Overview & Level 1 Fish Habitat Assessment and Level 2 Enhancement Recommendations

Woods Creek, Campbell River, BC

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Executive Summary

This document contains a combined Overview and Level 1 Assessment Report for the Woods Creek (WC: 920-609500) watershed including mainstem Woods Creek, North and South Forks, and four tributary channels (Figure 1). The Woods Creek watershed drains a total area of approximately 531 ha (Figure 1). The Woods Creek mainstem ("North Fork") flows for approximately 5.2 km in a roughly easterly direction before draining into the Strait of Georgia. The Woods Creek tributary ("South Fork") has a length of 2.5 km that has its confluence with Woods Creek approximately 1.4 km upstream of the creek mouth near Hwy 19A.

Study objectives include:

a. assessing the status of historical enhancement project components and making recommendations for their repair, maintenance, or decommissioning;
b. identifying limitations to fish productivity on a reach-by-reach basis; and
c. providing recommendations for new enhancement/restoration projects based on ground-level assessment results.

The Overview assessment provides background information on geological and hydrological characteristics, and land-use regime changes within the watershed. The Level 1 Assessment compares the quantitative values of critical habitat conditions for salmonids within each reach and characterizes the quality of the feature as poor, fair, or good. The Level 1 Fish Habitat Assessment is based on methods adapted from Fish Habitat Assessment Procedures (FHAP) (Johnston & Slaney 1996) and Urban Salmon Habitat Program (USHP) Assessment Procedures (Michalski, Reid, & Stewart 1997).

Level 2 Enhancement/restoration recommendations (Section 6) are detailed by reach and chainage that include the proposed removal of potential barriers to fish migration, restoration of reaches affected by rural development and forest harvesting practices, and upgrading/replacement of weirs previously constructed in 1999-2000.

The results of the Level 1 Assessment include a presence/absence fisheries assessment, and detailed reach descriptions that include the results of the habitat assessment and recommended enhancements for each of seven reaches where relevant.

The results of the Level 1 Assessment, undertaken Nov. 2019 – Feb. 2020 showed three of the assessed reaches received a *Fair* rating and six received a *Poor* overall rating. Overall, the primary limiting factors to productivity in the Woods Creek watershed are the lack of summertime base flows and prevalence of fine sandy alluvium. Habitat parameters commonly missing across all assessed reaches include lack of off-channel habitat, low % boulder cover, low % spawning gravel, high % fine substrates, low % pool areas, and impacts to riparian vegetation related to clearing on private property and forest harvesting practices.

Beaver activity is common throughout the watershed but appears to be concentred in Reach 5, 7 and Trib. 3. The presence of beaver dams has effectively enhanced water retention within extensive wetland type habitats that will help to reduce the negative impacts of seasonal drying by extending the hydroperiod in reaches that might otherwise dry in the absence of dams. Conversely, beaver dams have also created a series of partial barriers to fish migration where juvenile salmon are unlikely to move upstream under certain flow conditions, and in some circumstances spawning habitat has been impaired where constructed weirs have been completely enclosed or backwatering from dams and have detained fine sediments that have occluded spawning grade gravels.

Recommendations for restoration projects for Woods Creek are based on potentially limiting factors to fish production derived from the Level 1 Assessment. Habitats that includes suitable spawning gravel are concentrated in Reaches 2 & 3 upstream of Highway 19A and in Reach 6 in the upper North Fork of Woods Creek. These reaches are ideal candidates for spawning habitat enhancement projects as they are proven to show natural recruitment of coarse materials, whereas lower gradient reaches are commonly dominated by fine sediment that have impaired weir function in some historically enhanced reaches.

Restoration recommendations also include the construction of 19 rock weir/riffles with integrated spawning gravel platforms and upstream pools that will contain at least 16 scour inducing LWD complexes. These measures are included within the inventory of recommended maintenance/enhancement works for existing weirs (Section 5.3) and other habitat features that have been historically implemented in the Woods Creek watershed (Section 2.4). Based on existing bio-standards these habitat enhancements will give rise to an overall estimated increase of 963 coho and 287 cutthroat smolts annually.

Contents

1 Introduction

The Campbell River Salmon Foundation (CRSF) contracted Current Environmental Ltd. (CEL) to carry out a Level 1 /2 Fish Habitat Assessment (the Assessment) including recommendations towards salmon habitat enhancement within the Woods Creek watershed (WC: 920-609500). Physical overview information covering the study area is provided in Section 2 while Fisheries Information is in Section 3. This Assessment is based on methods described in *Fish Habitat Assessment Procedures* (FHAP) (Johnston & Slaney 1996) and *Urban Salmon Habitat Program (USHP) Assessment Procedures* (Michalski, Reid, & Stewart 1997) and was executed according to *Methods* detailed in Section 4.

This document contains a combined Overview/Level 1 Assessment Report (Section 5) for the stream channels within the Woods Creek watershed as well as *Level 2 Habitat Enhancement Recommendation*s (Section 6) covering an area of 531 ha (Figure 1).

The objectives of the overview assessment include providing background information on geological and hydrological characteristics, and land-use regime changes while the *Past Enhancement Projects* heading is intended to describe historical approaches taken to address limitations to fish productivity. These sections of the overview assessment are organized under the *Description of Study Area* heading (Section 2), whereas *Fisheries Information* such as life history and distribution information based on known fish presence is compiled in Section 3.

The *Results* of the Level 1 Assessment are provided in Section 5 and include a presence/absence *Fisheries Assessment* (Section 5.1), and detailed *Reach Descriptions* (Section 5.2) that include the results of the *Habitat Assessment* for each of nine reaches and four tributary channels. For ease of reference, a watershed-wide condition assessment of existing weirs is summarized in Section 5.3.

Level 2 Enhancement/restoration recommendations (Section 6) are detailed by reach and chainage that include the proposed removal of potential barriers to fish migration, restoration of reaches affected by rural development and forest harvesting practices, and upgrading/replacement of weirs previously constructed in 1999-2000. The Appendix contains the raw quantitative data for each reach presented in USHP spreadsheet format.

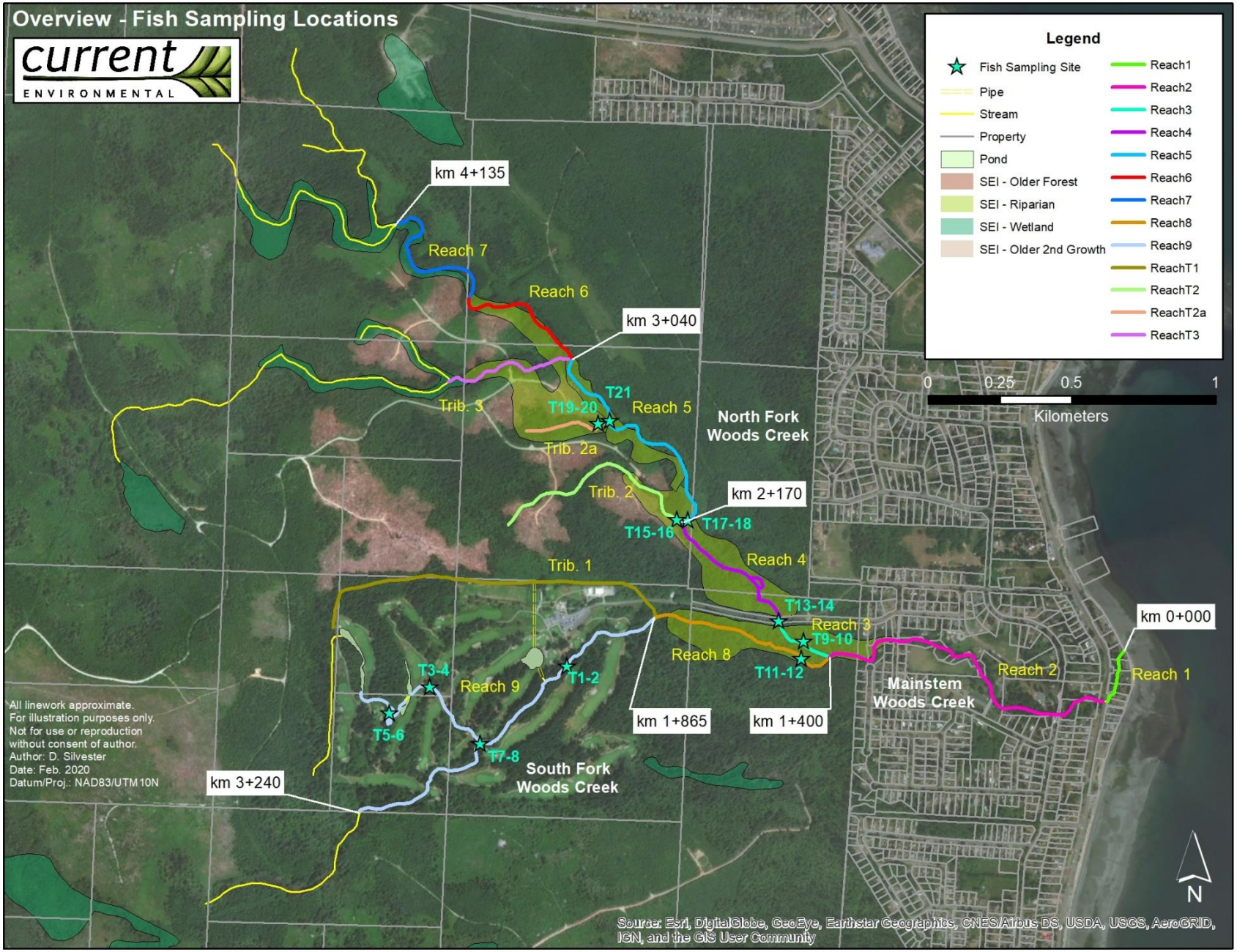


Figure 1. Assessment area overview showing reaches, chainages, and fish trapping sites.

1.1 Scope and limitations

2. The assessment area is watershed wide, covering mainstem Woods Creek, North and South Forks, and four tributary channels (Figure 1). The upstream ends of the assessment area were established where extensive wetlands were encountered during field work. Nine assessment reaches and four tributaries have been identified based on their morphological differences and/or man-made reach breaks (e.g. culvert road crossings).The overall assessment area's downstream Point of Commencement originates at the upper extent of tidal influence (km 0+000).

3. The primary objectives of this assessment include:

    a. assessing the status of historical enhancement project components and making recommendations for their repair, maintenance, or decommissioning;
    b. identifying limitations to fish productivity on a reach-by-reach basis; and
    c. providing recommendations for new enhancement/restoration projects based on ground-level assessment results.

4. The methods used in the collection and treatment of habitat assessment data were adapted from the *Fish Habitat Assessment Procedures* (FHAP) (Johnston & Slaney 1996) and *Urban Salmon Habitat Program (USHP) Assessment Procedures* (Michalski, Reid, & Stewart 1997). A summarized account of the assessment procedures is in *Methods* (Section 4).

5. The assessment of instream features was timed to coincide with periods of moderate flow to help highlight habitat function (Oct. 2019 - Feb. 2020). The system is known to both contain reaches that dry seasonally and be exposed to periods of high peak flows; neither of which are ideally suited to understating how historical enhancement projects are functioning.

6. Furthermore, the Fisheries Assessment was limited to a presence/absence survey at a selection of reach breaks using baited minnow traps (Section 5.1; Figure 1). The Fisheries Assessment was timed to coincide with a period of moderate flow, prior to smolt out-migration in order to reflect a one-time grab sample of coho distribution in the watershed.

2 Overview - Description of Study Area

The Woods Creek watershed drains a total area of approximately 531 ha (Figure 1). The Woods Creek mainstem (“North Fork”) flows for approximately 5.2 km in a roughly easterly direction before draining into the Strait of Georgia. The Woods Creek tributary ("South Fork") has a length of 2.5 km that has its confluence with Woods Creek approximately 1.4 km upstream of the creek mouth near Hwy 19A. Chainages recorded in this report begin at the interface of the marine shoreline with the mainstem Woods Creek east Hwy 19A at km 0+000 (Figure 1).

2.1 Geology

According to a survey completed by Jungen (1985), in Ministry of Environment Technical Report 17, the most common soil taxonomy for the Woods Creek watershed is from the Bowser Soil Association of "gleyed humo-ferric podzol". This soil class is considered imperfectly draining, containing distinct mottling that indicates gleying within 1 m of the surface, and sandy loam medium-moderately coarse textured parent material. The surficial geology of the Woods Creek watershed is shown in Figures 2a, 2b, & 2c and is further described by Jungen et al. (1989) where it is stated that:

> “Bowser soils have developed on gently undulating landscapes below 130 m elevation. The parent materials are sandy fluvial or marine veneers underlain by silty marine deposits. Bowser soils are imperfectly to moderately poorly drained and have seasonally perched watertables."

Jungen et al. (1989) goes on to describe the soil classification as supporting a productive forest and its suitability for agricultural purposes but notes that because of its high-water table during the winter and spring seasons that urban and related uses are constrained.

