Perseverance Creek

Fish Habitat and Proper Functioning Condition Assessment



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EXECUTIVE SUMMARY

The Cumberland Community Forest Society (CCFS) is a non-profit organization, established in the year 2000, with the goal of purchasing and protecting private forest lands surrounding the Village of Cumberland (the Village). To date, the CCFS has purchased over 110 hectares of forested land that has been transferred to the Village, and that is protected under conservation covenants. The CCFS is currently in negotiations with land owners to acquire an additional 91.4 hectares of land surrounding Perseverance Creek to add to the Village's holdings. Perseverance Creek holds many ecological and social values, including providing fish habitat and the Village's drinking water supply. The creek and adjacent land have been heavily used and modified by people over the past century and a half, altering the quality of the creek's fish habitat and the functioning condition of the hydro-riparian area. The purpose of this study was to gain a greater understanding of the current fish habitat and functioning condition of Perseverance Creek between Allen Lake and Comox Lake and to investigate restoration and management options that could improve the condition and function of the creek.

Specifically, the objectives of this project are threefold:

1. To describe the current status of fish habitat in Perseverance Creek by presenting the results of a reconnaissance-level quantitative and qualitative fish habitat assessment;
2. To describe the current status of the ecological function of Perseverance Creek's hydro-riparian area by presenting the results of a proper functioning condition assessment (PFC) based on quantitative and qualitative data; and,
3. To provide conceptual restoration and management options that benefit fish habitat and hydro-riparian function, as well as identify knowledge gaps that should be filled prior to implementing restoration or management activities.

In general, the results of the fish habitat and PFC assessments indicate that the overall current PFC is 'Functional-at-Risk' that there is a downward trend in fish habitat quality and the PFC of the creek. This is because high fall and winter flows degrade the channel morphology by eroding the stream banks and transporting bedload materials downstream, where they accumulate at great depths in the channel, and behind large log jams (that have also been created by high flows), leading to a more uniform morphology. Subsequently, low summer flows remain largely below the accumulated bedload, only surfacing in residual pools.

The modified channel condition degrades fish habitat in that: upstream migration is impeded by high flows and lack of refuge habitat (e.g., evenly-spaced boulders, deep pools, large woody debris) in the fall and winter months, and by lack of connected surface flows during low water in the summer months. Overwintering and rearing habitat is also compromised by the lack of evenly spaced refuge features, whereas spawning habitat is likely compromised by frequent 'blow out' events that may regularly disturb the gravels. The lack of continuous flow through the creek during the summer months is of particular concern to fish as this likely leads to the stranding and mortality of fish throughout the length of the creek as the creek dries.

The condition of Perseverance Creek is on a downward trend; nevertheless, the creek and hydro-riparian area maintain several attributes that contribute to high quality fish habitat and a high functioning system. The majority of the riparian habitat in the assessed reaches is a mixed deciduous-coniferous maturing young forest that includes a large floodplain. Although, there is evidence of some erosion of riparian habitat into the creek, the floodplain has largely been able to withstand regular flooding associated with high flows and channel aggradation, and continues to contribute riparian fish habitat values (e.g., temperature moderation, nutrient inputs, bank stabilization, large woody debris contributions). As well, old large woody debris persists in the stream, under which pools form and create refuge habitat for fish. Similarly, scour pools on hard pan clay and in bedrock provide refuge pools for fish through the winter high flows and summer low flows. Water quality in these residual pools largely remains sufficient (i.e., low temperature, adequate oxygen) to support fish year-round. Furthermore, during field studies, fish were detected throughout the assessed reaches, indicating that nodes of habitat are available to fish even in the warm summer months.

Results indicate that the hydrology of Perseverance Creek is likely the dominant contributing factor the observed downward trend. The current hydrology of the creek largely results from the natural flow regime, the Village's drinking water supply system, forest management in the watershed and a changing climate. Although many of the elements that influence the hydrology of the system occur outside of the assessed reaches, there are several options to improve fish habitat and the condition of Perseverance Creek within the assessed reaches.

Options for restoration and management within the assessed reaches include:

- High flows can be mediated by timber retention (especially of riparian habitat) and wetland creation. Suitable locations for wetland creation may exist at the base of the Allen Lake overflow and upstream of the Davis Lake Main bridge and in the lower floodplain reaches near the Comox Lake Road bridge;
- Undersized culverts can be replaced with appropriately sized and styled culverts to facilitate fish passage and reduce erosion;
- Bank erosion can be mediated by armoring with carefully planned and sited vegetation planting, boulders and LWD; and
- Groundwater fed backchannels could be created to provide summer and winter refuge for fish.

Future studies should be geared towards furthering knowledge to strategically implement restoration and management recommendations to maximize their effectiveness. These include:

- Studying the relationship between flows in Perseverance Creek and the water conveyance system, and calculation of an appropriate target instream flow for the morphology of the system;

- Determination of the source of erosion materials and the rate of migration to understand if bank stabilization efforts should be applied to a specific area (e.g., large eroding slope adjacent to the 'bear buns' trail upstream of assessment area) and if it is worthwhile to remove some of the aggraded substrates in the channel or if it would continue to infill rapidly;
- Understanding the locations with good groundwater percolation and poorly drained soils that would provide good backchannel habitat for fish during low and high flows;
- Investigating potential areas for wetland creation for stormwater retention; and
- Studying the potential value of the Cumberland wetlands for water attenuation and providing off-channel habitat.

Our recommended next step is to prepare a conceptual restoration plan for the watershed with a tiered action approach that includes actions that can be completed in the near future, actions that require further study before implementation, and future goals that depend on the management of the greater system. Furthermore, near future actions should be accompanied by clear goals that are tied to measurable objectives and consideration of effectiveness monitoring techniques to ensure objectives are met.

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1. INTRODUCTION

Located in Cumberland, B.C., Perseverance Creek is a locally and regionally important hydro-riparian system. The creek is an integral part of the Village of Cumberland's water supply system, provides valuable habitat for fish, wildlife and ecological communities, and is an important resource to the community. The Cumberland Community Forest Society (CCFS), in partnership with the Village of Cumberland (the Village) and the Comox Valley Land Trust (CVLT), has secured and managed portions of the creek and associated wetlands to protect the ecological integrity of the lands and waters for their intrinsic natural values and for the community. The CCFS aims to secure additional lands surrounding Perseverance Creek in the near future.

Perseverance Creek has been adversely impacted by a multitude of human caused disturbances over the past century and a half, yet recent studies by the CVLT (Ennis 2016, pers. comm.), and by Ecofish Research Ltd. (Ecofish) (Ballin *et al.* 2017), demonstrate that Perseverance Creek retains relatively high ecological value and thus is a conservation priority for the Comox Valley. Furthermore, previous studies of the creek recommended additional inventory work, specifically of the flow, pool locations, and fish habitat present during the dry season (Ellefson 2003). The CCFS retained Ecofish for support in gaining a greater understanding of the current condition and function of Perseverance Creek and to investigate potential restoration and management activities to improve the condition and function of the creek.

The overall objectives of this project are therefore threefold:

1. To understand the current status of fish habitat in Perseverance Creek with a fish habitat assessment;
2. To understand the current status of the ecological function of Perseverance Creek's hydro-riparian area with a proper functioning condition assessment (PFC); and,
3. To understand what restoration or management opportunities would benefit fish habitat and hydro-riparian function.

More specifically, the objectives of the fish habitat assessment were to:

a. Describe fish habitat in Perseverance Creek from Allen Lake reservoir to Comox Lake;
b. Quantify the habitat attributes of Perseverance Creek (e.g., substrate, channel morphology, riparian vegetation etc.); and,
c. Provide conceptual options for restoration, management and future studies.

The specific objectives of the proper functioning condition assessment were to:

a. Describe the hydrological, riparian (vegetation and soils), and geomorphic condition of Perseverance Creek from Allen Lake to Comox Lake;
b. Collect quantitative and qualitative data to support condition assessments (e.g., residual pool size and character, characteristics of channel substrates etc.);

c. Understand the potential natural community, capability of the system, the PFC and altered PFC, condition trends and factors preventing PFC; and,

d. Provide conceptual recommendations for restoration, management, and future studies.

Reconnaissance (1:20,000) Fish and Fish Habitat Inventory (RISC 2001) and Proper Functioning Condition assessment methods (Dickard *et al.* 2015), as well as a background review of the current environmental and social context, were used to accomplish these objectives (CCFS 2017a).

2. ENVIRONMENTAL AND SOCIAL CONTEXT

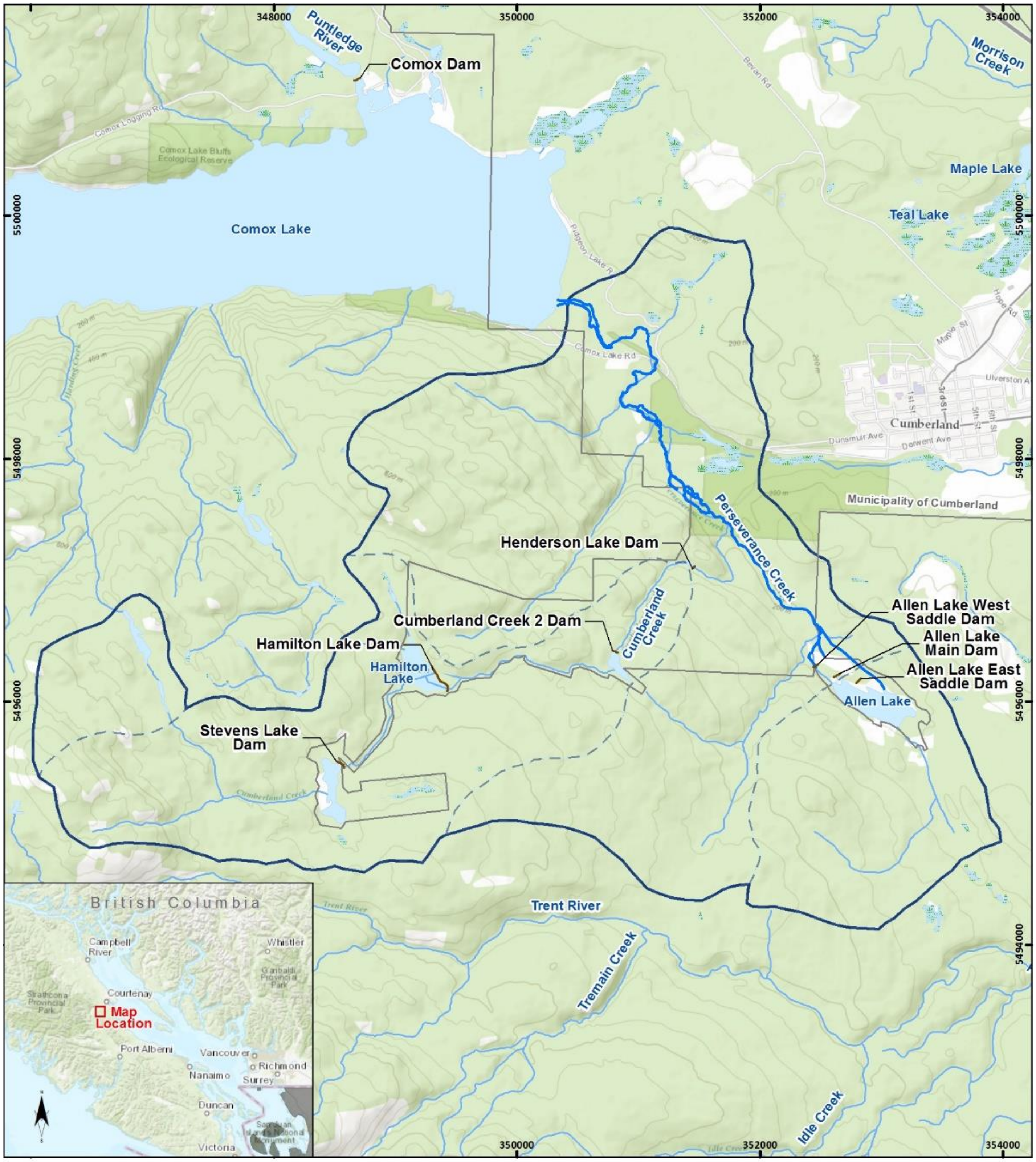
2.1. Study Area

The study area includes Perseverance Creek and its riparian area, from its headwaters at Allen Lake to its outflow into Comox Lake, including the spillway of the Allen Lake reservoir and the channels connected to the mainstem (Map 1). Excluded are the tributaries to Perseverance Creek (e.g., China Creek, Cumberland Creek, Pond #2 spillway), and the wetland complex bordering the floodplain of the creek. The study area ranges from an elevation of 235 m at Allen Lake to 131 m at Comox Lake. The total length of the mainstem of Perseverance Creek within the study area is approximately 6 km, and the area of the riparian habitats is approximately 51.5 hectares (as calculated using a model that identifies adjacent low lying areas that are assumed to be hydrologically connected, a fixed 30 m buffer from the creek centerline, and air photo interpretation) (CCFS 2017a, Ballin *et al.* 2017; Map 2). The total drainage area of Perseverance Creek is approximately 2,099 hectares (Ellefson 2003).

Perseverance Creek primarily flows into the Comox Lake watershed. However, it is connected via subsurface flow (and occasionally by surface flows during high water) to the Cumberland wetlands. The Cumberland wetlands flow into two watersheds: the Trent River and the Comox Lake watersheds. Perseverance Creek's main tributary is Cumberland Creek, which flows from a series of four dammed lakes starting at 900 m elevation: Stevens, Hamilton, Pond #2, and Henderson Lakes.

The project is in the asserted traditional territory of the K'ómoks, Sliammon (Tla'amin) and Homalco (Xwemalhkwu) First Nations (FWCP 2011).

Perseverance Creek



Legend

- Perseverance Creek Study Area
- Perseverance Creek Watershed
- Perseverance Creek Subwatershed
- Municipality of Cumberland
- Dam
- Lake
- Wetland
- Parks and Protected Areas

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 1 km

Scale: 1:45,000

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Date Saved: 21/11/2018
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 1

Path: M:\Projects-Active\1367_CCF\MXD\1367_Perseverance_ProjectOverview_2018Nov21.mxd

2.2. Ecological and Cultural Context

The study area is located in the eastern variant of the very dry maritime subzone of the Coastal Western Hemlock Biogeoclimatic zone (CWHxm1) (DataBC 2018). The ecosystems here are transitional between the temperate rainforests that characterize the majority of the coast of British Columbia, and the sub-Mediterranean "rainshadow" ecosystems of the adjacent Coastal Douglas-fir Biogeoclimatic zone that occupies the majority of the Nanaimo Lowlands Ecosection, positioned on the south east coast of Vancouver Island. An orographic effect from the Vancouver Island ranges and adjacency with the temperature moderating marine environment create the region's distinct biogeoclimatic characteristics (MOF 1991). The regional climate of the study area is characterized by four distinct seasons: cool winters with abundant rainfall, warm spring and fall seasons that experience moderate precipitation, and hot, dry summers. These summer conditions result in a soil moisture deficit for much of July and August (Swift and Ran 2012). In addition, wildfires cause infrequent, stand-initiating events during summer droughts as a part of the natural disturbance regime (NDT2) (Swift and Ran 2012).

