits	5			
		Watershed scale benefits	4			
		Multi-stream/waterbody scale benefits	3			
		Localized stream reach scale benefits	2			
		Highly localized site scale benefits	1			

		Uncertain	0
5)	**Anticipated time of impaired habitat functions/processes to fully respond to actions of proposed restoration project**	**Very quick response (< 1 year)**	5
		Quick response (1 - 2 years)	4
		Moderate amount of time to respond (2 - 5 years)	3
		Slow response (5 - 10 years)	2
		Very slow response (> 10 years)	1
		Unknown / Not provided	0
6)	**Anticipated longevity of expected benefits attributable to the proposed restoration project**	Benefits will **persist > 10 years**	5
		Benefits will **persist 5-9 years**	4
		Benefits will **persist 2-4 years**	3
		Benefits will **persist 1-2 years**	2
		Benefits will **persist < 1 year**	1
		Unknown / Not provided	0
7)	**Level of risk of potential negative impacts from the proposed restoration project on other elements of the environment**	**No risk** of negative environmental impacts	5
		Minimal risk of negative environmental impacts	4
		Moderate risk of negative environmental impacts	3
		High risk of negative environmental impacts	2
		Very high risk of negative environmental impacts	1
		Unknown / Not provided	0
SOCIAL CONSIDERATIONS			
8)	**Level of landowner support/cooperation for the proposed restoration project**	**Very low to negligible social resistance and easy land/infrastructure access concerns** owing to very high level of support/endorsement from private landowners and property abutters	5
		Low social resistance and promising land/infrastructure access concerns owing to the high level of support/endorsement from private landowners and property abutters	4
		Moderate social resistance and some potential constraints on land/infrastructure access concerns owing to moderately low support/endorsement from private landowners and property abutters	3
		High social resistance and limited access to land/infrastructure concerns owing to low support/endorsement from private landowners and property abutters	2
		Very high social resistance and very limited access to land/infrastructure concerns owing to very low support/endorsement from private landowners and property abutters	1
		Unknown/not provided/ or no possibility of access (this may also be project no go criteria)	0

	Not required / not relevant for the restoration project type	5
9) Level of regulatory agency concern, related permitting issues for the proposed restoration project	**Very low to negligible potential project 'implementability" concerns** across local, provincial, and/or federal regulatory agencies	5
	Low potential project 'implementability' concerns across local, provincial, and/or federal regulatory agencies	4
	Moderate potential project 'implementability concerns across local, provincial, and/or federal regulatory agencies	3
	High potential project 'implementability' concerns across local, provincial, and/or federal regulatory agencies	2
	Very high potential project 'implementability' concerns across local, provincial, and/or federal regulatory agencies	1
	Unknown/not provided/or no possibility of project permitting (this may also be project no go criteria)	0
	Not required/not relevant for the restoration project type	5
10) Level of cultural benefit associated with the proposed restoration project	**Very high cultural benefit** associated with undertaking the proposed project	5
	High cultural benefit associated with undertaking the proposed project	4
	Moderate cultural benefit associated with undertaking the proposed project	3
	Some cultural benefit associated with undertaking the proposed project	2
	Very low / negligible cultural benefit associated with undertaking the proposed project	1
	Unknown / Not provided	0
11) Level of long-term stewardship commitment to the proposed restoration project (following initial implementation)	**Commitment will persist > 10 years** post project implementation	5
	Commitment will persist 7-9 years post project implementation	4
	Commitment will persist 6-8 years post project implementation	3
	Commitment will persist 3-5 years post project implementation	2
	Commitment will persist < 3 years post project implementation	1
	Unknown / Not provided	0
12) Level of associated training opportunities for LFFA First Nations' community members in undertaking the proposed restoration project	**Highly diverse and very significant training opportunities** available within the project	5
	Considerable level of training opportunities available within the project	4
	Moderate level of training opportunities available within the project	3
	Small level of training opportunities available within the project	2
	Negligible training opportunities available within the project	1
	Unknown / Not provided	0
13) Level of associated educational benefit to members of the local community(s) from the proposed restoration project	**Very high educational benefit** to local community members associated with undertaking the project	5
	High educational benefit to local community members associated with undertaking the project	4