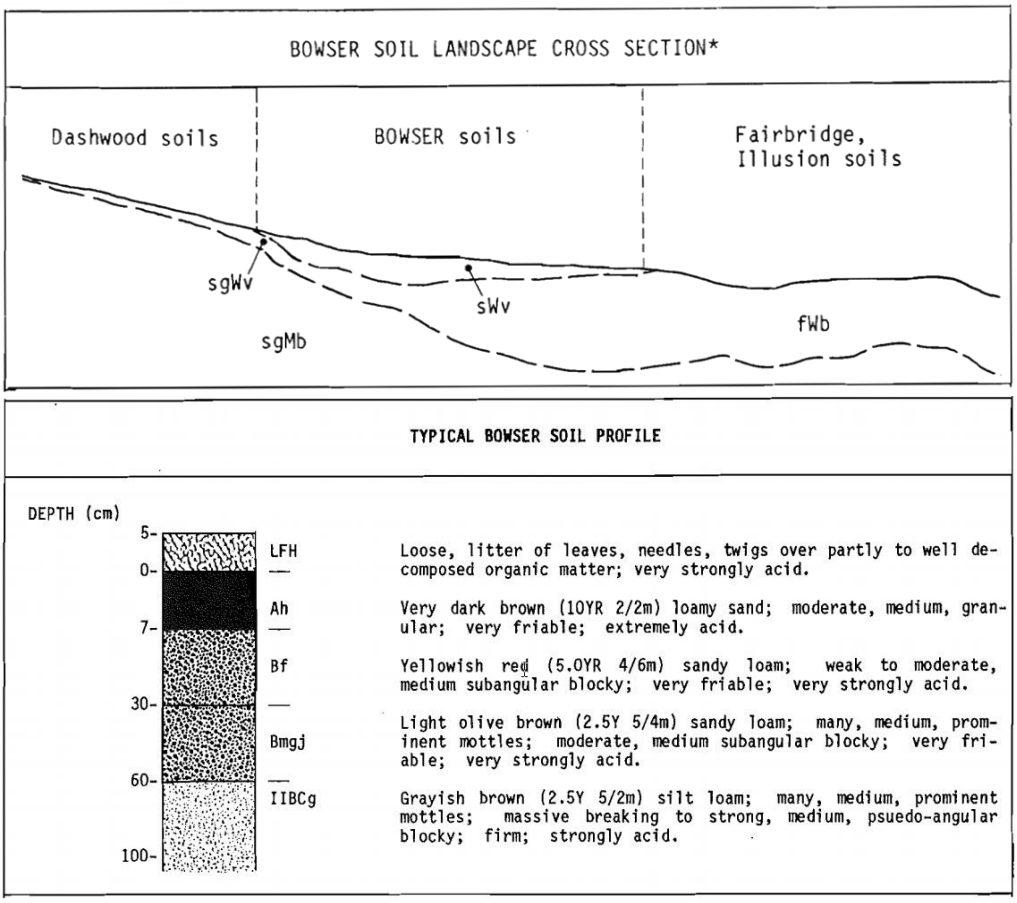


Figure 2a & 2b. Geologic cross-section and soil profile of the Bowser Soil Association area that includes the Woods Creek watershed. Source: Jungen et al. (1989).

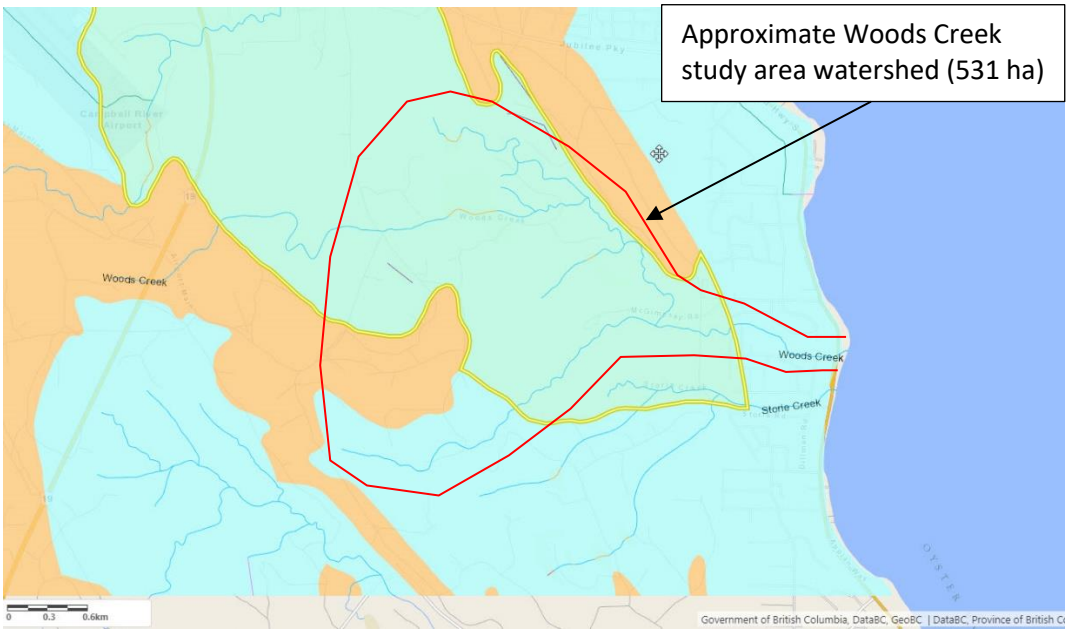


Figure 2c. Surficial geology of the Woods Creek watershed dominated by the Bowser Soil Association (turquoise). Source: iMap BC

2.2 Hydrology

The Woods Creek watershed is known to experience a period of low to trickling flows in the lowermost reaches from approximately July-September each year, where the watershed is described by Argast (1999) as having "summer low flows that plague this system". Contributing factors to low summer base flows may include the relatively small overall catchment area, geology supporting seasonally perched water tables, and lack of contiguous forest canopy in the headwaters related to forest harvesting practices.

The overall watershed contains a number of wetland complexes, all of which are enhanced by the presence of beaver dams that are very common throughout the study area; including within a series of forested wetlands (WN:sp) identified under the Sensitive Ecosystem Inventory (SEI) as: 4.4 ha wetland #S0656 located upstream of Reach 7, and 6.9 ha wetland #S0654 and 4.9 ha wetland #S0770 upstream in Tributary 3 (Figure 1).

The SEI mapped wetlands were not ground-truthed as part of this assessment and are likely to fluctuate in location and extent based on beaver activity. Approximately 20 beaver dams (active and historic) were observed throughout the study area during the period of assessment that are most concentrated in the upper reaches of the North Fork starting at the approximate midway point of Reach 4 (Figure 1). Mapped streamlines were corrected from the BC Freshwater Atlas GIS linework based on field measurements using a handheld GPS.

In addition to wetlands located in the headwaters, flows are collected within a catchment area that includes extensive areas of "Riparian" vegetation identified by the Sensitive Ecosystem Inventory (SEI 2004) along both North and South forks. Changes to the upper watershed resulting from forest harvesting practises include areas within the SEI Riparian polygon as detailed in Section 2.3.1. below.

According to the Ministry of Environment's iMap BC online database, there is a single unlicensed shallow groundwater well in use for private/domestic use in the lower watershed located between Wavecrest Rd. and Hwy. 19A. An additional old well near McGimpsey Road has been abandoned. No real-time or historical hydrometric data from Water Survey of Canada[1] is available for the Woods Creek watershed.

2.3 Land use

For the purposes of this study land use changes are defined as anthropomorphic modifications to the Woods Creek watershed affecting its natural hydrologic and nutrient cycles. These modifications include *Forest Harvesting* (Section 2.3.1) and *Rural Development/Urbanization* (Section 2.3.2); water withdrawal does not affect the subject watershed as described above in Section 2.2.

2.3.1 Forest Harvesting

Forest harvesting and early land use changes in Woods Creek watershed began in the 1880s when vast tracts of land in the region were pre-empted in connection with the Esquimalt and Nanaimo Railway land grant of 1884 that awarded Robert Dunsmuir with a massive tract of land stretching from Campbell River to Victoria in exchange for construction of an island railway (Mackie 1996). In order to finance construction of the railway the Dunsmuir's sold off parts of the E&N grant to speculators that included

1 https://wateroffice.ec.gc.ca/index_e.html

the Victoria Lumber and Manufacturing Company who's purchase enveloped the Woods Creek watershed.

Between 1889 and 1954 interests in logging rights to the lands surrounding the study area were sold to the Canadian Western Lumber Company, including its subsidiary the Comox Logging and Railway Company -which was ultimately taken over by Crown Zellerbach in 1954. The waterfront near Royston became the site of a water-based log sort where railcars from the areas north and west of the Comox peninsula would be transported by fledging railway. In recent history the blocks of land surrounding and encompassing Woods Creek have been harvested by TimberWest while Mosaic Forest Management manages forest planning, operations, and product sales on their behalf.

A block of Riparian Forest identified by the Sensitive Ecosystem Inventory (SEI 2004) includes an area of 29 ha within the Woods Creek watershed located along the North Fork and near the confluence of the North and South Forks to Woods Creek (Figure 1). However, recent aerial photos and ground-truthing indicate that the 29 ha area of Riparian forest has been reduced by 6.3 ha to 22.7 ha by recent forest harvesting activity by TimberWest (Figure 2). Although nearly the entire watershed was logged in the 1920-30s, ongoing and recent logging continues as shown by an approximate 76.2 ha (or 14 %) of forested area within the 531 ha watershed has been harvested within the past 10 years.

2.3.2 Rural Development/Urbanization

Expected negative effects from urbanization include increased areas of impervious surfaces and drainage density leading to elevated peak flows; and reduced vegetation communities that would maintain pre-development retention of rainfall and reduce erosion resulting in reduced rearing/spawning habitat quality. Notably, the Woods Creek watershed contains a relatively small urbanized area at approximately 5.6 % of its total area; qualifying it as *Sensitive* (*1-10 % impervious cover*) under a modified stream quality index from Scheuler (1994). A breakdown of percentage impervious area is shown below in Table 1.

Table 1. Percentage of recently modified area resulting from recent forest harvesting (w/ 10 yrs.), urbanized area including private property and road surfaces, and golf course area maintained as grasses in the Woods Creek watershed from GIS interpretation.

	Watershed Area	Urbanized Area	Recent Forest Harvest (w/n 10 years)	Golf Course Grasses	Total Recent Modified Area (w/n 10 years)
Area (ha)	531	30.0	76.2	28.6	134.8
% of total	100 %	5.6 %	14.3 %	5.4 %	25.4 %

The remainder of the watershed has been subject to historical and contemporary forest harvesting and golf course operation, the latter of which requires maintaining extensive areas of grasses free of canopy cover. Forest harvest management practices do have long-term effects on the watershed including significant decreases in rainfall interception and evapotranspiration, increased runoff and peak discharge leading to a "flashy" flow regime, wetland conversions or loss, channelization, erosion and sediment release, and wildlife habitat loss and species displacement. The conversion of forested landscapes into cut-blocks can impact aquatic systems by reducing available habitat and nutrients for rearing and overwintering juvenile salmonids, diminishing the filtration of stormwater runoff resulting in higher concentrations of deleterious substances flowing downstream, increasing bank erosion from higher velocity stormwater discharge, and reducing species richness.

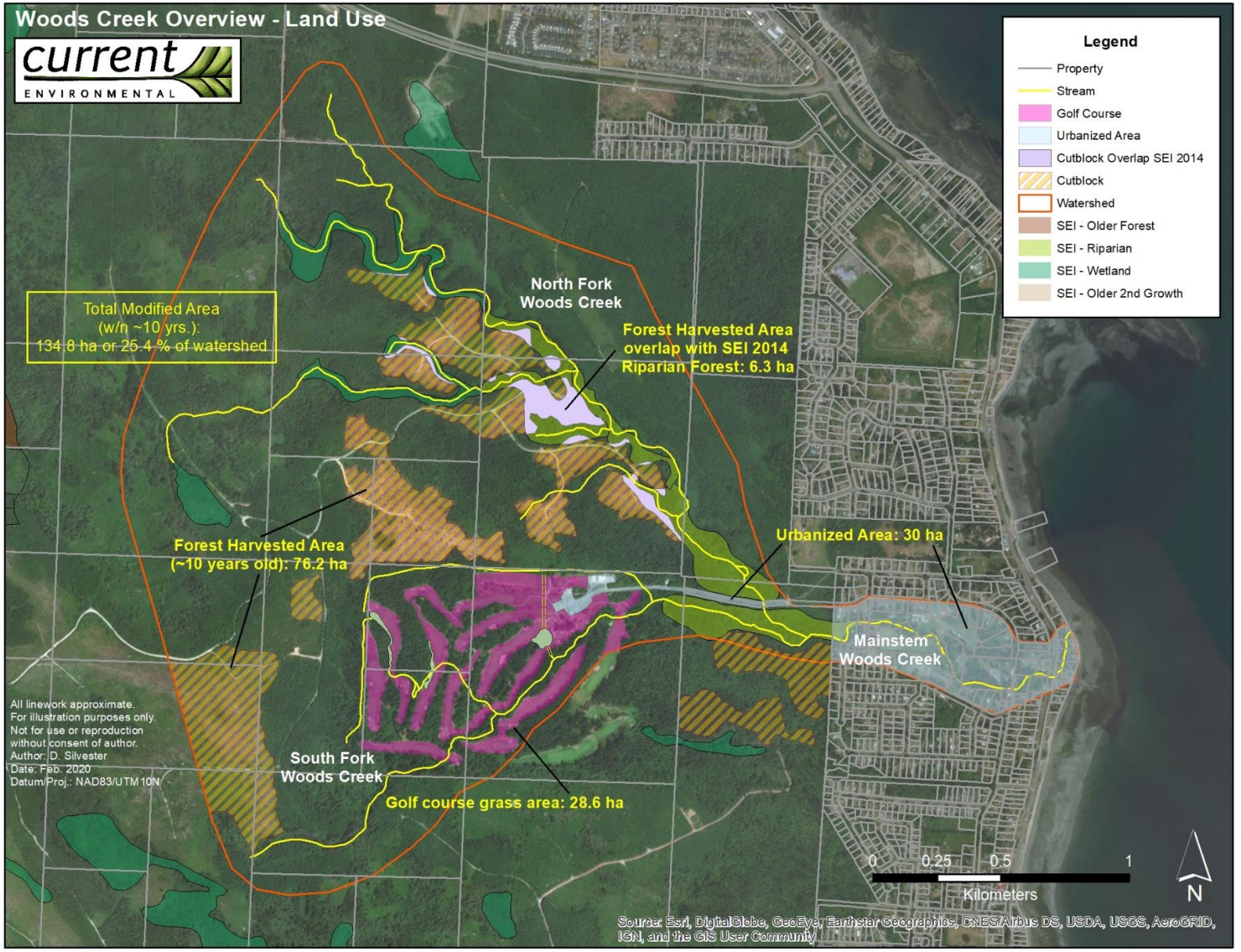


Figure 2. Overview site plan of the Woods Creek watershed showing extent of contemporary land-use changes including recent forest harvesting (approximately 10 years old), urbanization, and overlap with SEI 2014 riparian polygons.