Vegetation in the study area is typical of forested mesic and floodplain habitats in the CWHxm1, and occurs in various stages of succession resulting from the natural disturbance regime and historic and current land management activities (e.g., logging, farming, mining). The study area is characterized by well-developed riparian areas, floodplain forests, and off-channel swamps. Forest stands are generally comprised of large statured coniferous trees, including Douglas fir, western hemlock and western redcedar, with deciduous species such as red alder and black cottonwood in moist and recently disturbed areas. Understory trees, shrubs and herb occurrences vary with light, nutrient and moisture availability, with stream edges and floodplains typically supporting high densities of deciduous shrubs. Moss species, including step moss and Oregon beaked moss, generally blanket the forest floor. Invasive species typically occur on disturbed sites, especially in areas with high light availability.

ASAP Geomatix recently provided the CCFS with LiDAR mapping and orthophotograph data, as well as a digital elevation model (DEM), tree analysis, and drainage mapping that were derived from this data, and can be used to support an understanding of the ecology of the property (Appendix A).

2.3. Land Ownership and Current Use

Perseverance Creek bisects multiple ownership boundaries in the short length covered by the study area (Figure 1)(*note this map is out of date and the proposed purchase parcels have been modified as per Figure 2). The lands at Allen Lake are owned by the Village of Cumberland. Downstream of the lake, the creek bisects land owned by Comox Timber Ltd. (managed by Hancock Timber Resource Group), then meanders downstream through the Cumberland Community Forest, which is owned by the Village of Cumberland and has a conservation covenant held by the Comox Valley Land Trust registered on title. The creek then flows to the braided floodplain and wetlands in the Village of Cumberland's Coal Creek Park, to its outlet at Comox Lake, owned by Comox Lake Land Corp.

The majority of the Perseverance Creek watershed is currently managed as a working forest with recreational use. The system also provides the Village of Cumberland's water supply. Land targeted for acquisition by the CCFS is depicted in Figure 2.

Figure 1. Land ownership in the vicinity of Perseverance Creek below Allen Lake (CCFS 2017b).

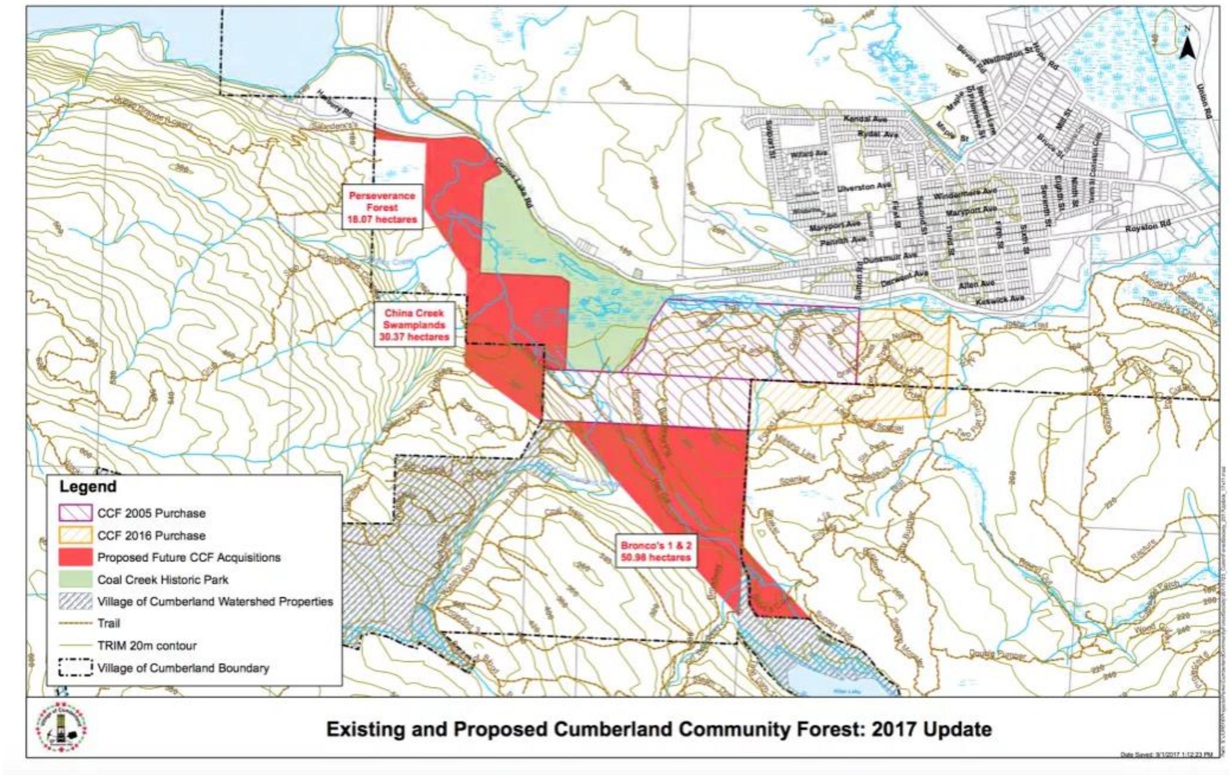
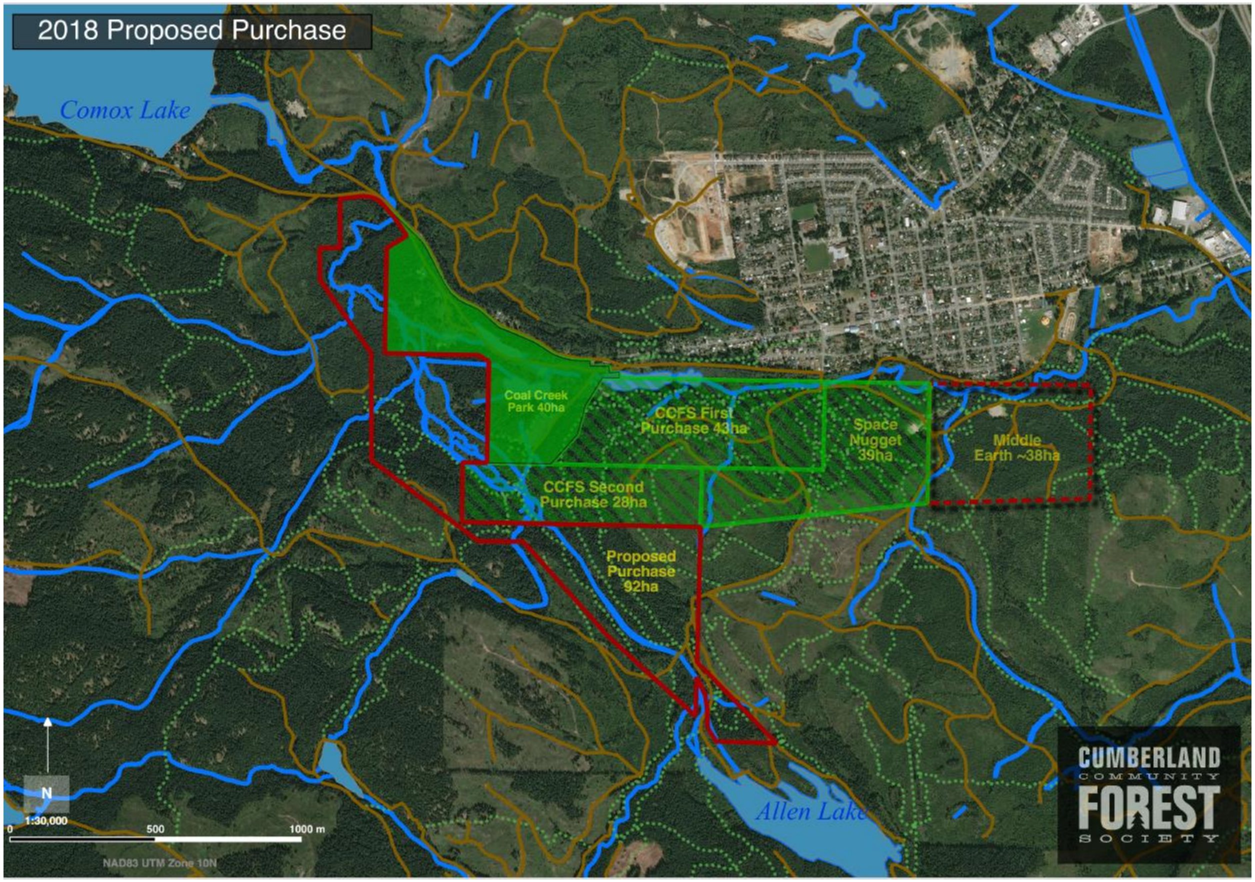


Figure 2. CCFS 2018 proposed land acquisition in the vicinity of Perseverance Creek below Allen Lake (Cursons, pers. comm. 2018).



2.4. Current and Historic Land Use

Perseverance Creek and the adjacent land has been heavily used and modified over the past century and a half, altering the ecology and function of the creek. Land use that currently and/or historically affects Perseverance Creek includes drinking water supply infrastructure, forestry and mining activities, human settlement and water extraction, railway, road and trail development, and hydroelectric development on connected waterways (Ballin *et al.* 2017, Cursons, pers. comm. 2017, Aqua-Tex 2016, Tetra Tech EBA 2015, Ellefson 2003).

The expected impacts of these modifications vary in character and severity. For example: water supply and control infrastructure and use alter the timing and severity of flows; forest harvesting, railway and road building on adjacent lands alters the timing and magnitude of flows, bank stability, water temperature, sedimentation and erosion, nutrient inputs and large woody debris delivery; mining activities divert water from the stream and may contribute pollutants to the stream; human settlement is associated with water extraction, diversion and diking, rerouting flows and changing the zone and magnitude of influence of the creek, as well as facilitating invasion of exotic species, building trails and roads, adding pollutants, and fishing; hydroelectric development on the Puntledge River and Comox Lake interrupted salmon migration routes and the supply of fish to the Perseverance Creek system and affects water levels in the lower reaches of the creek.

Currently the Perseverance Creek watershed provides the Village of Cumberland's water supply and contributes to the water supply for over 45,000 residents of the Comox Valley that use the Comox Lake system. Specifically, the Village of Cumberland's drinking water is extracted from five lakes that feed into Perseverance Creek, as well as a ground source at the Coal Creek Historic Park (Jenssen and Gower 2016, VOC 2014). Reservoirs can have both positive (e.g., flow retention and mediation) and negative (e.g., above normal release and retention) effects on hydrology. The series of dam structures that form the Village of Cumberland's water conveyance system and drinking water are suspected to be negatively impacting flows within Perseverance Creek (Aqua-Tex 2016, Tetra Tech EBA 2015). In particular, the overflow channel from Pond #2 that diverts water from Cumberland Creek to Perseverance Creek (above the connection with the Allen Lake tributaries) is thought to be contributing temporally high flows and promoting localized erosion to the stream banks adjacent to the Bear Buns trail (Jenssen and Gower 2016). The full storage of capacity of the reservoirs is 790,400 - 891,000 m^3 of water (Koers 2016, VOC 2012, McElhanney 2011). Approximately 1,500 m^3 is extracted from the reservoirs each day and 600 m^3 from the well (VOC 2018). Rough assessments have been conducted to understand what the minimum storage should be in the reservoirs and what the associated instream flow should be for the creek. Although no firm numbers have been determined (Davies, pers. comm. 2018), DFO has estimated that 0.068 m^3/s would be needed downstream from the Hai Gai bridge in Perseverance Creek (near the confluence with Cumberland Creek) to maintain the minimum base flow of 0.034 m^3/s required to maintain sufficient fish habitat in the lower reaches during low summer flows (Koers 2016, McElhanney 2011). Any work on the dams would require a *Fisheries Act* Authorization which would likely result in the setting of instream flow requirements for maintenance of fish habitat (Koers 2016, McElhanney 2011).

2.5. Hydrology and Climate

Due to the regional climate, which includes a mix of rainfall and snowfall, the Comox Lake watershed experiences a hybrid nival-pluvial (snow and rain) hydrologic regime, which contributes to naturally high discharge volumes during the rainy winter season, with moderate flows in the spring and fall and very low flows in the summer (Ciruna *et al.* 2007, Ellefson 2003). Climate models for the area show that future total annual precipitation may stay consistent (particularly in the summer months of May – September); however, the mean annual temperature will increase and precipitation will increasingly fall as rain rather than snow (UBC 2018). Furthermore, the higher temperatures will contribute to higher evaporation in the spring and summer months. This may further trend the hydrology regime towards a pluvial regime, rather than a nival regime, which would result in increased and flashier fall and winter flows and decreased spring and summer flow. However, the extent of change is uncertain because records indicate that currently rainfall, as opposed to snowpack, is the predominant factor in water supply throughout the year (McElhanney 2016).

The seasonal high flows in Perseverance Creek scour the canyonized and floodplain portions of the creek, resulting in erosion events and high turbidity within the creek (Ellefson, pers. comm. 2003) and increased sediment deposition and turbidity in Comox Lake (Aqua-Tex 2016).

The erosion events may be exacerbated because the amount of water currently diverted into the creek exceeds historic flows and the capacity of the creek, compounded by the unconsolidated bedrock geology characteristic of portions of the creek (Aqua-Tex 2017). Around 2003, hydrology gauges were installed throughout Perseverance Creek with the intent of monitoring flow and determining an appropriate instream flow requirement (Sutherst, pers. comm. 2018,). These one-meter tall gauges are now almost completely buried, a testament to continuous bank erosion and substrate migration. A turbidity gauge has been installed in the creek since 2008 (Jenssen and Gower 2016). The current gauge is installed on the Davis Lake Main bridge and operated by the Comox Valley Regional District (CVRD).

2.6. Fish

The presence of salmonids in Perseverance Creek over the past 150 years has been influenced by land use and development. The dam at the outlet of Comox Lake was first built in 1913, blocking access to fish. In 1958, the dam height increased. A fishway was built in 1991, however it wasn't until well after construction that fish were able to pass, meaning that anadromous fish access to Perseverance Creek was restricted for approximately 80 years (FWCP 2011, DFO 1958). Currently, the hatchery releases salmonids into Comox Lake each year including: 400-1,000,000 juvenile Coho; 100-200 adult Coho; 0-200 adult summer Chinook; and, ~50 Chinook jacks (Davies, pers. comm. 2018, Rotenburg, pers. comm. 2018). Several of the juvenile Coho that are released are thought to use Perseverance Creek (Davies, pers. comm. 2018, Perseverance Creek Streamkeepers, pers. comm. 2018).