		Moderate educational benefit to local community members associated with undertaking the project	3
		Limited educational benefit to local community members associated with undertaking the project	2
		Negligible educational benefit to local community members associated with undertaking the project	1
		Unknown / Not provided	0
14)	**Level of anticipated project visibility / public awareness associated with the proposed restoration project**	**Very high project awareness/public interest** and very high positive broader outreach benefit	5
		High project awareness/public interest and high positive broader outreach benefit	4
		Moderate level of project awareness/public interest and some outreach benefit outside the immediate action area	3
		Low project awareness/public interest, unlikely to come to attention of public outside action area	2
		Very low project awareness/public interest, unlikely to be noticed by anyone other than those carrying out the restoration action	1
		Unknown / Not provided	0
TECHNICAL AND FINANCIALCONSIDERATIONS			
15)	**Level of technical difficulty involved in implementing the proposed restoration project**	**No technical difficulty,** consistent, simple, and regularly repeated methods, consistently undertaken without any issues	5
		Minimal technical difficulty, relatively simple, established techniques, regularly undertaken, some potential issues but well understood and easily resolved	4
		Moderate technical difficulty, quite complex techniques often required, many potential issues but all or most should be resolvable, some limited uncertainty of successful implementation	3
		High technical difficulty, complex techniques but have been undertaken before as part of restoration programs, a multitude of issues that may arise, many of which are predictable and should be possible to work through in most cases but not always and successful implementation is uncertain	2
		Very high technical difficulty with associated high uncertainty of success, may represent novel and innovative approach(es) – likelihood of success very difficult to gauge based on limited available examples and experience from other restoration programs	1
		Unknown / Not provided	0
16)	**Capacity and experience of the key implementation organization / sponsor in delivering the proposed restoration project**	**Very experienced** implementation team (has successfully completed several similar projects in past)	5
		Experienced implementation team (has successfully completed at least one similar project in past)	4
		Some experience in the implementation team, capable (has strong capacity and theoretical understanding of type of restoration proposed but no prior demonstrations)	3
		Inexperienced implementation team (implementing organization/proponent has some team members that have experience with the type of restoration proposed and no prior demonstrations completing similar projects)	2
		Very inexperienced implementation team (theoretical knowledge only, no prior demonstrations even with peripherally related restoration)	1
		Unknown / Not provided	0
17)	**Anticipated time required to fully implement the proposed project**	**Very short duration** to fully implement **(< 0.5 year)**	5
		Short duration to fully implement **(0.5 - 1 year)**	4
		Medium duration to fully implement **(1 - 2 years)**	3

		Long duration to fully implement **(3 - 5 years)**	2
		Very long duration to fully implement **(> 5 years)**	1
		Unknown / Not provided	0
18)	**Ability of proposed project monitoring to contribute to demonstration of restoration action effectiveness and/or learning**	Project has a **very well defined and appropriate monitoring design that would provide significant learning about key uncertainties**	5
		Project has a **well defined and appropriate monitoring design that would provide some learning about key uncertainties**	4
		Project has a **modestly defined monitoring approach that would provide only a limited amount of learning about key uncertainties**	3
		Project has **limited proposed monitoring and the approach outlined is generally expected to provide only a very limited amount of learning about key uncertainties**	2
		Project has v**ery limited proposed monitoring and the approach outlined is generally not expected to provide any real learning about key uncertainties**	1
		Unknown / Not provided	0
19)	**Projected cost for the proposed restoration project**	**Very low project cost** (< $10K)	5
		Low project cost (< $10K - $25K)	4
		Moderate project cost ($25K - $50K)	3
		High project cost ($50k - $100K)	2
		Very high project cost ($100K - $250K)	1
		Unknown or above cap for near term funding availability (this may also be project no go criteria)	0
20)	**Level of potential economic benefit from undertaking the proposed restoration project**	**Very significant potential economic benefit** from undertaking the project	4
		Significant potential economic benefit from undertaking the project	4
		Moderate level of potential economic benefit from undertaking the project	3
		Some level of potential economic benefit from undertaking the project	2
		Negligible level of potential economic benefit from undertaking the project	1
		Unknown / Not provided	0
Maximum Unweighted Score = 100			**0**