2.4 Past Enhancement Projects

Past enhancement projects in the Woods Creek watershed began with a series of field and reporting efforts describing limiting factors to fish habitat in Woods Creek watershed completed from 1996-2000 that included an USHP Habitat and Riparian Assessment Report, SHIM Survey, and Overview and Habitat Assessment Report -alongside restoration prescriptions that guided works in 1999-2000.

These assessments were used to target restoration/enhancement opportunities that were implemented by the Storeys Creek Streamkeepers including instream work completed June-Sept. 1999 within the North Fork of Woods Creek. Enhancement works in the North Fork included wood and log weir construction at old beaver dam sites to augment water retention in order to enhance fry rearing survival during the dry summer months, as well as a series of rock weirs/riffles to enhance spawning and upstream pool rearing potential (Argast 1999).

In 2000, the previous year's work was followed up with the construction of a series of three weirs; one wood and two rock, in Tributary 3 following the same objectives as the North Fork enhancement measures, as well as a rock weir in the North Fork near its confluence with Tributary 2. The Province of BC holds a water license over a number of the weirs constructed in the North Fork and has indicated a willingness to entertain alternative measures of providing habitat benefits to fish that no longer necessitate licensing. The works completed in 1999-2000 were summarized in a site map produced by Greenways Land Trust in 2002 (Figure 3). North Fork weir repair/maintenance was completed in 2006.

Additional works have been undertaken on the Storey Creek Golf Course property over the period of decades that has included construction of multiple small rock weirs, a bypass channel and barrier removal in the upper NW Branch of the South Fork of Woods Creek, wood and rock weir construction in the South Branch, replacement of an undersized culvert near the 12th hole with a larger culvert containing baffles to improve fish migration, and new channel construction connecting a man-made groundwater-fed pond adjacent to the 14th hole -a site of DFO coho fry out-planting over many years and known to support a small population of cutthroat trout- to downstream habitat.

Fish counting fences (adult escapement & smolt out-migration) have historically been operated near the mouth of the Creek (Reach 1) through the late '90s - early '00s that have since been partially decommissioned. Some infrastructure remains in place including log and concrete weirs and some concrete abutments.

All of the above-mentioned historical enhancement sites have been located and surveyed for their current physical status and habitat function as part of this assessment (Section 5) and recommendations have been made for their maintenance, enhancement, or replacement.

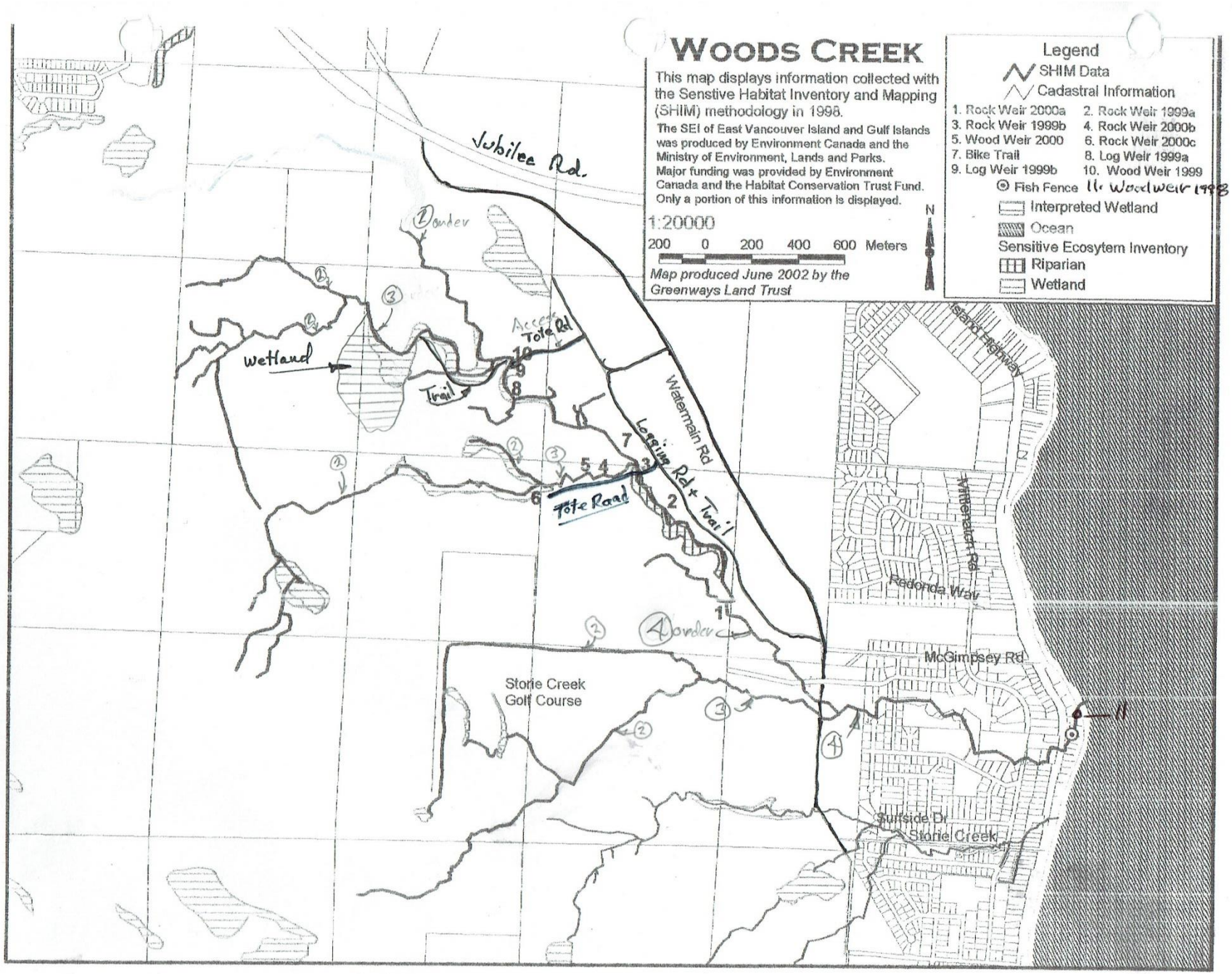


Figure 3. Site plan produced by Greenways Land Trust in 2002 showing locations and dates of weirs established in the North Fork of Woods Creek surveyed in this assessment.

3 Overview - Fisheries Information

Fisheries information has been gathered from several sources including the Campbell River Salmon Foundation and Greenways Land Trust library archives, online government databases and records, and a literature review of fisheries publications. The intent is to supply a comprehensive overview of historical and contemporary salmonid utilization in the Woods Creek watershed; should future enhancement work be undertaken this data may be used to help represent pre-enhancement salmonid ecology for comparison against post-enhancement conditions. The known *Distribution* of salmonid species in the watershed is described in Section 3.1; while a summary of the *Life History Timing* of salmonids during their freshwater residence and migration is in Section 3.2.

3.1 Distribution

Sampling using minnow traps in February 2020 (Section 5.1) has shown that the Woods Creek watershed supports a seasonal distribution of juvenile coho (*Oncorhynchus kisutch*). As a substantial proportion of the system is known to dry in the summer months the juvenile salmonid distribution is expected to be somewhat seasonal with the exception large tracts of pool habitat in the upper watershed and isolated pools in the lower reaches.

Sampling in late winter 2020 was timed during a period when all of the channels in the assessment area were observed to be flowing and was expected to coincide with the presence of overwintering fry/parr and possibly young-of-the-year that may have recently hatched. Sampling results have shown a distribution of coho in both North and South fork habitats (Figure 1 & Section 5.1).

A search of the BC Fish Inventory Data Query (FIDQ)[2] system indicated historical records for the presence of coho, pink, chum salmon; as well as anadromous and resident cutthroat trout; and threespine stickleback distributions in Woods Creek. The presence of these species is corroborated by records from the operation of adult counting and juvenile smolt outmigration fences.

As part of the Level 1 Assessment procedure a single-season Salmonid Presence/Absence *Fisheries Assessment* of the study area was completed using baited minnow traps on Feb. 12-13, 2020 with results discussed in Section 5.1. Expected emergence timing of coho fry is discussed in Section 3.2.2. The results of this survey showed the seasonal presence of salmonids in the upper North and South fork reaches and downstream mainstem habitat. The results of the survey are shown in Table 4 alongside water quality data (dissolved oxygen and temperature) collecting in conjunction with trapping effort, while sample locations are shown graphically in Figure 1.

[2] http://a100.gov.bc.ca/pub/fidq/viewSingleWaterbody.do

3.2 Life History Timing

Available Woods Creek escapement data from operation of the adult counting fence and from Provincial FIDQ records have been used to reflect the expected life history timings of salmon accessing the Woods Creek system. The life history timing of salmonids varies by species. Depending on the timing of fall freshet rainfall and flow volumes at the creek mouth (Reach 1), adult chum salmon are believed to return to the system in October, just before coho, that generally migrate into the system in November-December. No cutthroat trout were observed during sampling; however, it is possible that anadromous adults may enter the system alongside the annual salmon spawning migration. A summary of life history timings expected in Woods Creek for coho, chum, and cutthroat are detailed in the following sections and in Table 2 below.

Table 2. A generalized timetable of expected salmonid movement in and out of Woods Creek based on information in Groot & Margolis (1991) and FIDQ.

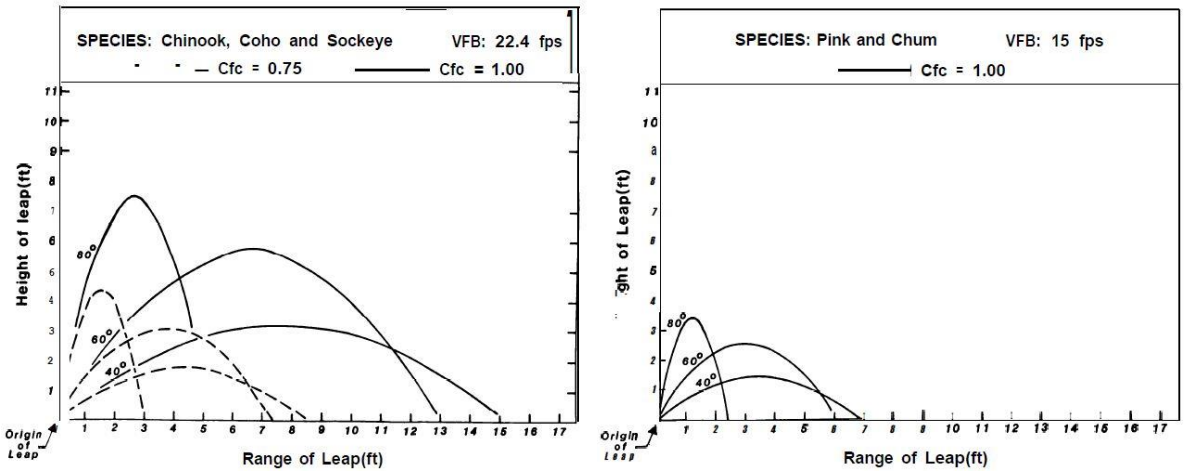
Species	Spawning	Out-Migration
Coho	Early November – Mid December	Late April – Mid June
Chum	Mid October – Late November	Mid March – Late April
Cutthroat (anadromous)	February	Mid April – Mid May

3.2.1 Escapement/Adult Spawning Migration

Migrating salmon must have suitable streamflow velocities and depths to provide successful upstream passage -particularly relevant in systems like Woods Creek that contain multiple potential barriers from beaver dams, relic weirs, and log/debris jams.

The leaping capabilities of adult salmon have been linked to their swimming speeds (Bell 1973; Powers & Orsborn 1985; Bjorn & Reiser 1991; Corvallis 2017) where coho salmon have a maximum burst speed of 3.23 - 6.55 m/s, and chum salmon have a burst speed of 2.35 - 4.57 m/s (Bell 1973). Based on a study of salmonid leaping abilities by Stuart (1962) it was determined that a minimum plunge pool depth of 1.25x any plunge height (i.e. over constructed weirs) is required for successful passage.

Using the maximum burst speeds proposed by Bell (1973) and assuming optimal jumping conditions from Stuart (1962), adult coho are expected to have a maximum jump height of 2.19 m and chum of 1.07 m (Figures 4-5). As a result, it is anticipated that healthy coho and chum migrating under suitable flow conditions can pass over the majority of weirs and beaver dams in the lower watershed with the exception of any barriers that either do not have a sufficient plunge pool depth, excessive plunge height, or combination of both.



Figures 5-6. Comparison of coho vs. chum leap height/range (ft.) curves based on maximum burst speeds and leaping angles (Powers & Orsborn 1985).

Juvenile coho jumping abilities have also been described in Pearson et al. (2005) where it was experimentally shown that flow and outfall drop are the primary factors affecting leaping success, while downstream pool depth and morphological characteristics also play a part. It was shown that an outfall drop of 25 cm is impassable to 97 % of coho salmon juveniles (~100 mm length).