Currently, Perseverance Creek supports Coho Salmon, Cutthroat and Rainbow Trout, Dolly Varden and Sculpin (DataBC 2018, Streamkeepers, pers. comm. 2018, Ellefson 2003, Griffith 1995). The distribution of these species along the creek varies dependent on the season and associated access to suitable habitats. Coho make it part way up the meandering lower floodplain of Perseverance Creek to spawn in some years (Murray, pers. comm. 2018). In November 2018, several pairs of spawning Coho were observed in the creek as far upstream as the bridge at Comox Lake Road, the most on record for any given year (Davies, pers. comm. 2018, Mathers, pers. comm. 2018). Although there have been a few observations of adult Coho in the creek over the years (Perseverance Streamkeepers, pers. comm. 2018), it is suspected that the majority of the Coho fry found in the lower reaches originate from Comox Lake (hatchery and wild fish) (DataBC 2018, Davies, pers. comm. 2018).

Cutthroat Trout occupy Hamilton Lake, which is connected to Perseverance Creek via Cumberland Creek (DataBC 2018, McMullin, pers. comm. 2018), and it is suspected that a population of Cutthroat Trout persists in Allen Lake. However, the majority of trout fry and sculpin are observed in residual pools in the lower reaches, and likely originate from Comox Lake (Streamkeepers, pers. comm. 2018, Griffith 1995). A single Dolly Varden observation exists from the canyon section approximately 500 m downstream of Allen Lake; however, the presence of Dolly Varden has not been confirmed (DataBC

2018). In the adjacent Cumberland wetlands, minnow trapping has resulted in captures of stickleback and newt (Ellefson 2003).

Fish observations from the provincial FISS database (DataBC 2018) were used to populate a fish-bearing model for streams in the Puntledge watershed (Ballin *et al.* 2017). Results of the model infer that fish have access to tributaries beyond Allen Lake and Hamilton Lake, which are the most upstream locations in the system in which fish have been observed.

The altered hydrology of Perseverance Creek may be adversely affecting fish habitat and fish populations in the system. Summer low flows create a habitat sink for thousands of Coho and other fry that are stranded in residual pools, rendering them susceptible to predation, desiccation and heat related pressures. Winter high flows regularly lead to flooding in low gradient areas or where obstructions to flow exist and alter habitat structure throughout the system (Ellefson 2003, Griffith 1995).

The Perseverance Creek Streamkeepers group has stewarded the creek for over a decade and cumulatively have an immense amount of knowledge about the creek. Their main activity is salvaging fry stranded in residual pools isolated during the dry summer months, however they also collect data on stream water levels, and more recently, water quality (Murray, pers. comm. 2018, Mathers, pers. comm 2017). Currently the Streamkeepers have annual salvage records dating from 2018 back over a decade. In addition, a citizen scientist, Steve Morgan, has been collecting data on the hydrology of the adjacent wetlands for several years as a means to understand temporal patterns and change.

3. METHODS

3.1. Background Review and Information Collation

A background review was conducted to compile publicly available information on fish presence and previous studies conducted on Perseverance Creek. Fish databases searched included the BC Ministry of Environment Habitat Wizard (MOE 2017a), Fisheries Information Summary System (FISS) (MOE 2017b), Ecological Reports Catalogue (ECOCAT) (MOE 2017c) and NuSeds (DFO 2017). In addition, a general internet search was conducted for information relating to Perseverance Creek associated with the CVRD's Watershed Protection Plan, the Village of Cumberland water supply, recreation, and fish and wildlife. Data was acquired from the Comox Watershed Project Watershed Society's digital files dating back to 2003 (Sutherst, pers. comm. 2017) and the Perseverance Streamkeepers (Murray, pers. comm. 2018).

Local knowledge was also documented during a site visit with the Perseverance Creek Streamkeepers (Mathers, pers. comm. 2017), the Comox Valley Land Trust (Tim Ennis) and CCFS (Meaghan Cursons) on October 13, 2017, and subsequent meetings and communications with the Streamkeepers (Perseverance Streamkeepers, pers. comm. 2018), DFO (Davies, pers. comm. 2018) and K'omoks First Nation technicians during field work (August 2018).

Information collected during the background review has been collated and incorporated into Section 2.

3.2. Reconnaissance 1:20,000 Fish and Fish Habitat Inventory

3.2.1. Habitat

Reconnaissance 1:20,000 Fish and Fish Habitat Inventory (RISC 2001) methods were used to collect quantitative information and qualitative observations of fish habitat at a mesohabitat scale along the entire length of Perseverance Creek from Comox Lake to the Allen Lake reservoir.

Physical attributes that were assessed and recorded included:

- Channel morphology including wetted and bankfull widths, depths and pattern;
- Substrate types;
- Fish habitat cover;
- Riparian habitat characteristics;
- Disturbance indicators;
- Rearing, spawning, overwintering and migration habitat suitability; and,
- Water quality parameters (i.e., temperature, dissolved oxygen, conductivity and pH collected with a YSI Pro).

Since Perseverance Creek provides habitat for trout (Rainbow and Cutthroat) and Coho over the majority of the assessed reaches, habitat quality was assessed in terms of these species.

Photographs were taken at the start and end point of each site and of significant stream features (e.g., log jam, gradient change, barriers to fish passage, culverts). Photographs at these locations included views looking upstream, downstream and cross-stream from bank to bank.

3.2.2. Fish Presence

Fish were opportunistically observed and identified during the reconnaissance survey. Otherwise fish data originates from background sources including public databases and local knowledge (Section 2.6).

3.3. Proper Functioning Condition of Hydroriparian Systems

3.3.1. Hydroriparian systems

Riparian areas can be defined as the interface between aquatic and terrestrial environments that extends vertically down to the groundwater, and up to and above the forest canopy (Tschaplinski and Pike 2010, MWLAP 2006, MOF 2002). For the purpose of this project, riparian habitat will include the area surrounding a waterbody that is influenced by the hydrologic regime of the waterbody (i.e., the area from the stream channel upland to where vegetation may be influenced by elevated water tables or flooding), as well as the upland area at a set distance from the waterbody that provides riparian functions (e.g., temperature moderation, shade, filtration of sediments, bank stabilization, inputs of organic debris and insects, large woody debris contribution, and wildlife habitat) (Hoover *et al.* 2006, Hawes and Smith 2005, Richardson *et al.* 2005, Richardson 2003, Naiman *et al.* 2000, Chilibeck *et al.* 1993, DFO and MELP 1998).

The hydro-riparian system is comprised of the riparian habitat and the aquatic instream habitat. Hydro-riparian systems can also be comprised of wetlands. Wetlands were not included in this assessment; however, the complementary function of wetland habitats will be considered in recommendations for enhancing the function of the creek.

3.3.2. Proper Functioning Condition Assessment

A PFC assessment was conducted to collect quantitative and qualitative data pertaining to the functionality of Perseverance Creek.

The PFC assessment used a checklist of assessment questions pertaining to key indicators of stream function (Table 1), supported by quantitative and qualitative data, to assess the function of the hydrology, vegetation and geomorphology/soils of hydro-riparian areas (e.g., Dickard *et al.* 2015, Tschaplinski and Pike 2010, Tripp *et al.* 2009, Buchanan *et al.* 2009, Prichard *et al.* 2003). The assessment identifies attributes that are indicative of processes that may be operating beyond the natural range of variation and that are altering the function of the hydroriparian area. Thus, the assessment is used to understand the current function of the hydroriparian system, identify shortcomings and trends, and can provide a basis for prioritizing management and restoration actions. It also provides valuable baseline data for monitoring the ecological health of a hydroriparian system over time. The methods used for the purpose of this project were modified from previous assessments to suit Perseverance Creek.

The specific methods used for this Project involved:

- Delineation of assessment reaches based on: biophysical attributes including Rosgen's stream classification system (Rosgen 1996), vegetation, stream morphology, soil/ bedrock geology, hydrogeology, major tributary confluences and management units (e.g., a steep coniferous slope vs. low gradient deciduous dominated floodplain, or eroding slope at the confluence of Cumberland Creek and Perseverance Creek), and previous mapping (Ballin *et al.* 2017).

- Determination of the potential natural condition (PNC) based on professional working knowledge of local ecosystem function, including hydroriparian processes, succession and climax communities, the natural disturbance regime, and similar sites. The PNC serves as a baseline from which to assess PFC. Because the condition of the creek will be in an altered managed state for the foreseeable future due to the Village of Cumberland water supply system, and the stream's position amongst managed forest lands, the highest ecological capability of each assessment area under current management was also considered. Since PFC cannot be attained under the current management regime, the capability was used as a basis from which to assess the 'altered PFC' (Dickard *et al.* 2015).

- Assessment of stream function based on qualitative questions requiring a score (yes/ no/ not applicable) (Table 1) for the hydrology, vegetation and soils, and geomorphology attributes as they compare to the PNC and system's capability, and processes that affect stream function; these functions and the guiding questions that were included on datasheets are summarized in Table 1.

- Assessment of the proper functioning condition as it pertains to the potential natural condition and an assessment of the 'altered' PFC in consideration of the site's capability, where a PFC score of Functional, Functional-At Risk, Non-functional or Unknown was assigned to each assessment reach (Prichard *et al.* 2003), as well as a trend (i.e., stable, downward, upward) (Table 2).

- Description of factors and mechanisms preventing achievement of PFC or altered PFC for each assessment area.

Table 1. Physical attributes and functions affecting stream function.

Process	Physical attributes and functions considered	Guiding questions/ statements
Hydrology (and climate)	Discharge patterns including extreme events; runoff patterns, infiltration, and baseflow relationships; position of water table, surface-/ground-water interactions; floodplain storage and release; flood modification; stream power; hydraulic controls; temperature; weather and precipitation patterns including extreme events.	1) Floodplain is inundated in 'relatively frequent' events 2) Beaver dams are stable 3) Sinuosity, gradient and width/ depth ratio are in balance with the landscape setting (i.e., landform, geology, and biogeoclimatic zone) 4) Riparian area is expanding or has achieved potential extent 5) Riparian impairment from the upstream or upland watershed is absent 6) The drainage feature have alluvial deposits and/or scour to a mineral substrate or continuous definable banks that are in balance with the landscape setting and stream morphology 7) The drainage feature receive more than 2/3 of its water from groundwater seepage, overland flow, or floodwater from adjacent water bodies, with less then 1/3 of its water from a lake, wetland or stream 8) The character and abundance of large and small instream wood is within the range of natural variation
Vegetation, Ecology and Soils	Community types and distribution; lotic and lentic indicator plants; disturbance dynamics and successional tendencies of plants; recruitment/ reproduction; root characteristics, soil texture and soil moisture regime; distribution of aerobic and anaerobic soils; soil organic matter.	1) There is adequate species diversity and age class diversity and maturity to stabilize riparian community vegetation recovery/ maintenance 2) Species present indicate maintenance of riparian soil-moisture characteristics 3) An adequate abundance of stabilizing riparian vegetation of adequate age classes and diversity capable of withstanding moderately high streamflow events are present along the streambank for recovery and maintenance 4) Riparian impairment from the upstream or upland watershed is absent 5) Riparian plants exhibit high vigour 6) Large woody debris contributions are intact (i.e., various size and decay classes, low occurrence of blowdown) and plant communities are an adequate source of woody material for maintenance/ recovery (characterize age, abundance and size of wood accumulations) 7) Exotic invasive species and native increaser species are within the threshold of the ecosystem and populations are stable or decreasing 8) The area of exposed/ bare soil and/ or disturbed ground is <10% or within the threshold of the ecosystem in consideration of the riparian slope
Geomorphology, Geology and Topography	Bedrock and surficial deposits; bank stability; bed stability; sediment characteristics; channel characteristics (cross-sectional area, bankfull width, width/depth ratio, pattern, sinuosity, gradient); floodplain accessibility and extent; valley bottom geometry; watershed properties.	1) Floodplain and channel characterisitcs (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy 2) Point bars are revegetating with stabilizing riparian plants 3) Streambanks are laterally and vertically stable 4) Stream is in balance with water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition) 5) Consider questions for hydrology and vegetation

Table 2. Proper Functioning Condition Scores (Dickard *et al.* 2015).

PFC Score	Description
Functional	A lotic riparian area is considered to be in PFC, or "functioning properly," when adequate vegetation, landform, or woody material is present to: dissipate stream energy associated with high waterflow, thereby reducing erosion and improving water quality; capture sediment and aid floodplain development; improve floodwater retention and ground-water recharge; and, develop root masses that stabilize streambanks against erosion; maintain channel characteristics. A riparian area in PFC will, in turn, provide associated values, such as wildlife habitat or recreation opportunities.
Functional At-Risk	These riparian areas are in limited functioning condition; however, existing hydrologic, vegetative, or geomorphic attributes make them susceptible to impairment.
Non-Functional	These riparian areas clearly are not providing adequate vegetation, landform, or woody material to dissipate stream energy associated with moderately high flows, and thus are not reducing erosion, improving water quality, etc.
Unknown	The PFC cannot be assessed with reasonable certainty.

4. RESULTS

4.1. Reconnaissance 1:20,000 Fish and Fish Habitat Inventory

4.1.1. Habitat Assessment

Fish habitat data were collected at 11 sites (reaches) in the Project area on August 21-24, 2018 including eight sites on the Perseverance Creek mainstem and three sites on each of the three tributaries (which act more like drainages) between Allen Lake and Perseverance Creek (Table 3; Map 3). The assessment was conducted over approximately six kilometers during low flows.

Table 3. PFC and Fish Habitat Assessments Sites.

Waterbody	PFC Site	Fish Habitat Site	UTM Coordinates (Z 10)		Date	Approx. Site Length (m)	Description
			Easting	Northing			
Perseverance Creek	PRS-PFC01	PRS-STC01	350342	5499304	18-08-21	480	Reach influenced by Comox Lake
	PRS-PFC02	PRS-STC02	350755	5498928	18-08-21	650	Just downstream of Whytes Bay bridge to just before Comox Lake bridge
	PRS-PFC03	PRS-STC03	351124	5498821	18-08-22	930	Comox Lake Bridge to wetlands
	PRS-PFC04	PRS-STC04	351177	5498252	18-08-22	1060	Wetlands to Hai Gai bridge
	PRS-PFC05	PRS-STC05	351688	5497505	18-08-23	200	Hai Gai bridge to above Cumberland Creek
	"	PRS-STC06	351806	5497341	18-08-23	270	To below canyon.
	"	PRS-STC07	351961	5497152	18-08-23	645	Canyon section to Davis Lake main bridge
	PRS-PFC08	PRS-STC08	352378	5496772	18-08-24	395	Davis Lake main to Allen Lake tributary 1
Tributary 1	-	PRS-STCT01	352477	5496619	18-08-24	450	Eastern tributary from Allen Lake
Tributary 2	-	PRS-STCT02	352483	5496500	18-08-24	330	Middle drainage from Allen Lake
Tributary 3	-	PRS-STCT03	352431	5496303	18-08-24	160	Western drainage from Allen Lake

The assessed reaches of Perseverance Creek can effectively be divided into four sections plus the three tributaries. Starting at Comox Lake and ending at Allen Lake the sections are: (1) the lowest reach which is affected by the elevation of Comox Lake to the Whytes Bay rail bridge (PRS-STC01); (2) the low gradient meandering and braided reaches below the Hai Gai bridge (PRS-STC02-04); (3) the steeper and canyonized reaches below the Davis Lake Main bridge (PRS-STC05-07); and (4) the low gradient section to the western most tributary (PRS-STC08). Habitat quality for rearing, overwintering, spawning and migration of fish species differed between these sections, and is described by habitat type below. Qualitative descriptions of each habitat type per reach are provided (Table 4; Table 5,) and are supported by quantitative and qualitative data (Table 6, Table 7, Table 8), as well as mapped features (Map 4) and photographs (Appendix B).

Habitat quality for rearing ranged from high to poor. High quality rearing habitat is present in the deep pools (e.g., PRS-STC01, 02, 03), and under log jams (Map 4) in the lower reaches, and in some deep pools (e.g., the potholes) in the middle reaches (e.g., PRS-STC06). However, in the lower gradient reaches, pool habitat would be significantly greater if the channel wasn't aggraded with substrates, and LWD was more evenly distributed throughout rather than in a few large accumulations (log jams) (e.g., PRS-STC02, PRS-STC03, PRS-STC04, PRS-STC05, PRS-STC08). Water quality in most pools was adequate to support fish (i.e., average 12.3°C, 9.5-13.8°C; average ~ 35% saturation D.O., 17-44%) throughout the summer, however, at the time of field work, Comox Lake temperatures (PRS-STC01) were warm and all the fish detected in the lower reach were dead. Cover in all reaches was moderate to abundant and was primarily comprised of overhanging vegetation, boulders, and large woody debris (LWD). Although water quality and associated habitat quality varied, pools supporting fish were present throughout the entire study area.

Overwintering habitat quality was considered very high to high in the lower reaches (PRS-STC01, PRS-STC02) where back channels, deep pools and log jams provide cover and refuge during high velocity winter flows, and decreased to poor in the middle to upper reaches (PRS-STC06, PRS-STC07) where gradients were steeper and more chutes were present, or the channel was infilled with substrate leaving minimal refuge locations (e.g., PRS-STC08).

Spawning habitat quality was variable throughout the assessed reaches and tended to be highest in the lower reaches (e.g., PRS-STC02, PRS-STC03) and decrease in the upper reaches as the substrate size increased and appropriate gravel sizes for spawning decreased (e.g., PRS-STC06, PRS-STC07, PRS-STC08).

Migration was considered moderate to poor for different reasons depending on the season. In the summer the majority of the channel is dry limiting migration potential. During moderate flows, several barriers exist including log jams (e.g., PRS-STC02, PRS-STC04) and bedrock chutes (PRS-STC07), whereas in the winter, high flows and a lack of refuge (e.g., evenly spaced pools and boulders) likely limit upstream migration, especially for juvenile fish. Furthermore, the canyon section (PRS-STC07) is expected to provide an upstream migration barrier to juvenile salmonids, and the falls below the Davis Lake main bridge is expected to create an upstream barrier to all fish. However, these barriers were only observed during low flows, and not under a variety of flow conditions, which would be necessary to confirm fish passage status.

Riparian habitat value was classified as very high throughout the study area and was comprised primarily of mixed maturing young forest.

Table 4. Fish habitat overview by site.

Site	Overview
PRS-STC01	Majority of reach back flooded by warm lake water (133.600 masl during survey). Substrate is mostly fines due to the very low channel gradient. Some elevated gravel bars are developing at the upstream end of the reach. A trickle of water intermittently flows through the channel above the lake influence. Pools above the lake level have improved water quality and support abundant Coho fry (50-200 fry in small pools). Stream keepers release salvaged fish into this reach of the lake (the lagoon; in mornings when temperatures are cooler), potentially condensing individuals to above optimal densities. Above the lake influence, cover (i.e., overhanging vegetation and large woody debris [LWD]) and spawning gravel increase.
PRS-STC02	A large log jam is holding back an elevated sediment wedge, lending to all water flowing subsurface for a distance upstream, then transitioning to isolated pools with Coho fry.
PRS-STC03	The culvert under Comox Lake Road is undersized and is concentrating energy on the eroding bank during high flows. Excessive substrate in the channel paired with winter flooding has deposited sediment through the riparian floodplain and behind log jams. Flooding may be more severe in recent years as evidenced by dying trees and unembedded channel substrates. The extensive sediment wedges above log jams are dry during summer flows. Accordingly, the reach is mostly dry with just a few residual pools with large woody debris and some Coho fry. A hardpan clay layer beneath the pools holds water.
PRS-STC04	The channel is aggraded in many places upstream of LWD accumulations. Downstream of LWD there are some scour pools with good overhanging vegetation. The adjacent wetland has poor water quality (18°C) due to lack of shade and flow. During the field survey the adjacent wetland was disconnected from the stream by the natural channel bank. Connectivity between the wetland complex and Perseverance Creek is expected at flood flows (every 2-5 years).
PRS-STC05	Excess bedload accumulations fill the channel and water flows subsurface in summer. Good riparian habitat (i.e., mixed maturing young forest) exists along the entire length of the stream, but few functional large woody debris pieces are present. Pools are potholes in bedrock. The moderate gradient (3.5%) is lending to the channel being scoured to bedrock.
PRS-STC06	Canyon reach has a steeper gradient averaging ~7% with sections up to 35%. Channel constricted to a couple of meters width in places. The stream is scoured to bedrock with pools held therein and trickle flow between pools. Some Coho were observed above a 6 m long chute. There is some boulder cover, but little LWD or overhanging vegetation. There is very little spawning material except behind one log jam in a low gradient stretch.
PRS-STC07	Section above the canyon and falls below Davis Lake Main crossing. A few Stickleback and two Coho fry observed above the canyon (and below the falls; fewer Coho fry than lower reaches). Trout in pools above and below the largest (5 m tall) falls. Low fish numbers and mostly trout in the canyon. The water quality is decent.
PRS-STC08	Channel is mostly dewatered due to extensive aggradation that has filled channel with bedload and spread into the forest in many places. The channel is comprised of coarse cobble and bedrock substrates and a moderate gradient (up to 6%). A few trout exist in bedrock pools. Some extensive erosion noted.
PRS-STCT01	This is the western overflow channel from Allen Lake. The channel was dry at the time of survey. Severe erosion and scour are present in a deep channel in steep sections. In other sections the channel is absent. Consequently the high flows disperse substrates throughout the forest. These processes are indicative of poor hydrology and fish habitat. Fines are present, clay on bed and banks could contribute to high turbidity downstream during high flows.
PRS-STCT02	The tributary does not provide fish habitat. Poorly defined channel containing seepage from Allen Lake. Dried up wetland-like feature is all that remains in summer. Single metal culvert could be velocity barrier to fish.
PRS-STCT03	The tributary does not provide fish habitat. There is only seepage flow, shallow water, low oxygen, iron algae blooms in places. It may be possible to create an overflow channel to spread the winter flow from the west tributary (T01) and create an artificial wetland to attenuate flows.

Table 5. Fish habitat - rearing, spawning, overwintering, migration.

Fish Habitat Site	Rearing	Spawning	Overwintering	Migration
PRS-STC01	Moderate - poor. Elements of very good rearing habitat because of LWD, deep pools and connectivity to Comox Lake. However summer water temperatures are high (19°C) in the reach connected to Comox Lake, and the only fish detected during the assessment were dead. During clear, moderate winter flows the lake influenced section likely provides good rearing habitat with the exception of high turbidity events during heavy rains. Large schools (40-50) of fish were present in the stream influenced pools just above the lake influence with more flow, shade, overhanging vegetation and LWD cover.	Moderate - poor. Low gradient with lots of fines; only some gravel bars at upstream end of reach that would be suitable for resident and/or anadromous spawning salmonids.	High. Low gradient deep pools paired with improved winter water quality (i.e., lower temperature, higher D.O.) would provide good habitat, however turbid water from storm events may decrease quality.	Moderate. Low gradient easy access, but limited summer flows confines fish to isolated pools at upper end of reach, only trickle flow
PRS-STC02	High. Contains elements of good rearing habitat even though this reach is lacking summer flow because of cover and refuge features (e.g., large clusters of LWD, overhanging vegetation, deep isolated pools, and an isolated back channel that extends 40 m into the floodplain [dry at time of survey]).	High. Abundant spawning gravels present.	Very high. Good overwintering pools and backchannel habitat.	Moderate. A dry aggraded section occurs upstream of the log jam in low water limiting migration during low water.
PRS-STC03	Moderate - poor. Lacking summer flow, partially due to substrate aggradation behind multiple log jams. Very limited pool habitat. A few small residual pools with low oxygen (e.g., 12%, 1.29 mg/L) and trickles between subsurface flow. Two larger pools (i.e., 13 m x 10 m x 1.5 m deep) downstream of Comox Lake Road offer the best rearing habitat in the reach.	Moderate - high. Abundant spawning material present but dry at the time of survey.	Moderate to high. Good overwintering habitat present in the few pools and under log jams, however channel is filling with substrate dissipating flows and filling in deep pools and refugia from winter storms.	Moderate - poor. Several barriers ranging up to 2 m high comprised of log jams with gravel aggradation built up behind them. Reach mostly dry during survey. The undersized culvert under Comox Lake Rd. is likely a velocity barrier to juveniles during high flow.

Table 5. Continued.

Fish Habitat Site	Rearing	Spawning	Overwintering	Migration
PRS-STC04	Moderate. Mostly dry with a few shallow residual pools (e.g., 20m x 8m x 0.45m depth). Increasing pools then aggraded channel again above log jams.	Moderate. Significant spawning material, but channel mostly dry and substrate transitions to coarse cobble and scoured near Hai Gai bridge.	High. Some good overwintering habitat at pools with LWD.	Moderate. Seasonal barrier at log jams and dry sections, low gradient (1-1.5%). Access to wetland complex limited.
PRS-STC05	Poor. A couple of residual pools exist but most of the reach is de-watered. There is excessive aggradation within the channel and only a trickle of flow surfaces in short sections of the reach.	Poor. Substrate mostly too coarse (large gravel and cobble) for resident spawners, some patches of smaller gravels may be suitable for Coho.	Moderate. Decent overwintering habitat in deep pools with LWD. However there is only moderate protection from materials mobilized during storms.	Moderate - poor. Seasonal barriers exist due to lack of summer flow and the presence of steeper chutes (i.e., 6% gradient and 6 m long). The chutes would pose barriers for juvenile salmonids but be passable for adults. Similarly winter flows are likely excessive and a barrier to migration.
PRS-STC06	Moderate. Good summer rearing, surface water flowing between pools, with good water quality (e.g., 13.8°C, 40.7% O2, 4.18 mg/L, 108.1 uS; 13.8°C, 4.18mg/L). One flatter stretch (2% gradient) but mostly steeper (~7% and up to 35%). Less LWD than lower reaches. The high flow velocities, steep gradient and limited refuge limits rearing habitat in high flows.	Poor - moderate. Very little spawning material in most areas. Scoured to rock and boulders. Some gravel behind log jam.	Poor. Boulder refuge is available during winter flows, but high velocities would be present during storm events, only one small lower gradient section (2%). The high flows and limited refuge limits the value of overwintering habitat.	Poor. Seasonal barriers for juveniles and adults in high and low flows. Migration limited to pools in low flows. Steep chutes (e.g. 35% gradient, 6 m long) over bedrock present. However, Coho observed above.
PRS-STC07	High. Deep bedrock controlled pools (1.5 m deep, 2 m diameter) contain larger trout (up to 200 mm) and a few Coho below the big falls. Water quality in pools is good for rearing (13.8°C, 44% O2, 4.46 mg/L).	Poor. No spawning habitat, scoured to rock.	Moderate. Some pool habitat for overwintering with boulder refuge	Poor. Waterfall (5 m tall) over sandstone is a barrier to most fish. The constricted canyon has high winter velocities which create a velocity barrier in winter storm flows. Thus observed trout juveniles in the canyon reach are expected to originate from upstream.

Table 5. Continued.

Site	Rearing	Spawning	Overwintering	Migration
PRS-STC08	Poor. The channel is mostly dry due to bedload aggradation (e.g., the bankfull depth of the channel is 0.2-0.6 m where it should be ~1.5 m). Consequently small to moderate sized substrate (fines, cobble and gravel) has overflown the banks and is deposited throughout the forest. A few warm pools with moderate water quality (depths 0.2-1.7 m deep; 16.3°C, 47.7 % O2, 4.67 mg/L, pH 8.09) with a few trout and stickleback are present just above the Davis Lake Main bridge.	Moderate. Channel filled with cobble and large gravel patches in some places. Too large for resident trout but some patches suitable for Coho.	Moderate - poor. Overwintering habitat is present in a few pools, however the channel is mostly filled in or scoured due to the moderately steep morphology.	Poor. Moderate gradient (up to 6% would concentrate flows in winter), channel is mostly dry in the summer.
PRS-STCT01	Poor. Dry at time of inspection, no defined channel in places, and severely eroding with up to 8% gradient in others, good riparian forest habitat.	Poor. Fines in places, scoured to clay in others, undefined channel.	Poor. Unstable habitat with severe erosion and high velocities in places and dispersed flows and an undefined channel in places.	Poor. Dry at the time of visit, lacking defined channel in places. Three small metal round culverts under access road are likely a velocity barrier in high flow.
PRS-STCT02	Poor. Dry.	Poor. Small deposits of fines are the only mineral substrates in the stream.	Poor. Possible marginal habitat in winter.	Poor. Dry in summer, no defined channel.
PRS-STCT03	Poor. The stream is mostly dry - just a trickle of poor quality water in some locations.	Poor. Fines only.	Poor. Steep gradient at the junction to the mainstem is likely a barrier to fish.	Poor. Only a trickle of flow only in summer.

Table 6. Summary of fish habitat parameters – channel morphology, cover and bed materials.