Chum salmon are expected to spawn from mid-October to late-November with peak spawning activity occurring late November; while coho are expected to spawn from late October to early January with a peak in numbers seen in the last half of November, following approximately 1.5 years at sea (Sandercock 1991).

It is apparent that spawning adult coho gather at the mouths of shallow coastal streams, such as Woods Creek, and begin to move upstream when the water levels reach a sufficient depth to allow passage. In the case of chum, high water levels are not essential; however, their runs do coincide with fall rains when water temperatures range between 7- 11°C (Groot & Margolis 1991). If autumn precipitation freshets do not occur for a sustained duration and are instead infrequent, the upstream migration will be pulsed. Coho spawners are most likely to begin their migration upstream when the stream experiences a large flow in conjunction with a high tide (Fraser et al. 1983), water temperatures between 7.2 - 15.6°C, depth at a minimum of 18 cm, and the water velocity at a maximum of 2.44 m/s (Reiser & Bjorn 1979). It is believed that the aforementioned conditions at the mouth of streams are conducive to allowing coho passage to “small headwater tributaries where good spawning and rearing conditions may be found” further upstream (Sandercock 1991). Suitable spawning reaches have been identified based on Overview/Level 1 data collection and are discussed in Section 5.2.

3.2.2 Fry/Parr

Salmonids emerging from their winter gravel incubation are called fry. According to Neave (1949), coho fry may migrate upstream or downstream where they are capable of inhabiting areas inaccessible to adults, such as wetlands. The fry will distribute themselves throughout the stream where they will setup territories for extended periods. This behaviour has the beneficial result of creating a relatively low density of fry in any one area and reduces competition for food resources. However, territorial tendencies can have some negative results, for example the size disparity between late emerging fry and their larger, early emergent relatives, may be compounded by smaller fry being chased out of prime

feeding grounds to less favourable sites, consequently, the later emergent fry grow more slowly (Chapman 1962).

Conversely, for most of their life cycle, chum are obligate ocean dwellers (Hoar 1958). As fry, they begin their migration downstream to estuarine waters shortly after emergence from the gravel as alevin. According to Groot & Margolis (1991) juvenile chum migrate into saltwater with warming nearshore waters and associated plankton blooms in the spring season, the timing of migration is also closely related to latitude.

3.2.3 Smolt

In general, it has been found that the timing of coho smolt out-migration depends on a number of factors including the size of fish, flow conditions, water temperature, dissolved oxygen levels, amount of daylight, and food availability (Shapovalov & Taft 1954). Flow conditions and temperatures leading to migration have been outlined by Lawson et al. (2004) where "correlates for the Oregon Coast stocks were the […] flow during smolt outmigration. Air temperature is correlated with sea surface temperature and timing of the spring transition so that good freshwater conditions are typically associated with good marine conditions", and where "annual air temperatures and second winter flows correlated strongly with smolt production."

Regarding out-migration, Hartman et al. (1982) found "most coho fry move out of river systems with freshets. However, even during periods of stable flow, fry continue to migrate. The numbers of fry moving do not correlate well with the water discharge rate because the first freshet may move most fish, whereas the second freshet, a few days later, may move only the few that are still left in the stream."

4 Level 1 Assessment Methods

A winter sampling regime was implemented for the habitat assessment in order to assess watershed wide habitat function under moderate flows as well as potential salmonid distributions during the over-wintering life phase. Fish presence/absence trapping assessments were done in February 2020 in conjunction with completion of FHAP/USHP data acquisition that began in November 2019. Trapping was completed using minnow traps wetted for a minimum of 24hrs. Results of the trapping assessment are provided in Section 5.1.

Field methodology for the Level 1 Assessment was adapted from the WRP Technical Circular No. 8 – Fish Habitat Assessment Procedures (FHAP) by Johnston and Slaney (1996) and the Urban Salmon Habitat Program (USHP) Assessment Procedures for Vancouver Island Manual (Michalski, Reid, & Stewart 1997). Representative photos of sample sites and significant habitat features were recorded. Raw data sheets including reach characteristics and chainages are available in the Appendix. Specific methods for *Data Collection* are described in below in Section 4.1, and *Data Processing* in 4.2.

The Assessment was completed in stages prescribed by Michalski, Reid, & Stewart (1997) and is described as follows:

1. Overview Assessment: was done to determine the extent of past documented assessment and enhancement efforts to help inform the assessment process moving forward. Literature and Information Search completed before field work begins. A search of Department of Fisheries

and Oceans (DFO) and BC Ministry of Environment online databases. Hardcopies of existing literature on the study area was accessed from Campbell River Salmon Foundation and Greenways Land Trust libraries.
    a. Preliminary reaches and reach breaks identified for field assessment were also delineated during the Overview process.
2. Field Assessment: Field collection of stream habitat data. Field data collection was done using FHAP methods described in Johnston and Slaney (1996).
    a. Field work was completed November 2019-February 2020.
3. Habitat Data Entry: A standardized Excel spreadsheet supplied by Tracy Michalski, Ministry of Forests Lands and Natural Resource Operations (MFLNRO), and USHP methods descried in Michalski 1997 were used to input collected field data.
4. Mapping: Maps were generated according to USHP Mapping Procedures using technology described in Section 4.1.

4.1 Data Collection

Field data was collected and transcribed according to methods described in Johnston and Slaney (1996). Reach breaks were determined wherever a significant man-made break such as a bridge crossing, culvert, or natural feature such as tributary confluence was encountered.

Representative photographs were taken of each reach with upstream and downstream views of most Habitat Units. Locations for photographs, chainages, reach breaks, habitat unit breaks, obstructions, off-channel habitat, and other points of interest were recorded using a handheld Garmin GPSmap 60cx with an expected accuracy of ±3 m. Relevant points and linework are shown graphically in maps produced using a desktop GIS platform.

Low intensity fish presence/absence assessment was completed February 12-13 using minnow-traps with results summarized in Section 5.1. Traps were baited with salted roe and left to soak a minimum of 24 hrs.

4.2 Data Processing

Raw field data (Appendix A) was input into a Microsoft Excel spreadsheet produced by the USHP and retrieved from the online Ministry of Environment Ecological Reports Catalogue[3]. The USHP spreadsheet automatically generates ratings for the habitat parameters to help identify habitat limitations in the watershed. The rating scale is as follows: 1 = Good; 3 = Fair; 5 = Poor. The ratings for each parameter are totaled to produce an overall rating for the reach with a separate rating scale: <15 = Good; 15-27 = Fair; >27 = Poor. The following Table 3 shows the criteria used in rating habitat parameters:

[3] https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=8766

Table 3. Habitat Parameter Ratings for the Comparison of Assessment Data to Habitat Diagnostics.

Habitat Parameter	Ratings (1 - 5) for the Comparison of Assessment Data to Habitat Diagnostics
Pools (% area)	< 40% (Poor)= 5; 40 - 55% (Fair) = 3; >55 % (Good) = 1
Large Woody Debris freq (pcs/bfw)	< 1(Poor) = 5; 1 -2 (Fair) = 3; > 2 (Good) = 1
Pool Frequency (# channel widths/pool)	>4 (Poor) = 5; 2-4 (Fair) = 3; <2 (Good) = 1
Percent Cover in Pools	0-5% (Poor) = 5; 6-20% (Fair) = 3; > 20 (Good) = 1
Boulder Cover	<10% (Poor) = 5; 10 - 30% (Fair) = 3; >30% (Good) = 1
Overhead cover	< 10/% (Poor) = 5; 10-20% (Fair) = 3; >20 %(Good) = 1
Substrate (% Fines)	>20 (Poor) = 5; 10-20 (Fair) = 3; < 10 (Good) = 1
Erosion Sites	1 point assigned for each identified site
Number of Obstructions (eg. Dams, perched culverts, bedload);	1 point assigned for each obstruction
Number of Stream Alteration Sites (eg. Riparian removal, channelization, infilling);	1 point assigned for each altered site
% Wetted Area (Wetted Area/Total Area);	<70%(Poor) = 5; 70%-90% (Fair) = 3; >90% (Good) = 1
Substrate % gravel	<20 (Poor) = 5, 20-40 (Fair) = 3; >40 (good) = 1

The resulting parameter ratings and overall reach ratings help exemplify where and how each reach may be deficient in habitat features that are known to improve salmonid productivity and highlight areas that may prove to be good candidates for enhancement works. *Level 1 Assessment Results* shown in the following Section 5 and a discussion and *Level 2 Recommended Enhancement* summary is in Section 6.

5 Level 1 Assessment Results

Level 1 Assessment Results include the outcomes of a *Fisheries Assessment* (Section 5.1), *Reach Descriptions & Habitat Assessment Results* (Section 5.2), while *Level 2 - Recommended Habitat Enhancement Summary* are separated by reach in Section 6.

5.1 Fisheries Assessment

Winter, moderate flow salmonid presence/absence surveys within the study area were completed using baited minnow traps on February 12-13, 2020. Minnow traps are not expected to capture larger trout because of the size of the trap's entrance diameter (~ 4 cm Ø); therefore, trapping should not be considered a complete representation of species composition and distribution in the assessment area. However, this method does effectively capture coho/chum fry and smolts, young trout, and other species such as stickleback, sculpin, and crayfish -and is useful to determine their distribution in the study area.

The timing of trapping effort in late winter helps characterize the distribution of coho fry during their overwintering life phase and while flows in the Woods Creek system are present; as many of the smaller channels are known to dry seasonally.

Traps were set near reach breaks concentrated towards the mid-reaches of the watershed as the lower reaches are known to contain juvenile salmonids and the upper reaches were largely outside the boundaries of the assessed area and were wetted for a minimum of 24 hrs. Water quality parameters for Dissolved Oxygen (DO; mg/L) and Temperature (°C) were collected alongside trapping sites shown in Table 4, and locations in Figure 1.

Table 4. Summary of fish trap results from baited minnow traps in the study area during sampling effort on Feb. 12-13, 2020.

Reach	Chainage (km)	Trap #	Species	# Caught	Trap ID	Water Quality	
3	1+625 & 1+500	4	CO fry	0 1	T13-14 & T9-10	DO: 10.7 mg/L DO: 11.1 mg/L	Temp.: 4.2 °C Temp.: 3.5 °C
4	2+170	2	-	0	T17-18	DO: 10.8 mg/L	Temp.: 3.2 °C
Trib. 2	2+190	2	-	0	T15-16	DO: 9.6 mg/L	Temp.: 6.1 °C
5	3+040	1	CO fry	2	T21	DO: 10.4 mg/L	Temp.: 4.3 °C
T2a	0+030	2	-	0	T19-20	DO: 9.3 mg/L	Temp.: 5.3 °C
T3*	0+475	-	CT	-	-	-	
8	1+520	2	CO fry	3	T11-12	DO: 10.4 mg/L	Temp.: 4.8 °C
9	2+250 2+670 2+950 3+200	8	CO fry	1 0 0 0	T1-2 T7-8 T3-4 T5-6	DO: 9.6 mg/L DO: 10.0 mg/L DO: 9.2 mg/L DO: 8.9 mg/L	Temp.: 6.1 °C Temp.: 5.3 °C Temp.: 5.6 °C Temp.: 5.9 °C
*Trib. 3 fish presence data based on Mosaic (previously TimberWest) SP Stream Assessment Mapping. May 2004.							

5.2 Reach Description & Habitat Assessment

According to the results of this *Fish Habitat Assessment*, three of the assessed reaches received a *Fair* rating and six received a *Poor* overall rating. Habitat parameters commonly missing across all assessed reaches include lack of off-channel habitat, low % boulder cover, low % spawning gravel, high % fine substrates, and impacts to riparian vegetation related to clearing on private property and forest harvesting practices.

The following sub-headings (Sections 5.2.1 - 5.2.4) are categorized by reach number and with associated chainages. They include reach *Descriptions* discussing general characterizations of riparian habitat and instream features; *Habitat Assessment Results* expounding the findings of the Fish Habitat Assessment survey and a description of habitat deficiencies. *Recommended Enhancement* projects and candidate sites have been identified and discussed in Section 6. Prior to initiating any instream enhancement work a Qualified Environmental Professional (QEP) should be consulted to provide detailed prescriptions for project design and implementation, including acquisition of relevant permits.

5.2.1 Mainstem Channels

5.2.1.1 Reach 1 (0+000 – 0+200)

Description

Reach 1 begins at the marine shoreline and extends 200 m upstream to an approximate 16 m long culvert under Highway 19A. Reach 1 runs roughly parallel to Highway 19A as it crosses a series of privately owned properties from south to north (Figure 7). The channel retains a relatively natural sinuosity while having heavily modified banks associated with urban development. These modifications include bridge abutments, riparian vegetation clearing to the top-of-bank, encroachment of invasive plant species and lawns, bank erosion, and residual weirs and abutments from decommissioned salmon counting fence installations (Photos 1-6).

Channel substrates are dominated by gravels (60 %) with sub-dominant fines (30%) and some sections of boulder/cobble (10%). It is apparent that sections of Reach 1 are subject to seasonal flooding where

banks adjacent to relatively a low elevation property near the south end of the reach has installed a sandbag berm along the top-of-bank to mitigate flooding risk. This property has also installed rip-rap revetment structures to reduce erosion, as well as cabled a strait log parallel to the right bank to provide some salmon habitat (Photos 5-6).