Stream	Site	Channel Width (m)	Wetted Width (m)	Residual Pool Depth (m)	Bankfull Depth (m)	Stream Gradient (%)	Cover			Bed Materials		D95 (cm)[3]	D (cm)[4]
							Total[1]	Dominant[2]	Sub-dominant[2]	Dominant	Sub-dominant		
Perseverance Creek	PRS-STC01	21.6	10.7	0.9	2.0	0.5	M	DP	LWD	Fines	Gravel	10.0	10.0
Perseverance Creek	PRS-STC02	13.0	6.2	0.8	1.1	1.0	A	OV	LWD	Gravel	Cobble	8.0	6.0
Perseverance Creek	PRS-STC03	12.9	4.1	0.6	1.2	0.8	A	OV	LWD	Gravel	Fines	5.0	8.0
Perseverance Creek	PRS-STC04	15.3	6.0	0.7	1.4	1.3	M	OV	LWD	Gravel	Fines | Cobble	8.0	4.0
Perseverance Creek	PRS-STC05	11.4	2.5	0.4	1.7	2.8	A	BO	OV	Cobble	Gravel	10.0	37.0
Perseverance Creek	PRS-STC06	8.3	3.1	0.4	1.2	11.8	M	BO	LWD	Boulder	Cobble	75.0	75.0
Perseverance Creek	PRS-STC07	11.1	4.6	0.9	1.6	3.5	M	BO	OV	Bedrock	Cobble	15.0	70.0
Perseverance Creek	PRS-STC08	14.2	3.0	0.4	1.2	3.1	M	CU	BO	Cobble	Gravel	0.2	0.3
Tributary 1	PRS-STCT01	18.8	0.5	0.2	0.8	4.5	A	LWD	OV	Fines	Cobble	30.0	20.0
Tributary 2	PRS-STCT02	4.8	0.0	0.0	0.4	0.5	A	OV	-	Fines	-	-	-
Tributary 3	PRS-STCT03	4.3	0.7	0.1	0.6	0.5	A	OV	LWD	Fines	-	-	-

[1] A=abundant - cover exists over > 20% of the site; M=moderate - cover exists over 5-20% of the site.

[2] DP=deep pool; OV=overhanging vegetation; BO=bolder; CU=cutbank; LWD=large woody debris.

[3] D95= The diameter of the bed material that is larger than 95% of other materials.

[4] D= The diameter of the largest particle on the channel bed that will be moved at channel forming flow levels.

Table 7. Summary of fish habitat parameters - water quality and morphology.

Site	Water Temperature (°C)	Conductivity (µS/cm)	Turbidity	D.O. (%)	D.O. (mg/L)	pH	Morphology	Pattern	Bars	Confinement
PRS-STC01	19.3 (lake), 9.5 (pools)	41	Clear	51 (lake), 36-44 (pools)	5.03 (lake), 3.94-4.94 (pools)	7.43	Riffle Pool	Sinuous	side bar / point bar|mid-channel bar	Occasionally Confined
PRS-STC02	10.1-12.0	54	Clear	22.0	5.20	6.50	Riffle-Pool	Irregular|Wandering	mid-channel bar|span	Occasionally Confined
PRS-STC03	10.9	51	Clear	17.0-22.0	1.84	6.60	Riffle-Pool	Straight	span	Unconfined
PRS-STC04	9.5	31	Clear	20.7	2.35	6.01	Riffle-Pool	Irregular|Wandering	mid-channel bar|span	Unconfined
PRS-STC05	13.3	109	Clear	41.4	4.30	7.64	Cascade Pool	Sinuous	mid-channel bar|span	Occasionally Confined
PRS-STC06	13.5	104	Clear	44.9	4.64	7.50-7.86	Cascade Pool	Sinuous	span	Confined
PRS-STC07	13.8	98	Clear	43.5	4.46	7.81	Cascade Pool	Sinuous	none	Confined
PRS-STC08	12.6	41	Clear	-	2.88	6.45	Riffle-pool|Cascade-pool	Sinuous	side bar / point bar|diagonal bar|mid-channel bar|span	Occasionally Confined
PRS-STCT01	15.0	66	Clear	23.0	2.26	6.60	Cascade Pool	Irregular|Wandering	span	Unconfined
PRS-STCT02	-	-	-	-	-	-	Riffle Pool	Sinuous	-	Unconfined
PRS-STCT03	15.0	67	Clear	23.0	2.26	6.60	-	Sinuous	-	Unconfined

Table 8. Summary of fish habitat parameters - riparian vegetation.

Stream	Site	Left Bank				Right Bank			
		Shape	Texture	Riparian Vegetation	Vegetation Stage	Shape	Texture	Riparian Vegetation	Vegetation Stage
Perseverance Creek	PRS-STC01	Vertical	gravels	Mixed Forest	Young Forest	Vertical	gravels	Coniferous Forest	Young Forest
Perseverance Creek	PRS-STC02	Sloping	fines	Mixed Forest	Young Forest	Sloping	fines | gravel	Mixed Forest	Young Forest
Perseverance Creek	PRS-STC03	Sloping	fines	Mixed Forest	Young Forest	Sloping	fines	Mixed Forest	Young Forest
Perseverance Creek	PRS-STC04	Sloping	fines	Mixed Forest	Young Forest	Sloping	bedrock	Deciduous Forest	Young Forest
Perseverance Creek	PRS-STC05	Vertical	gravels | bedrock	Mixed Forest	Young Forest	Vertical	bedrock	Mixed Forest	Young Forest
Perseverance Creek	PRS-STC06	Vertical	bedrock	Mixed Forest	Young Forest	Sloping	cobbles	Mixed Forest	Young Forest
Perseverance Creek	PRS-STC07	Vertical	bedrock	Mixed Forest	Young Forest	Vertical	bedrock	Mixed Forest	Young Forest
Perseverance Creek	PRS-STC08	Sloping	fines	Mixed Forest	Young Forest	Vertical	fines | bedrock	Mixed Forest	Young Forest
Tributary 1	PRS-STCT01	Vertical	fines	Mixed Forest	Young Forest	Vertical	fines	Mixed Forest	Initial
Tributary 2	PRS-STCT02	Sloping	fines	Coniferous Forest	Young Forest	Sloping	fines	Mixed Forest	Young Forest
Tributary 3	PRS-STCT03	Vertical	gravels	Mixed Forest	Pole-Sapling	Vertical	gravels	Mixed Forest	Pole-Sapling

4.1.2. Fish Presence

Fish were observed in pools throughout the entire assessed length of Perseverance Creek during field work. No fish were observed within the drainage tributaries between Allen Lake and Perseverance Creek, although it is expected that fish access the western tributary (PRS-STCT01) during high flows. Resident trout and stickleback were observed over the entire assessed length of Perseverance Creek. Coho fry were observed from Comox Lake up to the base of the 5 m tall falls part way up the canyon below Davis Lake Main bridge.

4.2. PFC

Assessments were conducted at six sites in the Project area on August 21-24, 2018 concurrent with fish habitat assessments (Section 3.2), and associated with fish habitat sites. Quantitative data collected for the fish habitat assessments were used to supplement and substantiate data collected specifically for the PFC.

The PFC of Perseverance Creek is generally characterized as 'functional at risk' with a downward trend towards 'not functional' (Table 9). Of the disciplines considered in the scoring, riparian habitat function scored the highest (85%), followed by the hydrology (59%) and geomorphology (55%) functions (Table 10).

Riparian habitat function scored high because: the riparian and floodplain habitat of Perseverance Creek is of sufficient extent and structure to withstand high flows; moisture availability is adequate to maintain high vegetation vigour and a diversity of riparian species; large woody debris contributions from the assessed reaches are intact; and, invasive species colonization appears stable.

The lower scores of the hydrology and geomorphology discipline are due to high flows that are out of balance with the landscape setting (e.g., channel characteristics different than expected in an intact system), as evidenced by excessive erosion and deposition. Examples of this include: aggradation of bedload materials (e.g., cobbles, gravels) in the channel; frequent breaching of the channel into the floodplain (evidenced by sediment deposition and formation of side channels); channel scour; large woody debris jams that span the channel; and, unstable, unvegetated and eroding streambanks. Primary factors suspected to be preventing achievement of proper functioning condition are: upstream water management/ water conveyance system, forest management activities in the watershed, and regulation of water levels in Comox Lake. These factors are contributing to frequent high storm flows beyond the capacity of the creek which exacerbate the impact of the low summer flows because the naturally low waters are flowing through aggraded bedload materials, only surfacing in occasional deep scour pools rather than maintaining a continuous surface flow though the stream's thalweg. In addition, climate change may be exacerbating high fall and winter flows, further degrading the channel morphology.

Table 9. PFC Determinations for Perseverance Creek.

PFC Site	Fish Habitat Site	PFC Determinations		Trend	Factors and Mechanisms Preventing PFC
		Altered PFC[1]	PFC[2]		
PRS-PFC01	PRS-STC01	Functional at Risk	Functional at Risk	Stable	Upstream water management contributing to high energy winter flows (leading to bank erosion and LWD and mineral substrate contributions to the stream) as well as low summer flows. Regulated Comox Lake water levels lending to dewatering of lower reaches of stream.
PRS-PFC02	PRS-STC02	Functional at Risk	Functional at Risk	Downward	
PRS-PFC03	PRS-STC03	Functional at Risk	Functional at Risk - Not Functional	Downward	Upstream water management contributing to high energy winter flows (leading to bank erosion and LWD and mineral substrate contributions to the stream) as well as low summer flows. Regulated Comox Lake water levels lending to dewatering of lower reaches of stream.
PRS-PFC04	PRS-STC04	Functional at Risk	Functional at Risk - Not Functional	Downward	
PRS-PFC05	PRS-STC05/ 06/ 07	Functional at Risk	Functional at Risk	Stable (with exception of section below canyon)	
PRS-PFC06	PRS-STC08	Functional at Risk	Functional at Risk - Not Functional	Downward	

[1] The PFC as it relates to the systems ecological capability under the current management regime

[2] The PFC as it relates to the Potential Natural Condition, or reference condition, in the absense of human management or inflicted change

Table 10. Condition of hydrology, vegetation/soil and geomorphology functions.

PFC Site	Fish Habitat Site	Discipline Descriptions					
		Hydrology		Vegetation and Soil		Geomorphology	
		Score (Y/N/NA)	Description	Score (Y/N/NA)	Description	Score (Y/N/NA)	Description
PRS-PFC01	PRS-STC01	5/2/1	Floodplain extensive and includes meandering side channels, back channels and tributaries; the vegetation community appears to be maintained by annual flooding; most water inputs are through ground and surface water from the adjacent lake. Infrequent channel blockages present.	7/1/0	Trees exhibit minor drought stress, otherwise vegetation exhibits high vigour. Large woody debris contributions (are intact and instream LWD includes old stumps and older large wood (10-47 cm dbh). The presence of exotic invasive species appear stable and include bars vegetated with reed canary grass, which may be excluding later successional species. Bare soil is limited to areas where there is 4x4 activity and footpaths. The water is low part of the year which exposes unvegetated banks but otherwise the floodplain is mostly well vegetated with riparian vegetation except for the banks around the coal sleggs.	4/0/0	Evidence of large sediment plumes during high waters that transport materials from upstream; minimal undercut banks however banks are continuously eroding; the lower reaches have eroded slopes associated with double track roads; alluvial deposits are present, some are vegetated and stabilized by reed canary grass and some are not; the channel is scoured to clay in some areas and there is some infill of small gravels as mentioned.
PRS-PFC02	PRS-STC02	4/3/1	Floodplain is wide with multiple low gradient and side and back channels that contain fresh deposits of gravels and fines. Riparian area occupies active floodplain and has reached its potential extent. Flow has been altered from water control structures upstream however the extent of which hydrological abnormalities can be attributed to water management is difficult to quantify. At time of sampling, surface flow was disconnected in the majority of the reach and experiencing sub-surface flow only. During the rainy season, flow would be connected.	7/1/0	Coniferous forest over 50 years old. Riparian vegetation in floodplain is prolific and diverse with moisture and richness loving species such as devils club, salmonberry, western redcedar and red alder present. Large and small instream wood slightly higher than expected in consideration of natural variation however it mostly originates from upstream reaches. Contributions within reach are in balance.	2/2/0	Moderate occurrence of channel blockages. Excessive deposition behind LWD jam that spans channel near Whyte's Bay trail crossing resulting in a shallow bankfull depth for ~100 m before pools and bar morphology return. Blockage contributing to more frequent flooding and channelization of floodplain (i.e., streambanks are not laterally or vertically stable), as well as deposition of substrates in floodplain. Floodplain effective in dissipating energy of high flows.

Table 10. Continued.

PFC Site	Fish Habitat Site	Hydrology Score (Y/N/NA)	Hydrology Description	Vegetation and Soil Score (Y/N/NA)	Vegetation and Soil Description	Geomorphology Score (Y/N/NA)	Geomorphology Description
PRS-PFC03	PRS-STC03	2/5/1	Some portions of the riparian area and stream banks in balance with setting below culvert under Comox Lake Road, however the majority of the area demonstrates high energy flows. Sediment has filled main channel leading to water topping the banks, pooling and depositing substrates into the forest. Parts of channel contain clay pools holding water. Flow mostly from upstream with some dewatering and ground water flow.	7/1/0	Vegetation is well established with a variety of species present, however some stretches in the lower floodplain and near wetlands are predominantly deciduous, likely due to past disturbance (e.g., washouts, flooding). Minimal presence of exotic species. Some mortality of conifers where water has flooded stream banks, otherwise vegetation displays good vigour. Minimal areas of bare, exposed or disturbed soil (<10%) with the exception of sediment deposition through riparian forest. Reach contains a good balance of older large (24-45 cm dbh) and small woody debris with some structural log jams.	2/2/0	Floodplain and channel characteristics seem adequate to disperse energy except for erosion downstream of culvert. Several log jams within reach causing sediment aggradation and channel de-watering. River right bank downstream of culvert is unstable, experiencing erosion and losing trees into creek. Numerous mid-channel bars present. Some span full channel. Scour pools present. Evidence of scouring in secondary channels at high flows. Small and large gravels.
PRS-PFC04	PRS-STC04	4/3/1	Stream subject to annual flooding events. Side channels present throughout floodplain. Significant aggradation behind log jams has also created gradient changes in stream bed. Discontinuous surface flow.	7/1/0	Riparian vegetation is mostly healthy, structurally diverse and species rich, with the exception of the wetland which is deficient in conifers. Some invasive species are present such as reed canarygrass and thistle but populations appear stable or decreasing. High amounts of LWD present including older and larger (up to 75 cm dbh) pieces are creating extensive blockages.	1/3/0	Large woody debris, the active floodplain and riparian vegetation are acting to dissipate energy. Streambanks are steep and sometimes undercut but mostly stable except in some localized areas and stream bed has been scoured to clay in places.

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Table 10. Continued.

PFC Site	Fish Habitat Site	Discipline Descriptions					
		Hydrology		Vegetation and Soil		Geomorphology	
		Score (Y/N/ NA)	Description	Score (Y/N/ NA)	Description	Score (Y/N/ NA)	Description
PRS-PFC05	PRS-STC05/ 06/ 07	5/1/2	Flood plain habitat decreases with an increase in gradient, steep banks and bedrock now prevalent as stream becomes more canyonized. Evidence of high energy storm flows still provided by large mobile substrates (cobble and boulders) and areas scoured to bedrock. Small tributaries present in lower reaches.	7/1/0	Riparian vegetation consistently healthy throughout reach despite drought conditions in the region. Conifers, shrubs and moss are the dominant vegetation. Floodplain mostly absent as much of section is canyonized. Stream banks mainly clay throughout downstream reaches, turning to shale and gravel in upstream reaches. Abundance of small woody debris in addition of LWD throughout (avg 35 cm diameter, various age/ decay classes). No invasive or exotic species observed. Slight trail erosion into stream.	2/1/1	Streambed largely bedrock throughout upstream portion of reach, helping to maintain stream morphology. Larger mobile substrates sourced from upstream present in lower reaches due to higher gradient and more concentrated flows. Localized bank erosion where finer substrates present and at base of canyon section.
PRS-PFC06	PRS-STC08	4/3/1	Reach experiences annual flooding, evidenced by debris and sediment deposition. Channel and flow should be more confined and narrower given the gradient. Sinuosity and gradient largely appropriate. Riparian habitat maintained on outer extent however control structures are altering flooding regime. Parts of channel experiencing aggradation. Stickleback observed in scour pools. Three tributaries inflow from Alan Lake, the first with triple culverts experiences high flows that top the culverts and flow over the road.	6/2/0	Reach contains lots of mature alder that is being replaced by conifer recruitment. Mineral and organic debris dispersed throughout floodplain. Riparian vegetation generally healthy. A road follows section of creek. Sections of bank beside road eroding.	1/2/1	At top of reach gradient increases to 6%, the channel narrows, banks steepen, and the forest has been logged to the banks. Lower gradient sections of channel aggraded with cobbles, few scour pools present. Absence of LWD, stream recruiting boulders and cobbles from banks.

5. RECOMMENDATIONS AND CLOSURE

The dominant factors contributing to the downward trending condition of Perseverance Creek occur beyond the assessment area (e.g., water management, forest management). However, some of the mechanisms contributing to the degradation of the function of the creek (e.g., high flows), and the associated effects (e.g., erosion), can be mediated in the assessed reaches. Restoration and management recommendations are provided by PFC assessment area (Table 11). Many of these recommendations are paired with recommended future studies to help fill information gaps. In addition, recommendations to improve the hydrologic function of the Perseverance Creek watershed have been made in previous reports and are, in part, integrated in the below recommendations (e.g., Aqua-Tex 2016, Jenssen and Gower 2016, Tetratech 2015, Ellefson 2003).

Overall, the most significant mechanism contributing to the degradation of the function of Perseverance Creek is high storm flows. Where possible, these should be in part mediated through management of the water conveyance system (Jenssen and Gower 2016, Koers 2016, Aqua-Tex 2016, Tetratech 2015), appropriate storm water management, and timber retention (including riparian buffers). High flows can also be mediated through creation of wetlands that capture, store and slowly release water. Some suitable locations for wetland creation may exist in the western tributary/ Allen Lake overflow, just upstream of the Davis Lake Main bridge, and in the lower floodplain reaches.

High flows are contributing to extensive bank erosion. Banks can be armored with boulders, LWD, and planted with vegetation, among other treatments, to reduce the rate of erosion. However, armoring of banks requires careful site planning and consideration of alternate energy pathways and potential downstream impacts. Also, as erosion is occurring in many areas, any bank stabilization should be prioritized in consideration of the watershed as a whole. Undersized culverts can be replaced with appropriately sized (e.g., to accommodate up to 100-year sized floods) and styled culverts (e.g., open bottom culverts or clear-span bridges) to reduce erosion, as well as facilitate fish passage.

Other recommendations from previous investigations include: reducing the number of trails around Perseverance Creek that may increase erosion potential (Aqua-Tex 2016), as well as restoring natural drainage patterns, ensuring culverts are large enough, and maintaining riparian buffers intact (Barraclough 2017, pers. comm.). Previous reports also provide management recommendations to improve the function and resilience of the overall watershed (Jenssen and Gower 2016).

Overall, fish habitat is primarily limited by channel aggradation and low flows. Creation of groundwater fed back channels that stay cool throughout the summer and do not fill with migrating channel substrates could provide refuge for fish during high and low flows. Suitable locations for backchannels are expected to include the floodplain adjacent to Comox Lake and potentially the floodplains above and below the canyon sections. High temperatures in Comox Lake limit suitable habitat in the lowest reach during the warm summer months. Planting native vegetation on the coal slags would be a relatively straightforward method to simultaneously reduce erosion and decrease the temperature of backwatered lake water where Perserverance Creek joins the lake.

Future studies that should be conducted to help guide the restoration and management of Perseverance Creek include:

- Studying the relationship between flows in Perseverance Creek and the water conveyance system, and calculation of an appropriate target instream flow for the morphology of the system;
- Determination of the source of erosion materials and the rate of migration to understand if bank stabilization efforts should be applied to a specific area (e.g., large eroding slope adjacent to the 'bear buns' trail upstream of assessment area) and if it is worthwhile to remove some of the aggraded substrates in the channel or if it would continue to infill rapidly;
- Understanding the locations with good groundwater percolation and poorly drained soils that would provide good backchannel habitat for fish during low and high flows;
- Investigating potential areas for wetland creation for stormwater retention; and,
- Studying the potential value of the Cumberland wetlands for water attenuation and providing off-channel habitat.

Furthermore, due to the uncertainty surrounding fish species presence and distribution, in particular the species of trout and the upper limit of distribution in the system, we recommend that a conventional fish sampling or eDNA sampling is conducted in Perseverance Creek.

Our recommended next step is to prepare a conceptual restoration plan for the watershed with a tiered action approach that includes actions that can be completed in the near future, actions that require further study before implementation, and future goals that depend on the management of the greater system. Furthermore, near future actions should be accompanied by clear goals that are tied to measurable objectives and consideration of effectiveness monitoring techniques to ensure objectives are met.

Table 11. Management and restoration options to improve the fish habitat value and PFC of Perseverance Creek and opportunity for future study.

PFC Site	Fish Habitat Site	Management/ Restoration Options	Future Studies
PRS-PFC01	PRS-STC01	Plant/ stake coal sleggs to stabilize and to increase cooling shade; restrict unsurfaced road access to stream; deepen groundwater fed backchannels to provide cool water refuge for fish.	Monitor reed canarygrass and tree recruitment; monitor groundwater influence.
PRS-PFC02	PRS-STC02	Deepen groundwater fed backchannels to provide cool water refuge.	Monitor groundwater influence prior to creating backchannel habitat, understand drying patterns for strategic placement of backchannels.
PRS-PFC03	PRS-STC03	Excavate gravel wedges behind log jams (> 1 vertical meter of substrate), if restoration is paired with management of substrate inputs (i.e., stabilized banks and moderated flows) and re-establishment of channel (e.g., LWD redistribution). Potential for groundwater fed back channel and deep pool construction on hardpan clay.	Investigate source and characteristics of substrate migration to understand value of clearing channel.
PRS-PFC04	PRS-STC04	Restore stream channel, groundwater hydrology and option to connect with wetlands once more shade is present and improved water quality conditions have been achieved. Plant coniferous trees where sparse in wetland environment to improve maintenance of cool water temperatures during summer. Improve year-round connection between wetland and main channel if water quality in wetlands is suitable. Other improvements to wetlands may be beneficial such as excavating deep pools that provide refuge for fish and that are too deep to be populated by reed canary grass. Note that a beaver baffle may be required to maintain connection. Disperse LWD, stabilize upstream erosion and control flooding.	Assess and monitor water quality in the wetlands to determine suitability for fish habitat and risks in connecting to Perseverance Creek.
PRS-PFC05	PRS-STC05/ 06/ 07	Stabilize banks with bioengineering and local larger cobble/ boulders. Moderate flows to this section with retention wetland creation in flat areas upstream. Clear out channel if substrate inputs can be moderated. Note that there is poor access for machinery to this section. Allow for the continued forest succession in watershed. Decommission ditches and roads, repair eroding areas and moderate flows with existing dams.	Study where substrates that are aggradating in channel are originating and how to moderate flows. Examine upland forest hydrology impacts on stream function; groundwater hydrology; upstream water retention opportunities; track sediment sources.
PRS-PFC06	PRS-STC08	Moderate flows with wetland creation upstream in Perseverance Creek and on tributary from Allan Lake overflow upstream of triple culvert.	Track source and movement of substrates.

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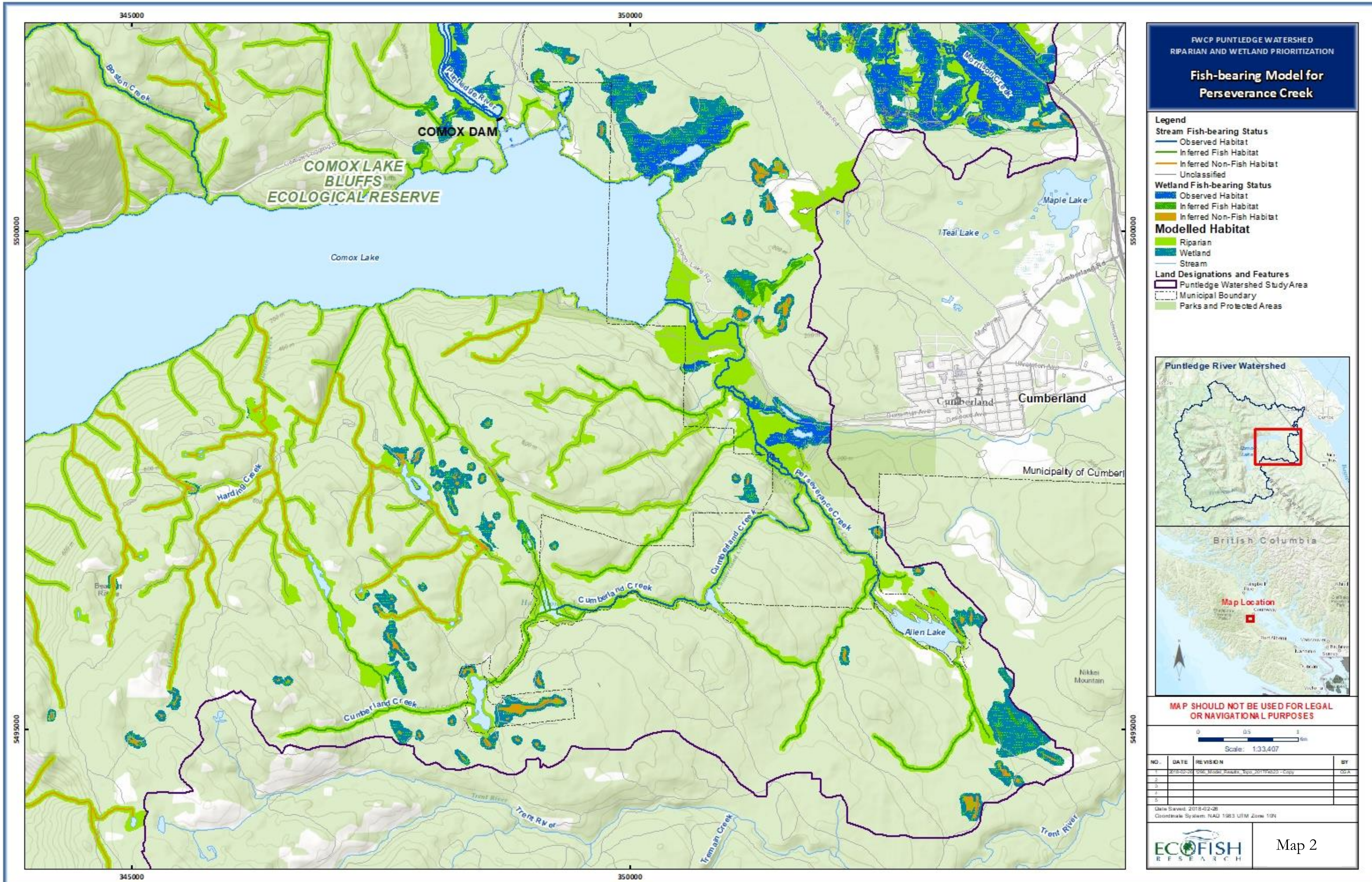
PROJECT MAPS



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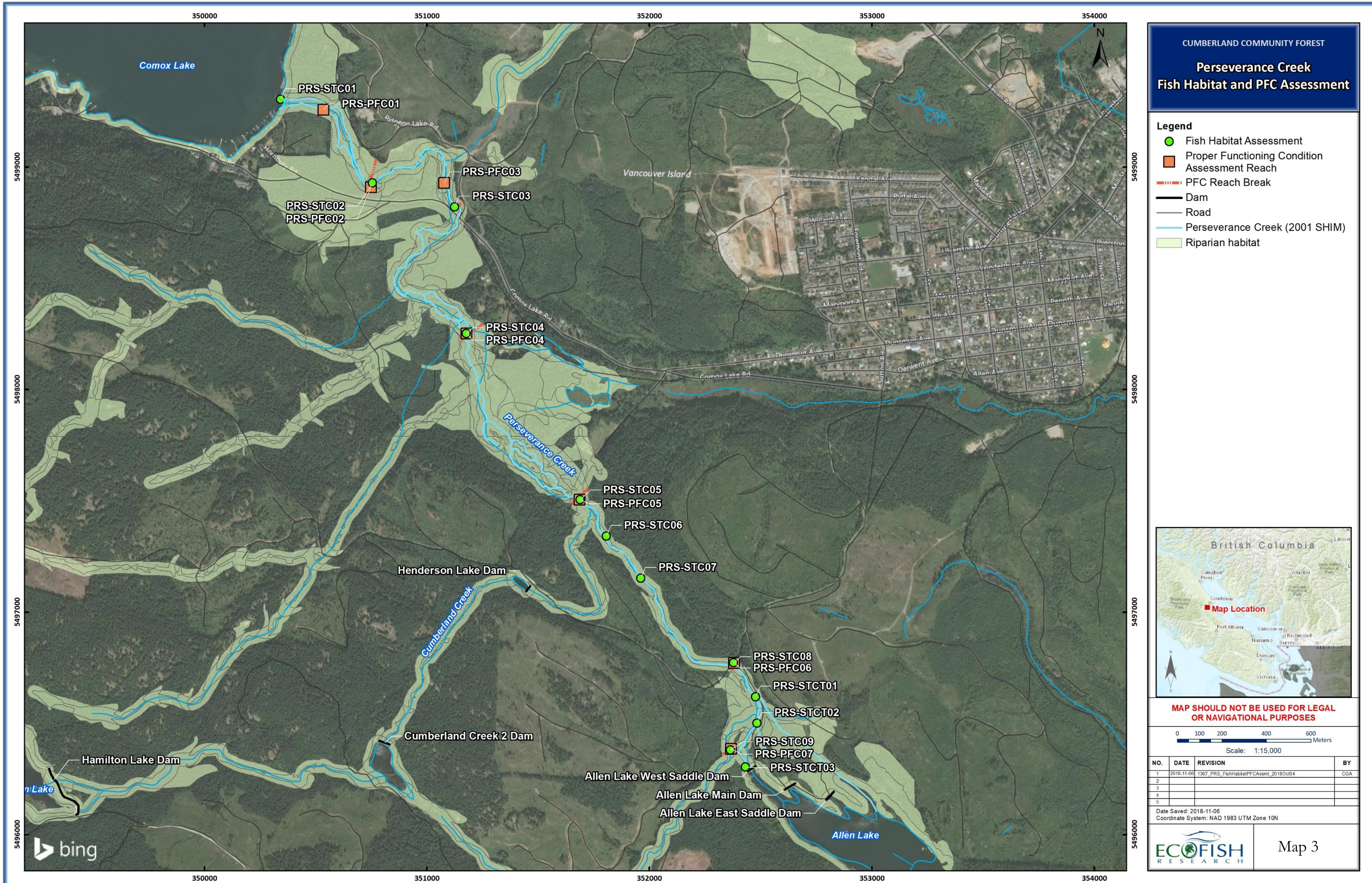