The existence of two weirs, one wooden, the other concrete (Figure 7; Photos 3-4), are potential partial barriers to fry migration as they have 0.25 m and 0.30 m vertical plunge drops, respectively. The drops at both sites flow into plunge pools of 0.65 - 0.75 m depth and are expected to be passable by adult salmon under most flow conditions but are barriers to upstream fry migration. Removal of approximately 30 cm of boards from the wooden structure should be considered to enhance passage for all salmon life stages while avoiding complex replacement techniques that might involve complete removal of the wir for completion prior to failure of the structures as they appear to be falling into disrepair (Photo 4). Artificial bed elevations resulting from the presence of existing weirs should be allowed to stabilize for at least one calendar year and re-assessed for suitability of installing permanent Newbury style rock weirs. Restoration prescriptions are discussed in Section 6.1.1.

Vegetation along the banks of this reach is dominated by invasive Himalayan blackberry and English ivy with sub-dominant native species that include willow, horsetail, salal, salmonberry, and small-flowering bulrush. Canopy closure is estimated at 20% (Fair) and is heavily modified but contains some remaining patches of red alder, grand fir, and Sitka spruce.

Habitat Assessment Results

Reach 1 (Table 5) was observed to contain pool and glide habitats resulting in part from the presence of weirs related to historical salmon counting fence installations. Reach 1 has a 2.5 % gradient with an average wetted width of 3.7 m, and bankful width of 4.9 m resulting in a 75 % wetted area for a *Fair* rating. Pool % Area is *Poor* at 16.6 % with Stream Cover rated *Fair* at 20 % largely a result of overhanging understory vegetation, including invasive blackberry, while disturbed canopy cover rates *Fair* at 20 %. Instream cover is very limited with few boulders, cut-banks and almost non-existent LWD, with a single installed and cabled straight log in the upper most pool (Photo 6).

The impacts from residential development have resulted in generally poor habitat parameters. The primary limiting factors in this reach are related to a history of disturbance, lack of suitable instream cover from LWD and boulders, low % pool area, and the presence of obstructions to fish passage. Furthermore, although it does not garner a rating, there is a high proportion of invasive plant species including dense mats of Himalayan blackberry and English ivy colonizing the banks of Reach 1.

Table 5. Habitat Ratings for Reach 1.

Habitat Parameter	MS1 (Mouth)	Ratings	
% Pool Area	16.60	5	Poor
LWD/BFW	0.09	5	Poor
% Stream Cover	20.00	3	Fair
Avg % Boulder	5.00	5	Poor
Average % Fines	30.00	5	Poor
Average % Gravel	60.00	1	Good
% Wetted Area	75.51	3	Fair
% Crown Cover	20.00	3	Fair
Erosion Sites	18	2	-
Obstructions	3	3	-
Totals		**35**	Poor

Photo 1 & 2. Views upstream of Reach 1 at km 0+122 (above left; Feb. 11, 2020) showing concrete retaining wall, historical counting fence structure (right of image), and riparian removal on right bank (left of image); and view downstream (above right; Feb. 11, 2020) showing riparian disturbances from driveway bridge installation, rock revetment (left bank) and English ivy encroachment (right bank).

Photo 3 & 4. View of wooden weir 0.25 m falls into a 0.65 m plunge pool at km 0+018 that is an obstruction to juvenile salmon migration (above left; Feb. 11, 2020), and view upstream of a concrete weir that is beginning to show signs of failure located near km 0+135 with a drop of 0.30 m into a 0.75 m plunge pool.

Photo 5 & 6. Upstream view of riparian clearing to the top-of-bank and *ad hoc* revetment using angular boulders near km 0+155 (above left; Feb. 11, 2020), and view downstream (above right) of the pool located behind the concrete weir (Photo 4) showing single cabled LWD piece in the entire reach (bottom right of image), and a historical counting fence abutment (top-left of image).

Figure 7. Reach 1, lower Woods Creek watershed showing existing conditions and proposed enhancement and restoration sites.

5.2.1.2 Reach 2 (0+200 – 1+400)

Description

Reach 2 extends from the Highway 19A crossing to the confluence of the North and South Forks of Woods Creek (Figure 8). This reach shows varying degrees of recent impacts from riparian clearing along the left and right banks related to urban development at its downstream end, and recent logging near the south (right) bank of the upstream section (Photos 7-8). Disturbances include multiple private bridge crossings, clearing to the top of bank and replacement with lawn grasses, eroding banks, invasive plant encroachment, and beaver dams. Currently, the canopy is dominated by maturing third growth mixed coniferous/deciduous forest that has been thinned and has a modified species assemblage as a result of urbanization and forest harvesting practices.

Reach 2 has a relatively steep gradient for the overall system (approximately 2-5%) and contains substrates dominated by cobbles with gravel recruitment suitable for spawning salmonids -a rarity in the watershed. Based on its position in the lower watershed, these gravels would most likely be utilized by chum for spawning; however, a general lack of gravels in the upper watershed reaches may attract coho to utilize the lower reaches as well. During ground-level assessment on Nov. 26, 2019 a redd was observed near km 0+900 (Photo 9). The presence of a beaver dam and debris jams in this reach are likely responsible for detaining finer alluvium between km 0+950 – 1+050 (Photo 10).

As a result of its gradient causing higher velocity flows, as evidenced by the dominance of cobble grade alluvium; and relatively low elevation left bank, that has been modified by urban development, it appears that flooding and erosion periodically affect this reach. An *ad hoc* bank revetment structure composed of angular rock is present near km 1+160, providing further evidence of erosive forces combined with anthropogenic bank modifications affecting this section of the reach (Photo 11). Known seasonal drying off the upper watershed make this Reach particularly important for the survival of juvenile rearing salmonids that can take refuge in some of the small pools found in this section of the lower watershed during low flow conditions. As well, the presence of spawning grade gravel provides some of the best spawning opportunities in the system.

Habitat Assessment Results

Reach 2 (Table 6) is dominated by riffle/glide habitat with coarse alluvium that defines the 2-5 % bed gradient. This reach has an average wetted width of 3.85 m, and bankful width of 5.70 m resulting in a 67.5 % wetted area for a *Poor* rating. Pool habitat is somewhat lacking as a result of aforementioned larger diameter alluvium and steeper gradients. The reach is deficient in LWD and boulder cover mostly due to the young stand age and urban impacts to the riparian forest stand that interrupt natural woody debris recruitment. Stream % Cover is rated *Good* at 28 %, largely because of dense overhanging vegetation encountered mid-reach. Crown cover is 37.5 % resulting in a *Good* rating notwithstanding the canopy is composed of mixed conifer-deciduous that are likely to provide even more canopy closure when the deciduous trees leaf out in the spring-summer. Furthermore, there are sections of the assessed reaches where urban/rural development has caused riparian vegetation clearing up to the top-of-bank that has undermined % canopy closure.

The primary limiting factors to fish productivity in this reach include low summer flows, low % Pool Area, limited LWD frequency and boulder cover, and % wetted area. All of these factors can be improved with enhancement measures described in Section 6 below.

Table 6. Habitat Ratings for Reach 2.

Habitat Parameter	Reach MS2	Ratings	
% Pool Area	16.27	5	Poor
LWD/BFW	0.74	5	Poor
% Stream Cover	27.98	1	Good
Avg % Boulder	2.00	5	Poor
Average % Fines	6.25	1	Good
Average % Gravel	35.00	3	Fair
% Wetted Area	67.54	5	Poor
% Crown Cover	37.50	1	Good
Erosion Sites	1	1	-
Obstructions	1	1	-
Totals		28	Poor

Photo 7-8. Downstream view of an upper-Reach 2 site near km 1+160 showing urban development up to the top of bank (above left; background) and upstream view showing riparian clearing related to forest harvesting practices at the same location (above right; background) (Nov. 28, 2019).

Photo 9-10. View upstream of the site of a salmon spawning redd located above the crest of a natural riffle near km 0+900 (above left; Nov. 28, 2019) and view upstream of a beaver dam at km 0+950 detaining sediment upstream and causing a partial barrier to fish migration (above right; Nov. 28, 2019).

Photo 13. *Ad hoc* bank revetment structure composed of angular rock present near 1+160 km, providing evidence of erosive forces combined with anthropogenic bank modifications including native riparian vegetation removal affecting this section of Reach 2.

Figure 8. Reach 2, lower Woods Creek watershed showing existing conditions and proposed enhancement and restoration sites.

5.2.2 North Fork Channels

5.2.2.1 Reach 3 (1+400 – 1+625)

Description

The downstream extent of Reach 3 begins at the confluence of the North and South Forks of Woods Creek forming the mainstem channel at km 1+400 (Figure 9). The riparian structure of Reach 3 has been moderately affected by forest harvesting practices and is composed of second or third growth mixed coniferous/deciduous forest that includes decent large woody debris recruitment into the stream margins (Photo 11). An ATV ford crossing near km 1+500 intersects a section of spawning grade substrates subject disturbance from vehicle traffic (Photo 12).

With an average bankful width of 5.7 m, gradient of 2-5 %, this riffle dominated reach provides some spawning potential in its lower half but is dominated by coarser materials and exposed hardpan in its upper half (Photo 13). This reach has moderate riparian cover with some impacts from forest harvesting practices to within 20 m of the stream bank. A canopy of mixed coniferous/deciduous trees provides good stream closure coupled with some overhanging vegetation provided by native understory species.

Enhancement opportunities exist for the upper half of Reach 3 that are detailed in Section 6.1.3.

Habitat Assessment Results

Reach 3 (Table 7) received an overall *Fair* rating. The stream channel is dominated by riffle habitat with an average 3.5 % gradient over its 225 m length. Pool % Area is relatively lacking throughout the reach resulting in a *Poor* rating, mostly due to a dominance of coarse materials and exposed hardpan. Stream cover is *Good* at 31% and substrates are *Poor* to *Fair* with respect to low % boulder cover and moderate % fines and gravel. LWD recruitment is *Fair* at just over 1 unit per bankful width. Crown cover is *Good* at 45 % largely because of the limited amount of land use changes with the exception of historical logging practices that have since partially recovered.

The primary limiting factors to fish productivity in this reach include low % pool area and % wetted area, the limited suitable instream cover from LWD and boulders, and lack of suitably spawning habitat. The upper habitat unit, with a 3.5 % gradient, is a good candidate for installing a series of riffles/pools with LWD to address these limiting factors (Section 6.1.3).

Table 73. Habitat Ratings for Reach 3.

Habitat Parameter	Reach 3 NF1	Ratings	
% Pool Area	10.32	5	Poor
LWD/BFW	1.10	3	Fair
% Stream Cover	31.45	1	Good
Avg % Boulder	2.00	5	Poor
Average % Fines	10.00	3	Fair
Average % Gravel	40.00	3	Fair
% Wetted Area	50.00	5	Poor
% Crown Cover	45.00	1	Good
Erosion Sites	0	0	0
Obstructions	1	1	0
Totals		27	Fair

Photo 11. Typical view of the downstream habitat unit of Reach 3 (left) showing cobble dominated substrates and large woody debris presence (Sept. 23, 2019).

Photo 12 & 13. View south (above left) of the ATV crossing site over Reach 3 near km 1+500 showing spawning gravels disrupted by vehicle traffic (Sept. 28, 2019), and the upper habitat unit between km 1+500-1+585 steeper gradient channel dominated by coarse substrates and exposed hardpan (above right; Sept. 28, 2019).

Figure 9. Reach 3, lower North Fork of Woods Creek showing existing conditions and a proposed enhancement site.

5.2.2.2 Reach 4 (1+665 – 2+170)

Description

The downstream end of Reach 4 is situated at the McGimpsey Road crossing and stretches upstream to the North Fork's confluence with Tributary 2 at a riffle originally constructed in 2000 near km 2+170. Riparian habitat surrounding the reach is relatively intact maturing second growth with the exception of recent forestry clearing within 20 m of the right bank at the upstream end of the reach. The forest canopy is primarily composed of Douglas fir, western red cedar, coastal western hemlock, big leaf maple, and red alder. The understory is dominated by salal, salmonberry, swordfern, dull Oregon grape, and red osier dogwood. The entirety of Reach 3 is contained within a BC Sensitive Ecosystem Inventory "Riparian" polygon (Figure 10).

The stream character varies between riffle and glide habitat with riffles concentrated in sections of the reach with gradients from 2-5 %, and glides from 1-2 % (Photos 14-15). Riffle sections subject to higher velocity flows contain much coarser substrates of cobble and exposed hardpan, while glides contain substrates dominated by fines, up to 95 % with little exposed gravels.

A relic sidechannel present between km 1+790 – 1+840 appears to be dry for the majority of the year as it contains fairly dense vegetated growth, only with some sections of exposed alluvium, but likely contains overflow from the mainstem North Fork during periods of peak flows.

Habitat Assessment Results

Reach 4 (Table 8) has an overall *Poor* habitat rating. The lower habitat units are dominated by glide/riffle habitat, and the upper reach primarily contains lower gradient glides with fine substrates detained by a series of small log jams. The assessed habitat units in the lower reach have an average gradient of 2.7 %, average wetted width of 4.7 m and bankful width of 7 m.

Although some steeper riffle habitat is present in the lower half the Reach is dominated by glide habitat overall and is reflected in the Pool % Area being *Poor* at 18 %; however, the pools that do exist have a *Good* rating for cover at 17 %. The maturing mixed canopy provides moderate LWD recruitment, achieving a Fair rating at over 1 piece of LWD/BFW, while boulder cover is largely non-existent for a *Poor* rating. Crown cover is *Good* at 50 % largely because of the maturing coniferous riparian vegetation that characterizes the lower habitat units (Photo 16).

The primary limiting factors in this reach include low summer flows, lack of boulder cover, low % pool frequency, low % gravel and high % fine substrates. Reach 4 only contains suitable spawning substrates in the lowermost habitat unit that would be suitable for both coho and chum salmon and has been identified for additional enhancement (Section 6.1.4).

Table 8. Habitat Ratings for Reach 4.