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APPENDICES

Appendix A. LiDAR imagery provided by ASAP

LIST OF FIGURES

CUMBERLAND COMMUNITY FOREST SOCIETY

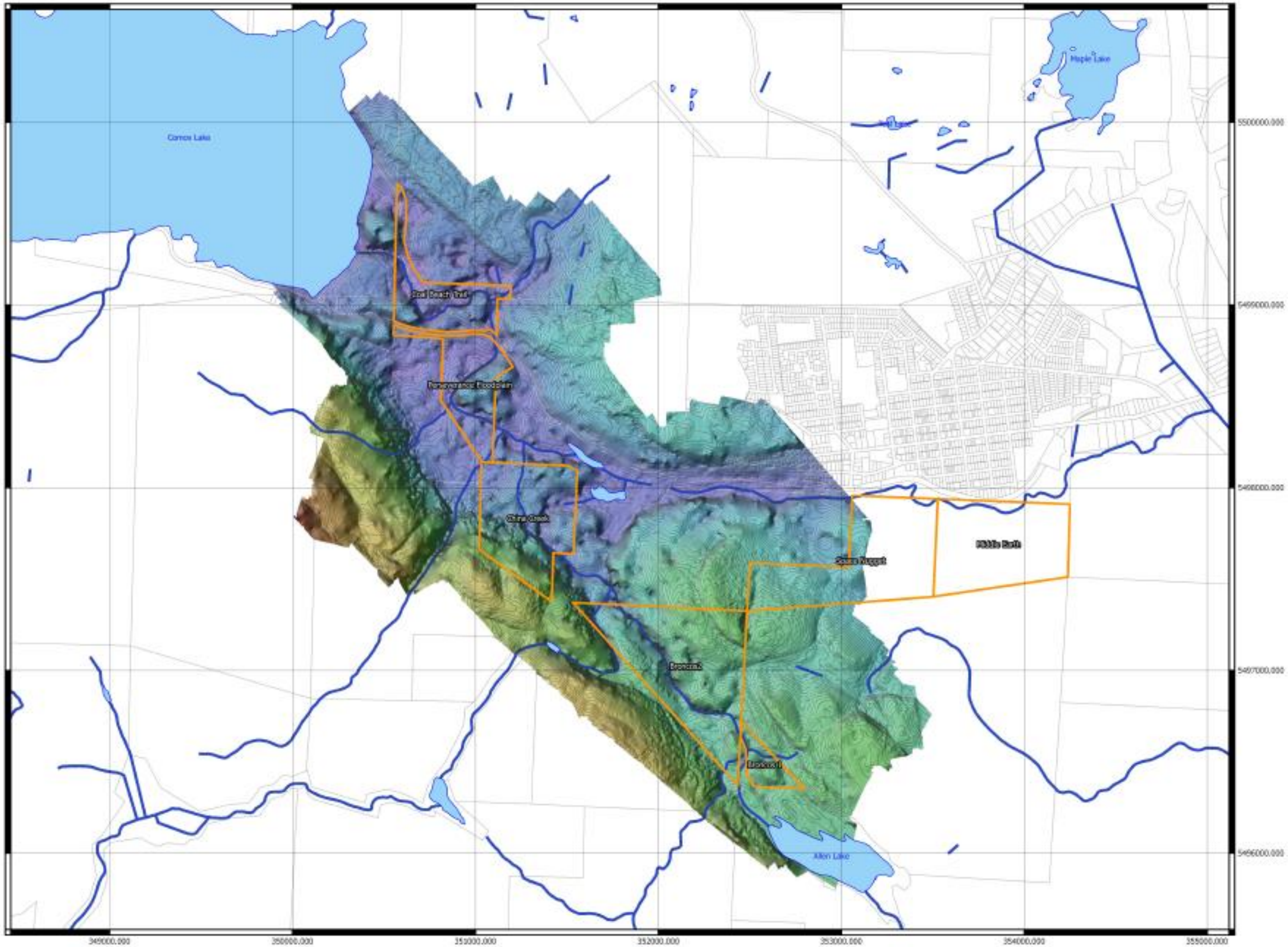
Cumberland Community Forest
DTM (Digital Terrain Map)

Legend

- FWA_BC FWA_LAKES_POLY
- FWA_BC FWA_ROUTES_SP
- FWA_BC FWA_WETLANDS_POLY
- Cumberland Community Forest Boundaries
- 1m Contours

18032_DTM_epsg26910

- 127m
- 166m
- 199m
- 263m
- 323m
- 371m
- 437m



500 0 500 1000 1500 2000 m

True North

Latitude: 49° 42' 27" North (49.7077° North)
Longitude: 125° 6' 15" West (125.1044° West)
Date: 2018-06-23

Magnetic declination: 16° 35.40' East

Annual Change (minutes/year): 9.8 '/y West

Grid Declination: 18° 11.70' East

Convergence Angle: 1° 36.30' West

Map Datum: NAD83 UTM Zone 10 (EPSG:26910)

Data collection date:23/JUN/2018
Data Collection Time: 17:55 - 18:36 UTC

Scale: 1:15,000

ASAP GEOMATIX

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1-250-923-8878

CUMBERLAND COMMUNITY FOREST SOCIETY

Cumberland Community Forest
Orthophoto Map

Legend

- FWA_BC FWA_LAKES_POLY
- FWA_BC FWA_ROUTES_SP
- FWA_BC FWA_WETLANDS_POLY
- Cumberland Community Forest Boundaries

18032_ortho_9cm_epsg26910

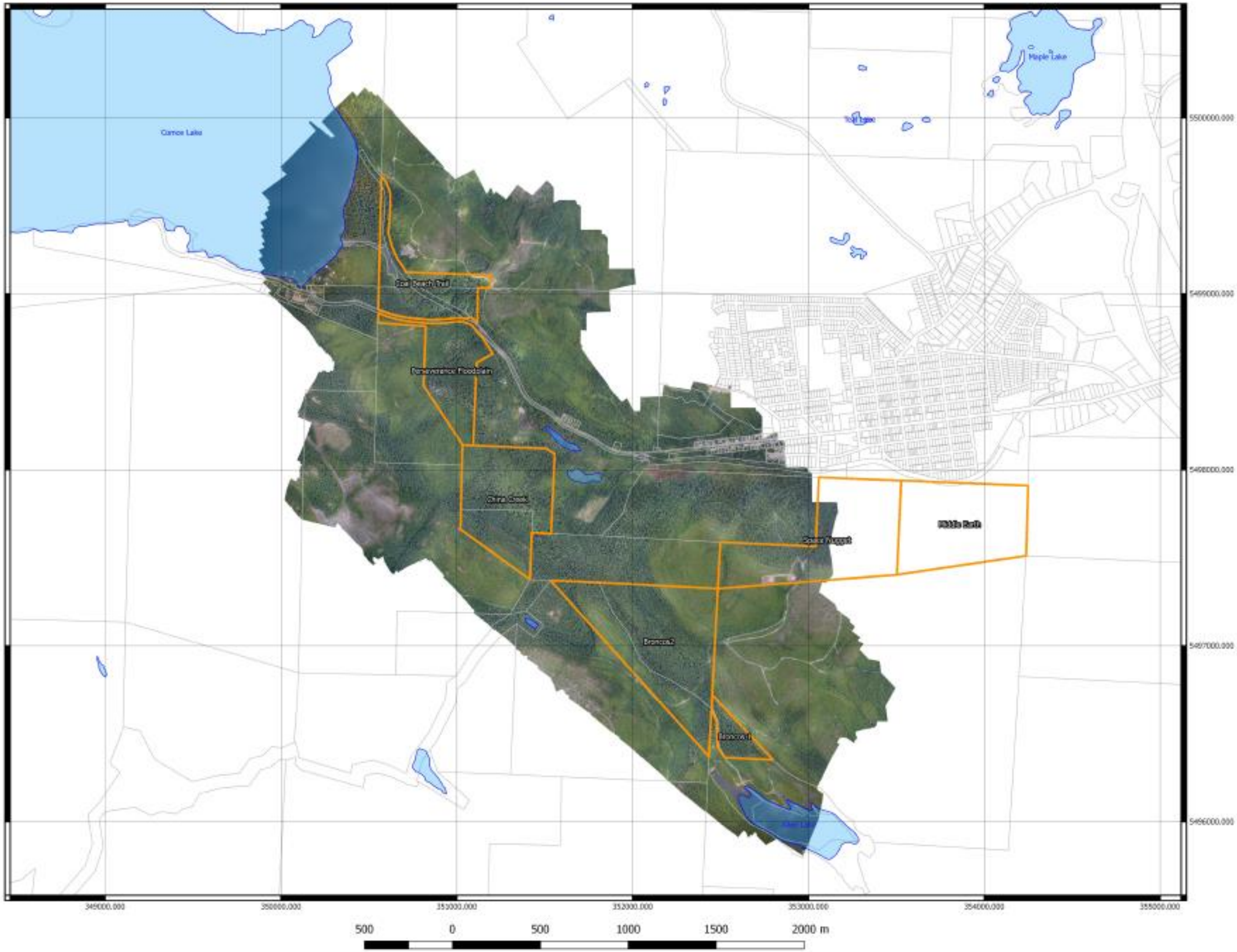

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Figure 3. Screenshot of tree mapping, colour coded by height (dark = tall, light = short) provided by ASAP.

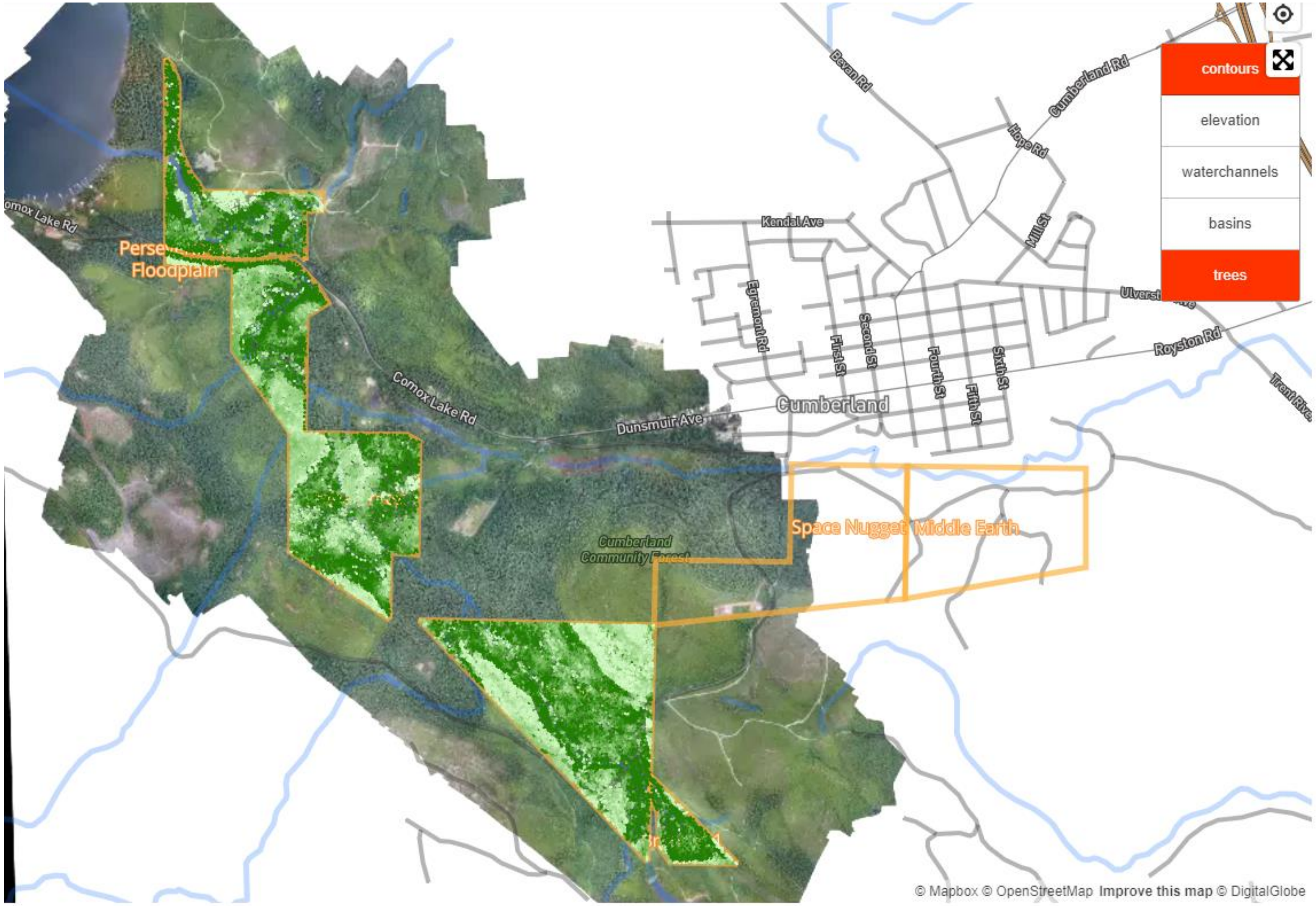
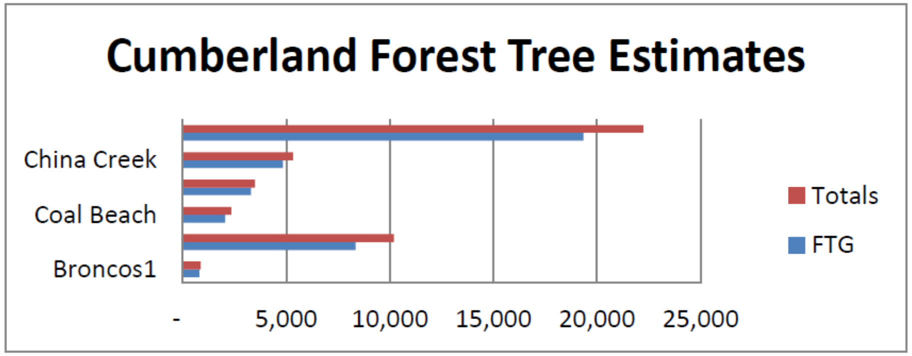
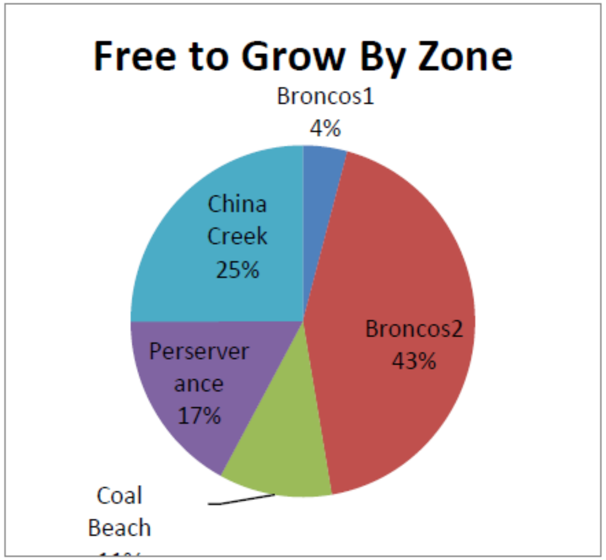