Habitat Parameter	Reach 4 NF2	Ratings	
% Pool Area	18.07	5	Poor
LWD/BFW	1.05	3	Fair
% Stream Cover	16.67	3	Fair
Avg % Boulder	0.00	5	Poor
Average % Fines	53.33	5	Poor
Average % Gravel	13.33	5	Poor
% Wetted Area	67.87	3	Fair
% Crown Cover	50.00	1	Good
Erosion Sites	0	0	0
Obstructions	1	1	0
Totals		31	Poor

Photo 14 & 15. Upstream representative views of Reach 4 showing typical steeper riffle habitat (above left) and glide habitat (above right).

Photo 16. Example of the maturing mixed 2nd or 3rd growth forest canopy that characterizes the riparian area of Reach 4.

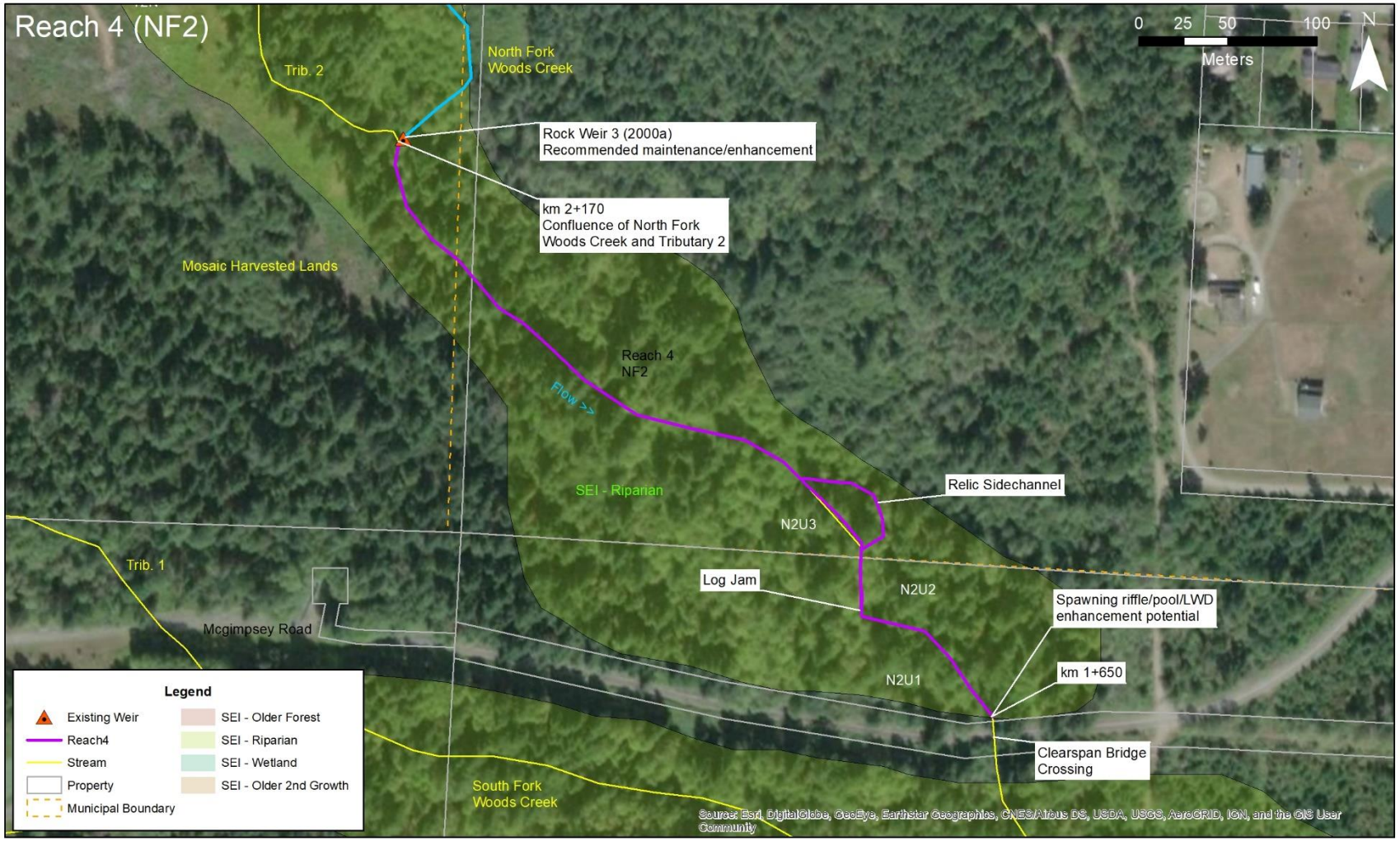


Figure 10. Reach 4, North Fork of Woods Creek located between McGimpsey Road crossing and the confluence with Tributary 2 showing existing conditions and proposed enhancement sites immediately upstream of the McGimpsey crossing and a Rock Weir originally constructed in 2000.

5.2.2.3 Reach 5 (2+170 – 3+040)

Description

With a gradient of 1-2 %, Reach 5 contains some of the lowest gradient mainstem channel observed in the study area. The low channel gradient coupled with, pure sand alluvium, and high frequency of beaver dams and log jams has created a wide, sinuous and shallow channel form that characterizes this reach (Photo 17). Although canopy cover remains at 50 %, recent logging activity along the south (right) bank appears to have contributed to riparian tree windthrow resulting in augmented in-channel woody debris recruitment (Photo 18).

Active and historical beaver dams are prevalent throughout the reach that is partially responsible for the high % pool area. The beaver dam activity, sandy alluvium, and windthrow recruitment have undermined the function of the two rock weirs constructed in this reach in 1999/2000 (Figure 11). A detailed discussion of weir function is provided in Section 5.3.

The riparian vegetation canopy is composed of mature second growth mixed coniferous/deciduous Douglas fir, grand fir, red cedar, alder, and coastal western hemlock with an understory of swordfern, salmonberry, red osier dogwood, and hardhack.

Habitat Assessment Results

Reach 5 (Table 9) has an average wetted width of 11 m, and bankful width of 15.5 m resulting in a 71 % wetted area for a *Fair* rating. Pool % Area is approximately 50 % throughout the reach as a result of a relatively high beaver dam and log jam frequency resulting in a *Fair* rating. Reach 5 is the reach with the highest per bankful width frequency of LWD at 7.61/bfw. Stream cover is *Fair* at 20% and crown cover is *Good* at 50 % largely because of the relatively dense growth of the recovering 2nd growth stand. Substrates are dominated by fines with little to no gravel or boulder presence (Photo 17).

The primary limiting factors in this reach include the dominance of fine sandy substrates and lack of spawning gravel and boulder cover. Because of the fine substrates and low gradient channel form it is not recommended that the existing weirs be repaired or that additional restoration/enhancement be prescribed for this reach.

Table 9. Habitat Ratings for Reach 5.

Habitat Parameter	Reach 5 NF3	Ratings	
% Pool Area	50.00	3	Fair
LWD/BFW	7.61	1	Good
% Stream Cover	20.00	3	Fair
Avg % Boulder	0.00	5	Poor
Average % Fines	100.00	5	Poor
Average % Gravel	0.00	5	Poor
% Wetted Area	70.97	3	Fair
% Crown Cover	50.00	1	Good
Erosion Sites	0	0	0
Obstructions	6	6	0
Totals		32	Poor

Photo 17 & 18. View downstream of the wide, sinuous, low-gradient channel in Reach 5 (above left) with high frequency beaver dam and LWD recruitment (above right). Feb. 12, 2020.

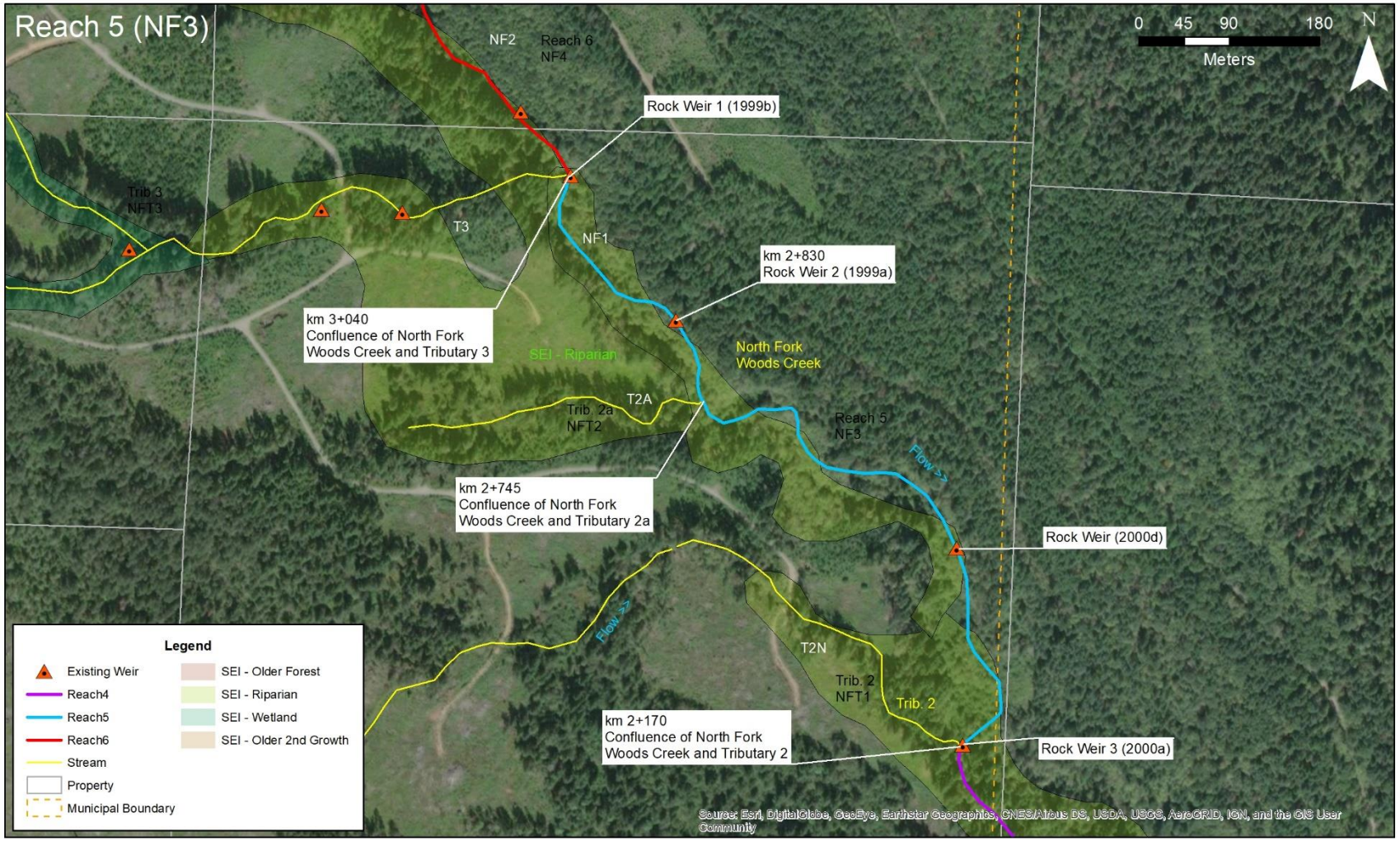


Figure 11. Reach 5, North Fork of Woods Creek located between the confluences of Tributary 2 at the downstream end near km 2+170, and Tributary 3 at the upstream end near km 3+040 showing existing conditions and proposed enhancement sites.

5.2.2.4 Reach 6 (3+040 – 3+535)

Description

Reach 6 stretches from the confluence of Trib 3. and the North Fork channel near km 3+040 upstream to a channel form change associated with beaver dam presence near km 3+535. The assessed reach 6 contains the most contiguous stretches of spawning grade substrate in the entire north fork channel (Photo 19). The presence of exposed spawning gravel can be associated with the steeper channel gradient, relative lack of beaver dam activity, and lower log jam frequency to detain fines associated with windthrow from nearby forest harvesting practices that characterize Reaches 4-5 by contrast.

Reach 6 contains some of the more contiguous older forest canopy in its riparian area along the North Fork (Photo 20). The remaining riparian forest around Reach 6 is approximately 80-100 years old and dominated by Douglas fir with subdominant grand fir and big leaf maple and an understory of dull Oregon grape, oceanspray, salal, and swordfern. Some younger stands are present, particularly in the northern half of the reach, and appear to be 20-30 years old.

Reach 6 is dominated by riffle habitat in its downstream half, and glide in its upstream with an average 2% gradient that contains negligible pool area, an average wetted width of 3 m and a substantial bankful width of 11.3 m vegetated with facultative hydrophytes that inundates under higher flow conditions (Photo 21). Reach 6 contains some suitable spawning grade gravel with the highest concentration in the mid habitat units.

Habitat Assessment Results

The bankful versus wetted areas of Reach 6 (Table 10) resulting in a 39 % wetted area for a *Poor* rating. This relatively low wetted area is in part the result of the flows observed during site assessment being located within a well defined, deeper channel centred around the thalweg (avg depth 0.3 m) with a well-developed floodplain area that receives flow during peak discharge. In addition, Pool % Area is also considered *Poor* mostly because of a dominance of riffle/glide habitat, and relative lack of beaver dams and log jams that commonly create pools in other reaches of the North Fork. Boulder cover is rated *Poor* while LWD achieves a *Good* rating. Large diameter tree fall associated with the maturing canopy provides good cover from instream LWD (Photo 22). Both gravel and fine substrates are present at approximately 30 % for *Fair* and *Poor* ratings, respectively. Overall, the reach receives a *Poor* rating but has good enhancement potential with respect to the gradient, good canopy cover (30%), and presence of gravels that lend to construction of restoration features to augment available spawning and rearing habitats (Section 6).

The limiting factors to fish productivity in Reach 6 are low % pool area, high % fines, low boulder cover, and low % wetted area. However, Reach 6 had one of the most intact canopies of any assessed reach and also contained suitable spawning substrates should migrating coho reach this upstream end of the watershed.

Table 10. Habitat Ratings for Reach 6.

Habitat Parameter	Reach 6 NF4	Ratings	
% Pool Area	0.00	5	Poor
LWD/BFW	3.29	1	Good
% Stream Cover	10.00	3	Fair
Avg % Boulder	0.00	5	Poor
Average % Fines	30.00	5	Poor
Average % Gravel	30.00	3	Fair
% Wetted Area	38.94	5	Poor
% Crown Cover	30.00	1	Good
Erosion Sites		0	0
Obstructions	0	0	0
Totals		28	Poor

Photo 19 & 20. Example of spawning quality gravel substrate present in Reach 6 (above left); and older mixed riparian canopy present near the left bank with younger deciduous stand in background (above right) Feb. 12, 2020.

Photo 21 & 22. Views upstream of relatively wide bankful channel width compared to wetted width resulting in a *Poor* % wetted area calculation (above left), and *Good* LWD frequency associated with the mature forest canopy (above right).

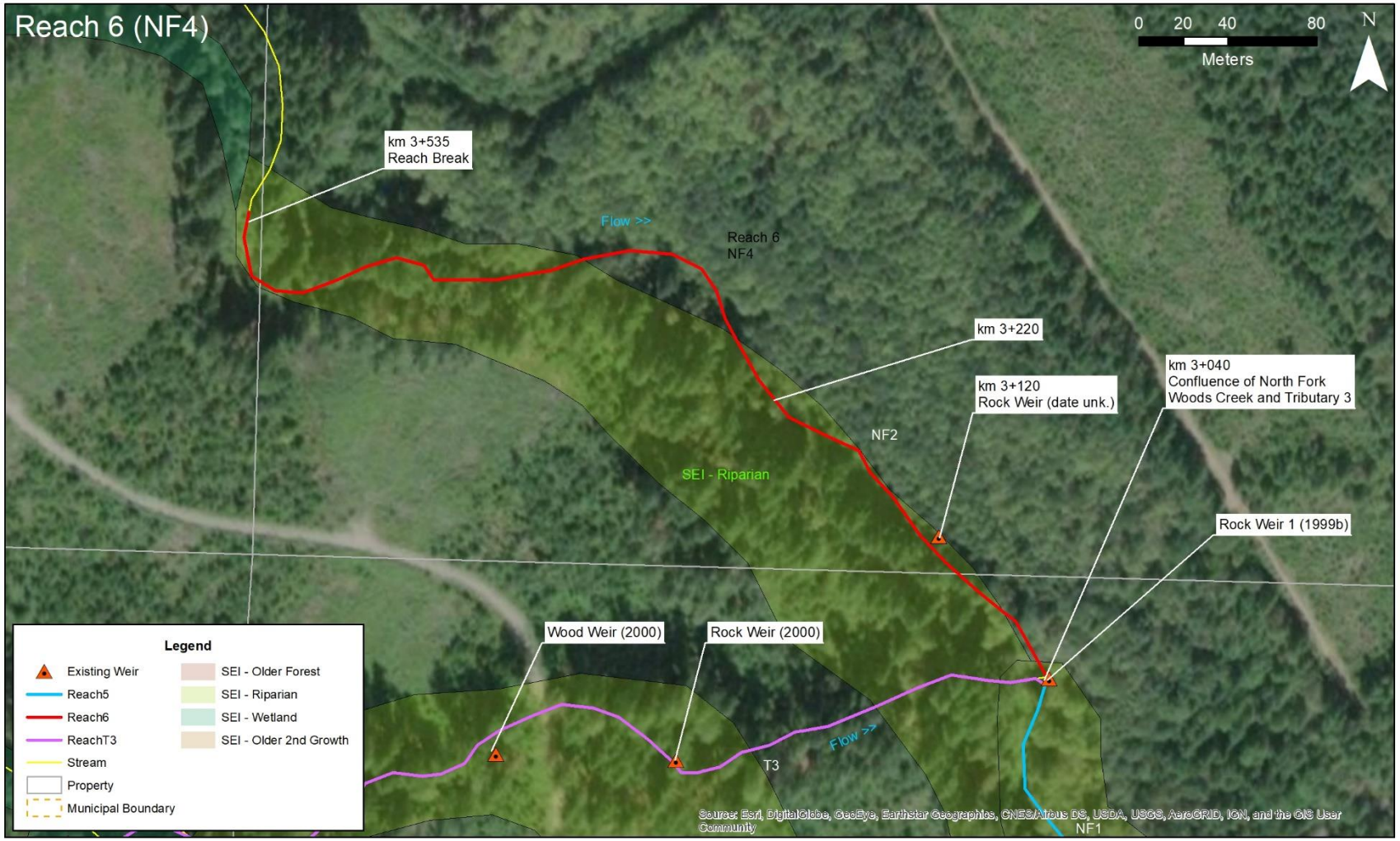


Figure 12. Reach 6, North Fork of Woods Creek located between the confluences of Tributary 3 at the downstream end near km 3+040, and wetland form habitat at the upstream end near km 3+535 showing existing conditions.

5.2.2.5 Reach 7 (3+535 – 4+135)

Description

This furthest upstream assessed reach of mainstem Woods Creek is surrounded by a 6.9 ha wetland complex described by the Sensitive Ecosystem Inventory in 2004 as a wetland:swamp (Polygon: S0654) (Photo 23). Based on site-observations the wetland form appears to be related in part to beaver activity and presence of log jams; with some substantial old dams having been observed. As the methods employed in this assessment are specific to stream channels, the wetland form surrounding Reach 7 was not assessed in detail.

Generally, the assessed Reach 7 habitat units had a well-defined wetted width while peak flows will activate the wider floodplain area inhabited by facultative hydrophytic vegetation (Photo 24). Substrates are dominated by fines with few small pockets of small gravel (cutthroat spawning potential) where flow velocities are highest. Overall, the prevalence of wetland/floodplain morphology is dictated by beaver dam activity while supporting a small proportion of stream channel characteristics.

In-stream vegetation includes slough sedge, common rush, skunk cabbage, and small flowering bulrush on the sandy floodplain. Riparian vegetation has been affected by forest harvesting practices with clearing up to 15 m from the right bank, while the stream banks support a canopy of maturing water tolerant Sitka spruce and red alder canopy species, and an understory of salmon berry, salal, and in low elevation areas thick growth of red-osier dogwood.

Habitat Assessment Results

Reach 7 (Table 11) has an overall *Fair* habitat rating in large part to the amount of % wetted and % pool areas contributed by beaver dam activity causing substantial areas of backwatering, as well as Good overhanging and canopy cover. Although considered Fair, the pool dominated habitat of this reach is best suited to rearing juvenile salmonids as spawning habitat is nearly non-existent. However, the presence of a series of beaver dams could have a marked effect on juvenile salmonid migration as the beaver dams are likely partial seasonal obstructions.

Although some glide habitat is present in its lower half, the Reach is dominated by pool habitat overall and is reflected in the Pool % Area being *Good* at 80 %. The maturing mixed canopy provides decent LWD recruitment, achieving a *Good* rating at over 7 pieces of LWD/BFW, while boulder cover and gravel substrates are largely non-existent for *Poor* ratings. Crown cover is *Good* at 40 % largely because of the maturing mixed deciduous/coniferous riparian vegetation that characterizes both banks of the habitat unit (Photos 23 & 24).

The primary limiting factors in this reach include low summer flows, lack of boulder cover, low % gravel and high % fine substrates. The volume and extent of pooling water is beneficial in this reach where spawning grade material is absent as it will help increase the hydroperiod downstream with slower releases of impounded water during the dry summer season. Based on the presence of beaver activity and lack of spawning habitat potential, no enhancement is recommended in this reach.

Table 11. Habitat Ratings for Reach 7.

Habitat Parameter	Reach 7 NF5	Ratings	
% Pool Area	80.00	1	Good
LWD/BFW	7.85	1	Good
% Stream Cover	25.00	1	Good
Avg % Boulder	0.00	5	Poor
Average % Fines	80.00	5	Poor
Average % Gravel	10.00	5	Poor
% Wetted Area	18.75	5	Poor
% Crown Cover	40.00	1	Good
Erosion Sites	0	0	
Obstructions	3	3	
Totals		**27**	Fair

Photo 23 & 24. View upstream of Reach 7 near km 3+925 (above left) showing typical wetland habitat formed by downstream beaver dams that characterize the reach, and flows through the wetland swamp in the sampled habitat unit showing floodplain inhabited by facultative hydrophytes activated under peak flows (above right). Feb. 12, 2020.

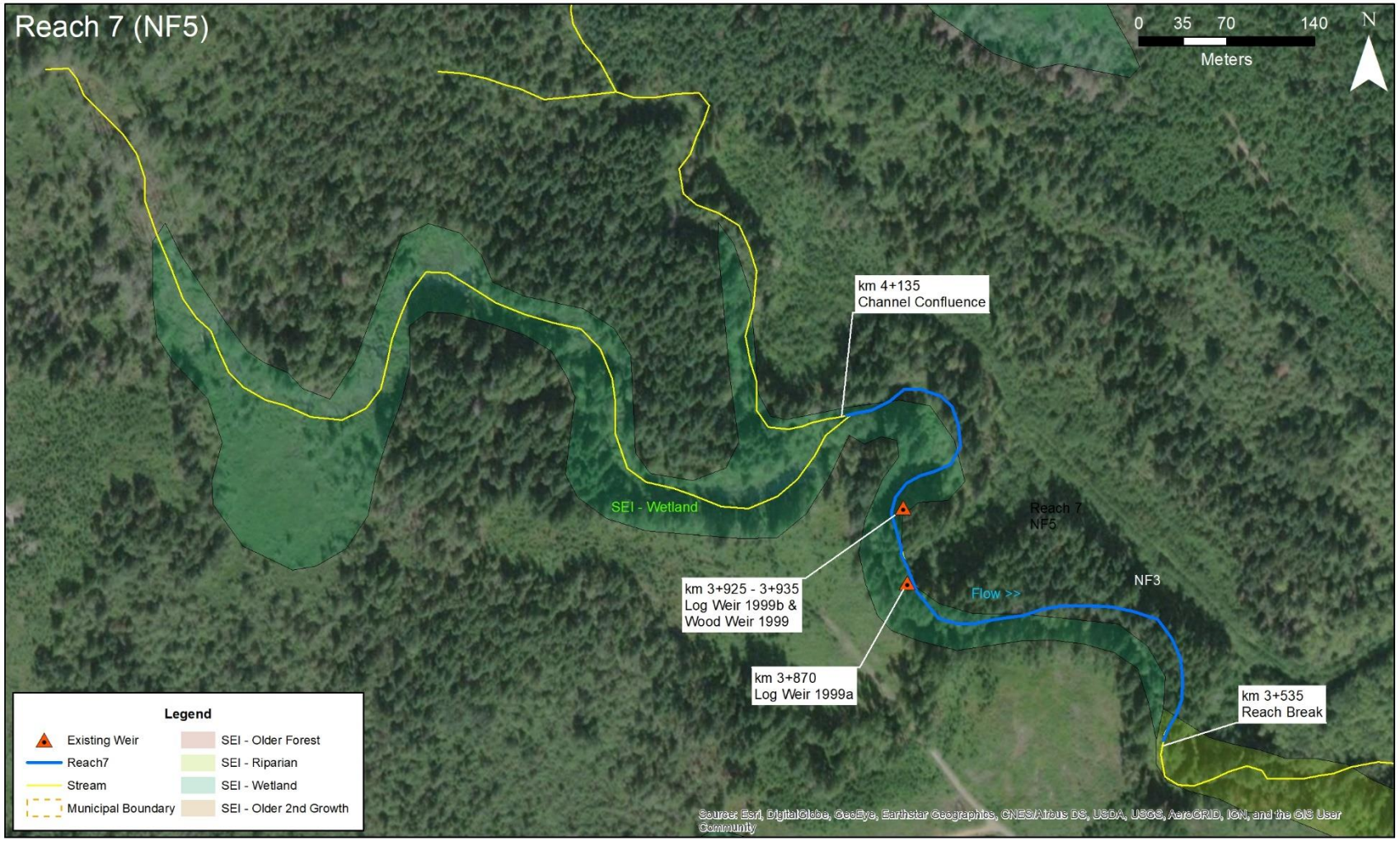


Figure 13. Reach 7, North Fork of Woods Creek located upstream of km 3+535 containing wetland habitat formed by beaver dam activity.

5.2.3 South Fork Channels

5.2.3.1 Reach 8 (km 1+400 - 1+865)

Reach 8 is the lowermost reach in the South Fork of Woods Creek with chainage continuing from its confluence with the North Fork at km 1+400. Forest harvesting in the upper section of this reach appears to be responsible for high LWD recruitment from windthrow causing a series of log jams and partial barriers to fish migration, as well as increasing entrainment of fine sediments (Photos 25-27).

Existing riparian vegetation is composed of a maturing stand of 2nd or 3rd growth mixed coniferous/ deciduous forest with a canopy dominated by Douglas fir, grand fir, coastal western hemlock, western red cedar, big leaf maple, and alder; with an understory of swordfern, salmonberry, and salal. Clearing has occurred up to approximately 15 m of the south bank along the southern side of the lowermost habitat units.

Fine, sandy substrates dominate the South Fork channels including Reach 8. Limited areas of exposed gravels and cobbles are present in sections of the reach with slightly steeper gradient suitable for spawning salmonids.