Figure 4. Tree analysis provided by ASAP

Cumberland Community Forest Report

Zone	FTG	Totals	Percentage FTG	Area (sq/km)	Acres	Ha
Broncos1	807	871	93%	0.053743	13.28016	5.3743
Broncos2	8,350	10,198	82%	0.455171	112.475	45.5171
Coal Beach	2,056	2,358	87%	0.181719	44.90367	18.1719
Perserverance	3,298	3,494	94%	0.180325	44.55921	18.0325
China Creek	4,844	5,327	91%	0.303134	74.90593	30.3134
Total	**19,355**	**22,248**	**87%**	**1.17**	**290.12**	**117.41**





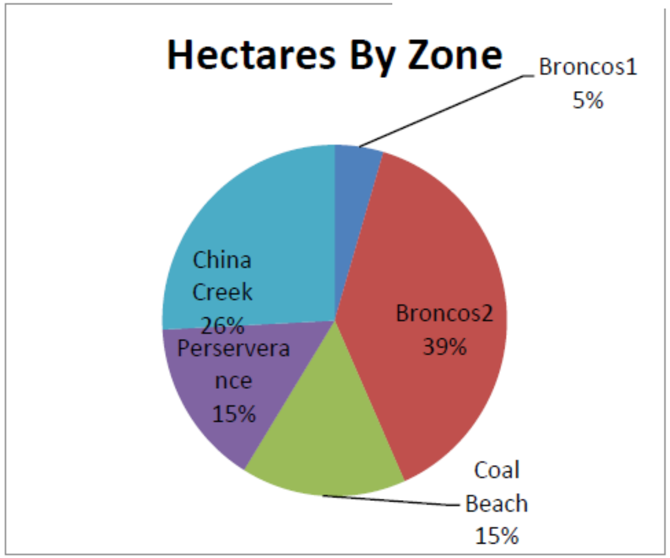


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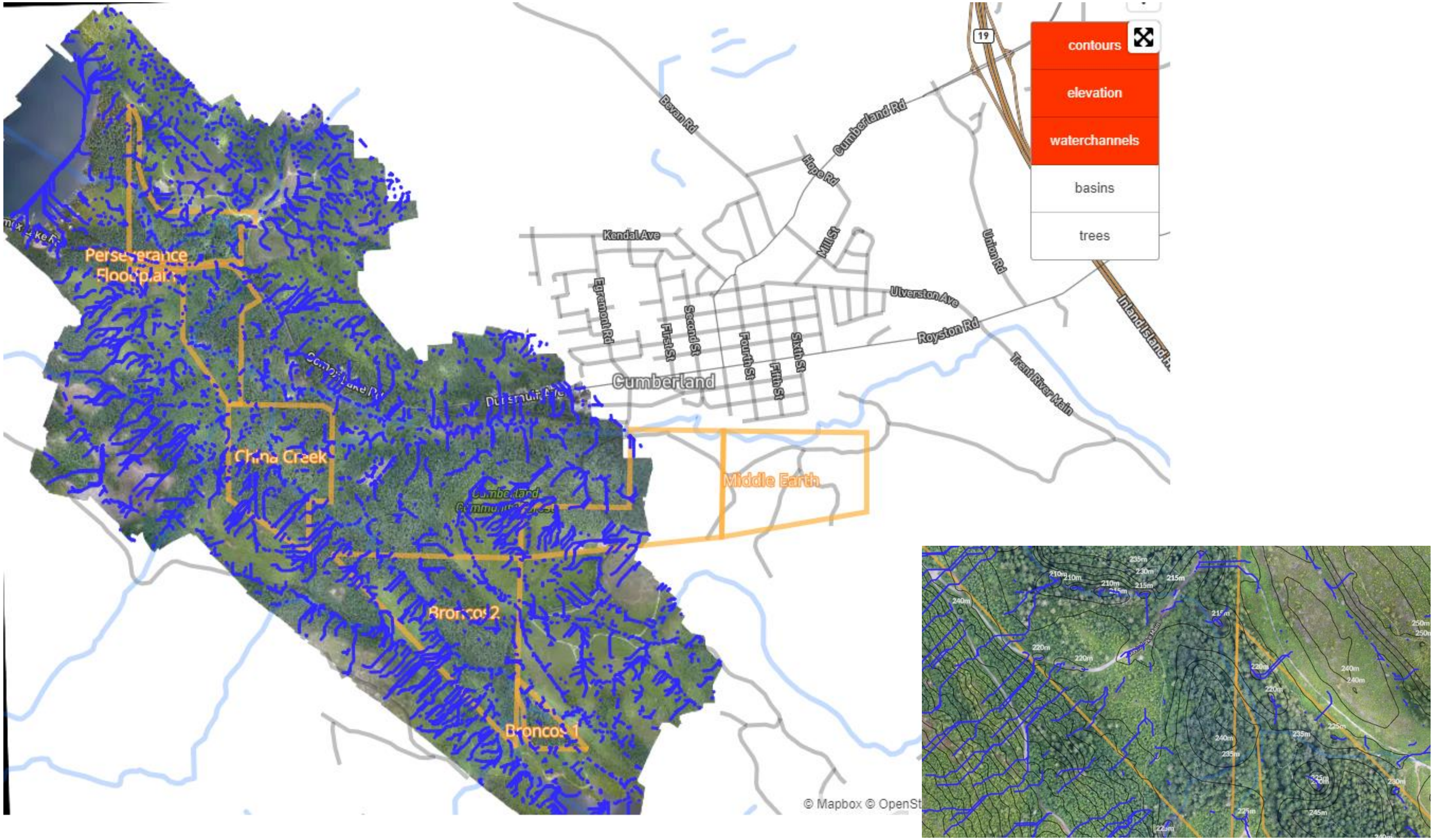
Figure 5. Screenshot of ASAP viewing tool with drainages delineated.



Appendix B. Fish Habitat and PFC Assessment Site Photos

LIST OF FIGURES

1. SITE CARD PRS-STC01 AND PFC PRS-PFC01

Figure 1. Start point at lake influenced reach of stream with warm water (19ºC), August 21, 2018.

Figure 2. Dead salmonid smolt, August 21, 2018.

Figure 3. ATV access and eroding banks, August 21, 2018.

Figure 4. Eroding banks on old coal slag piles, August 21, 2018.

Figure 5. Cooler pools with shade, flow, and cover at top extent of reach (Coho observed), August 21, 2018.

Figure 6. Isolated pool in back channel (possibly enhanced), August 21, 2018.

Figure 7. Log jam with sediment wedge behind it, August 21, 2018.

2. SITE CARD PRS-STC02 AND PRS-PFC02

Figure 8. Overhanging vegetation and deep pool, August 21, 2018.

Figure 9. Channel substrate; spawning gravels, August 21, 2018.

Figure 10. Back channel with overhanging vegetation and isolated pools, August 21, 2018.

Figure 11. Log jam barrier, August 21, 2018.

3. SITE CARD PRS-STC03 AND PFC PRS-PFC03

Figure 12. Culvert under Comox Lake Road, August 22, 2018.

Figure 13. Several pools exist below large woody debris (LWD) jams with substrate aggradation above, August 22, 2018.

Figure 14. Undercut banks and overhanging vegetation, August 22, 2018

Figure 15. Eroding bank visible from Comox Lake Road, August 22, 2018.

Figure 16. Mostly dewatered section of reach (subsurface flow present), August 22, 2018.

Figure 17. Fish presence; fry, August 22, 2018.

4. SITE CARD PRS-STC04 AND PFC PRS-PFC04

Figure 18. Wetland beside creek with little shade and no low flow connectivity to Perseverance Creek, August 22, 2018.

Figure 19. Good fish habitat in pools; LWD and overhanging vegetation; fish presence confirmed in lower section, August 22, 2018.

Figure 20. LWD jam; August 22, 2018.

Figure 21. Buried staff gauge (installed ~ 2001) behind log jam demonstrates recent aggradation, August 22, 2018.

Figure 22. Upper section includes more log jams, aggradation, and forest deposition; to Hai Gai bridge, August 22, 2018.

Figure 23. Eroding bank; August 22, 2018.

5. SITE CARD PRS-STC05 AND PFC PRS-PFC05

Figure 24. Deep pool with Coho observed below chute, August 23, 2018.

Figure 25. Excess bedload aggradation, including large substrates; dry with few pools, August 23, 2018.

Figure 26. Excess bedload aggradation, August 23, 2018.

6. SITE CARD PRS STC06 AND PFC05

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Figure 28. Bedrock pools with Coho fry and trout observed, August 23, 2018.

Figure 29. LWD jam, boulders and constricted channel, August 23, 2018.

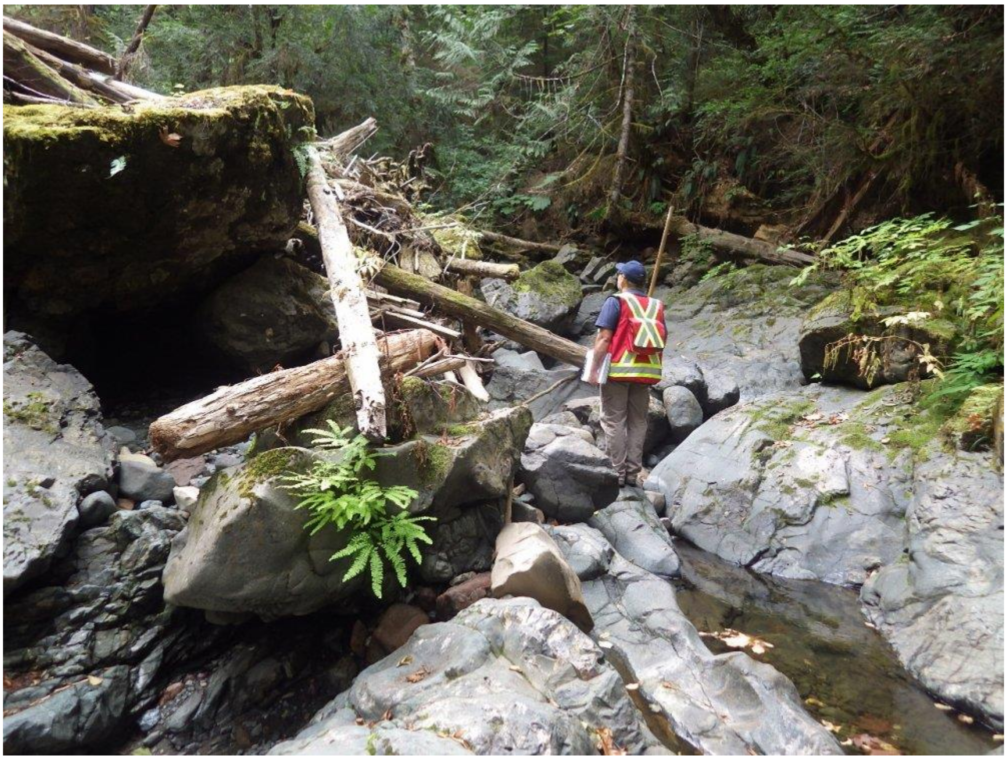

Figure 30. LWD jam supporting substrate aggradation, August 23, 2018.

Figure 31. Mink fishing in pools, August 23, 2018.

Figure 32. Pools in bedrock canyon, August 23, 2018.

Figure 33. Eroding banks, August 23, 2018.

Figure 34. Riparian vegetation covering canyon wall, August 23, 2018.

7. SITE CARD PRS-STC07, PFC PRS-PFC05

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Figure 36. Residual pools, August 23, 2018.

Figure 37. Eroding bank (3m high x 20m wide), August 23, 2018.

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Figure 40. Scour pools above falls with trout observed, August 23, 2018.

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Figure 42. Davis Creek Main bridge, August 23, 2018.

8. SITE CARD PRS-STC08 AND PFC PRS-PFC06

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Figure 44. Isolated pools with trout fry, August 24, 2018.

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Figure 50. Channel filled; bedload extends into forest, August 24, 2018.

Figure 51. Eroding bank; clear-cut close to stream bank, August 24, 2018.

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9. SITE CARD PRS-STCT01 – EASTERN TRIBUTARY

Figure 53. Allen Lake west tributary outlet beneath access road, August 24, 2018.

Figure 54. Thick riparian canopy, August 24, 2018.

Figure 55. Sediment through forest, August 24, 2018.

Figure 56. Log jam, August 24, 2018.

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Figure 58. Allen Lake overflow beneath access road, on August 24, 2018.

10. SITE CARD PRS-STCT02 – MIDDLE TRIBUTARY

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11. SITE CARD PRS-STCT03 – WESTERN TRIBUTARY

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Figure 61. Pole-sapling riparian stage at East Tributary, August 24, 2018.