Habitat Assessment Results

Reach 8 (Table 12) has an overall *Poor* habitat rating resulting from low % wetted and % pool areas and high % fines. Although the south bank has been impacted by recent forest harvesting practices overhead cover is rated *Good* at an average 40 % and instream cover provided primarily by overhanging vegetation with some LWD for a *Fair* rating at 17 %. LWD frequency, however, is rated *Poor* at 0.8 pieces per bankful width. As a result of the high percent fines and lack of pool area this reach is best suited to juvenile salmonid rearing (Photo 28).

The primary limiting factors in this reach include low summer flows, lack of pool area, and low % wetted area, low % boulder cover and gravels, dominated by high % fine substrates. The presence of high % fine substrates is exacerbated by a series of log/debris jams impounding fine alluvium that would otherwise flush downstream during periods of higher flow. These log/debris jams are likely partial obstructions to adult fish passage and recommendations to improve passage are provided in Section 6.

Table 12. Habitat Ratings for Reach 8

Habitat Parameter	Reach 8 SF1	Ratings	
% Pool Area	24.07	5	Poor
LWD/BFW	0.82	5	Poor
% Stream Cover	17.45	3	Fair
Avg % Boulder	0.00	5	Poor
Average % Fines	85.00	5	Poor
Average % Gravel	5.00	5	Poor
% Wetted Area	67.80	5	Poor
% Crown Cover	40.00	1	Good
Erosion Sites	0	0	0
Obstructions	4	4	0
Totals		**38**	Poor

Photo 25-26. View upstream of one of a series of log jams between km 1+465 – 1+505 resulting in part from windthrow related to forest harvesting practices along the right bank of the upstream end of Reach 2 (above left; Nov. 26, 2019), and entrained sediment upstream of the same log jam inundating gravels (above right; Nov. 26, 2019).

Photo 27-28. View south of right bank canopy taken from the South Fork stream channel of Reach 8 near km 1+460 showing the riparian canopy impacted by windthrow resulting from forest harvesting practices (above left; Sept. 23, 2020), and typical channel morphology of the sampled habitat unit near km 1+500 (above right; Sept. 23, 2020).

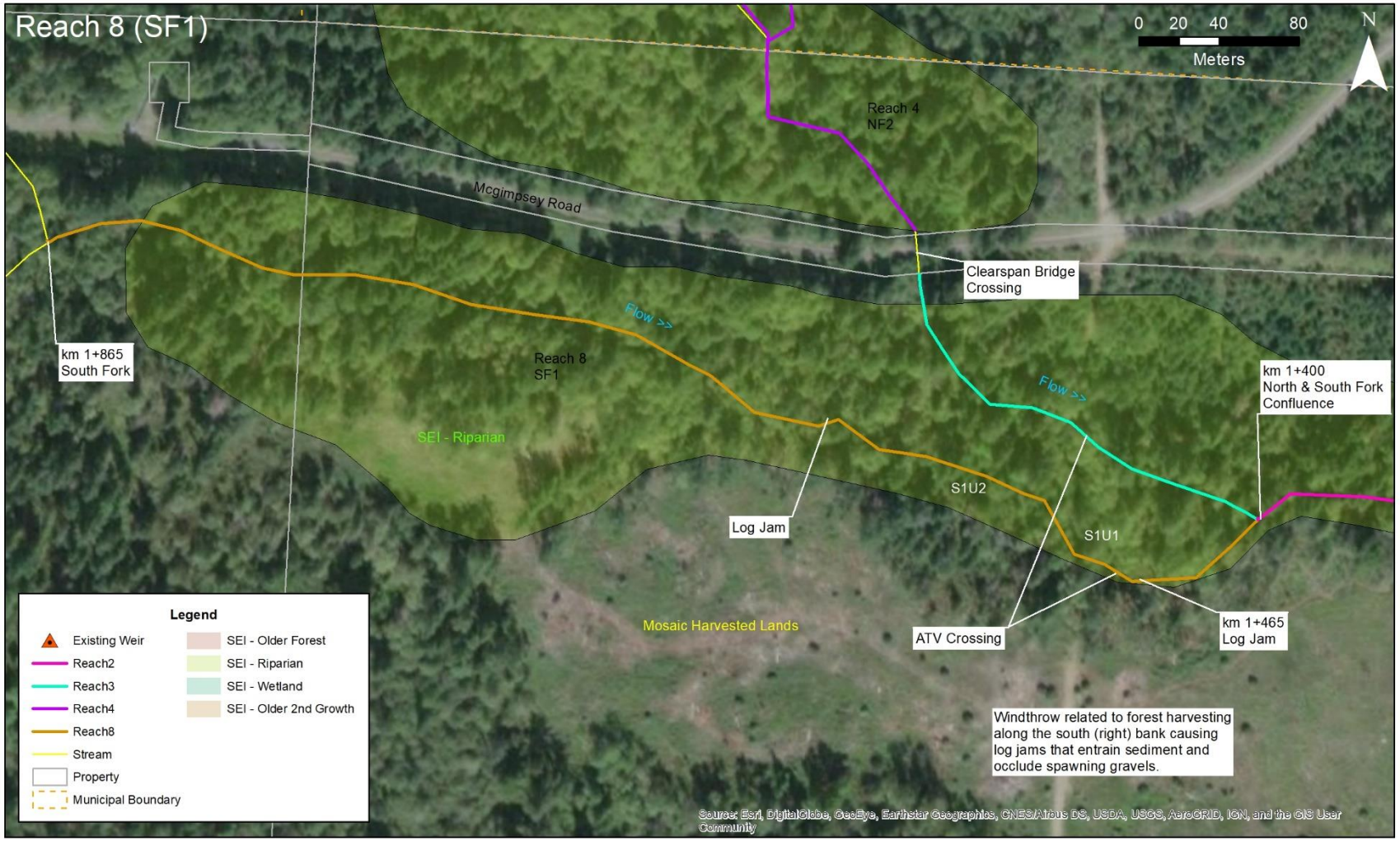


Figure 14. Reach 8, South Fork of Woods Creek located upstream of the confluence with the North Fork at km 1+400 showing existing condition.

5.2.3.2 Reach 9 (km 1+865 – 3+295)

Reach 9 is the uppermost reach in the South Fork of Woods Creek that encompasses the majority of channels on Storey Creek Golf Course (SCGC) with chainage starting at km 1+865 in the South Fork (Figure 15). In general, the riparian area surrounding Woods Creek and its tributary channels on SCGC are relatively intact with average depths of 17 m to 19 m on the left and right banks of assessed habitat units, respectively. The riparian canopy is composed of maturing second growth coniferous Douglas fir forest with patches of deciduous red alder in water collecting sites, and an understory of salal, dull Oregon grape, salmon berry, and swordfern (Photos 29-30).

Similar to Reach 8 located downstream, fine, sandy substrates dominate the South Fork channels including Reach 9. Limited areas of exposed gravels and cobbles are present, including some sections that have been subject to past enhancement works (Photo 32; described in Section 2.4).

Habitat Assessment Results

Reach 9 (Table 13) has an overall *Poor* habitat rating resulting from low LWD frequency, limited boulder and gravel, and high percent fine substrates. Although canopy cover over some sections of assessed reaches has been impacted by clearing for golf course operation (Photo 31), overhead cover is rated *Good* at an average 30 % and stream cover provided primarily by overhanging vegetation for a *Fair* rating at 18 %. Reach 9 contains high percent fines, limited spawning potential, and a *Fair* % pool area rating that is augmented by an existing wooden weir at km 2+670 resulting in habitat best suited to juvenile salmonid rearing.

The weir at km 2+670 is a partial obstruction to fish passage (juvenile migration) and recommendations to improve passage are provided in Section 6.

Table 13. Habitat Ratings for Reach 9

Habitat Parameter	Reach 9 SF2	Ratings	
% Pool Area	48.02	3	Fair
LWD/BFW	0.34	5	Poor
% Stream Cover	18.38	3	Fair
Avg % Boulder	0.18	5	Poor
Average % Fines	82.00	5	Poor
Average % Gravel	14.00	5	Poor
% Wetted Area	71.53	3	Fair
% Crown Cover	30.00	1	Good
Erosion Sites	1	1	0
Obstructions	0	0	0
Totals		**31**	Poor

Photo 29-30. View upstream of higher gradient channel in the downstream habitat unit showing good riparian depth and stream substrates that include gravel and fines (above left; Jan. 28, 2019), and lower gradient channel in an upper habitat unit backwatered by a wooden weir near km 2+670 (above right; Jan. 28, 2019).

Photo 31-32. Upper habitat unit flowing through golf course fairway showing cleared riparian vegetation (above left; Jan. 28, 2019), and tributary channel enhanced with series of small rock weirs near habitat unit GC5N (above right; Jan. 28, 2019).

Figure 15. Reach 9, South Fork of Woods Creek located on Storey Creek Golf Course upstream showing existing conditions.

5.2.4 **Tributary Channels**

Four small tributary channels feed into both South and North forks, with Trib. 1 flowing along the northern boundary of Storey Creek Golf Course and entering the South Fork near km 1+865 (Figure 15); while Trib's 2, 2a, and 3 flow into the North Fork near km 2+170, 2+745, and 3+040, respectively (Figures 1 & 11).

For consistency of reference, tributary nomenclature follows existing mapping produced by Greenways Land Trust and others (Figure 3).

5.2.4.1 Tributary 1

Tributary 1 is located along the northern boundary of Storey Creek Golf Course, has a man-made channelized form, over its 1.3 km length (Figure 15; Photo 33). The tributary channel has an average bankful width of 1.1 m, and depth of 0.2 m. Tributary 1 flows seasonally and has a young, maturing mixed canopy with overhanging vegetation along its banks. A section of the tributary channel that parallels the driving range has a riparian area that has been cleared to within 3 m of the right bank. The golf course operations manager has indicated that approximately 60 cedar trees will be planted along the southern edge of existing vegetation that will provide enhanced riparian depth.

Photo 33. View downstream of the Tributary 1 channel taken from near the Storey Creek Golf Course driving range (right of image) showing channelized form and status of riparian vegetation.

5.2.4.2 Tributary 2

Tributary 2 has its confluence with the North Fork of Woods Creek near km 2+170 (Figure 11). The tributary channel is approximately 800 m long and has a bankful width of 3.0 m and average depth of 0.14 m. In general, the tributary's riparian canopy is relatively intact in only the lower 40 m at its downstream end near the confluence with the North Fork (Photo 34), whereas the majority of the upstream habitat units have been heavily modified by recent forest harvesting practices that have cleared up to the top-of-bank in places (Photo 35).


Photo 34 & 35. View downstream of Tributary 2 channel near its confluence with the North Fork of Woods Creek (above left) and a section of an upper habitat unit showing impacts from forest harvesting practices at a decommissioned road crossing site (above right).

5.2.4.3 Tributary 2a

Tributary 2a has its confluence with the North Fork of Woods Creek near km 2+745 (Figure 11). This tributary is approximately 320 m long and has a relatively steep gradient at 3-5 % with a series of small cascades over debris jams in the lower habitat units (Photo 36). The tributary has an average bankful width of 2 m, depth of 0.2 m, and contains some small pool areas upstream of debris jams. Although forest harvesting has taken place nearby, the majority of the channel's banks maintain a younger mixed forest canopy and relatively thick overhanging vegetation. Tributary 2a flows seasonally and provides limited direct fish habitat function. No fish were caught here during trapping effort in Feb. 2020.

Photo 36. View upstream of Tributary 2a showing small cascades over debris jams located approximately 40 m upstream of the channel's confluence with the North Fork of Woods Creek.

5.2.4.4 Tributary 3

Tributary 3 is the largest tributary channel in the assessed area of Woods Creek with an approximate length of 2 km, and assessed habitat unit width of 7 m; while large areas of wetland habitat are contained upstream within 7.2 ha of mapped SEI polygons S0656 & S0766A (Figure 16). A series of weirs were installed in the lower reach in 2000 that area detailed in Section 6. Given its history as a restoration reach and substantial catchment and wetland areas, the lower 475 m of Tributary 3 has been

assessed alongside mainstem reaches using project methods. Upstream of km 0+475 in the tributary reach substantial wetland habitat, introduced above, is backwatered by beaver dams and have not been directly assessed (Photo 38).

The riparian area of the assessed reach of Tributary 3 is partially disturbed from nearby forest harvesting practices that have been historically cleared up to 15 m from the high-water mark of both banks. The channel resides within a shallow ravine, however, and the banks remain well vegetated and provides *Good* canopy cover (Photo 37). The frequency of LED is also *Good* at 8.3 pieces per bankful channel width.

Limitations to fish productivity include *Poor* % pool area as the assessed habitat unit is dominated by glides, and *Poor* % wetted area as a relatively wide floodplain appears to only become activated during periods of high flow. Sandy fine dominated substrates are also *Poor*, while % gravels is *Fair,* and lack of boulder cover also receives a *Poor* rating.

Table 14. Habitat Ratings for Reach T3

Habitat Parameter	Reach T3	Ratings	
% Pool Area	0.00	5	Poor
LWD/BFW	8.31	1	Good
% Stream Cover	25.00	1	Good
Avg % Boulder	0.00	5	Poor
Average % Fines	60.00	5	Poor
Average % Gravel	40.00	3	Fair
% Wetted Area	18.75	5	Poor
% Crown Cover	40.00	1	Good
Erosion Sites	0.00	0	0
Obstructions	0.00	0	0
Totals		**26**	Fair

Photo 37 & 38. View upstream of assessed habitat unit located near km 3+195 showing well vegetated banks and sand dominated substrates (above left), and wetland habitat catalogued in SEI Polygon S0656 located upstream of a beaver dam built on the site of Rock Weir 2000c (above right).

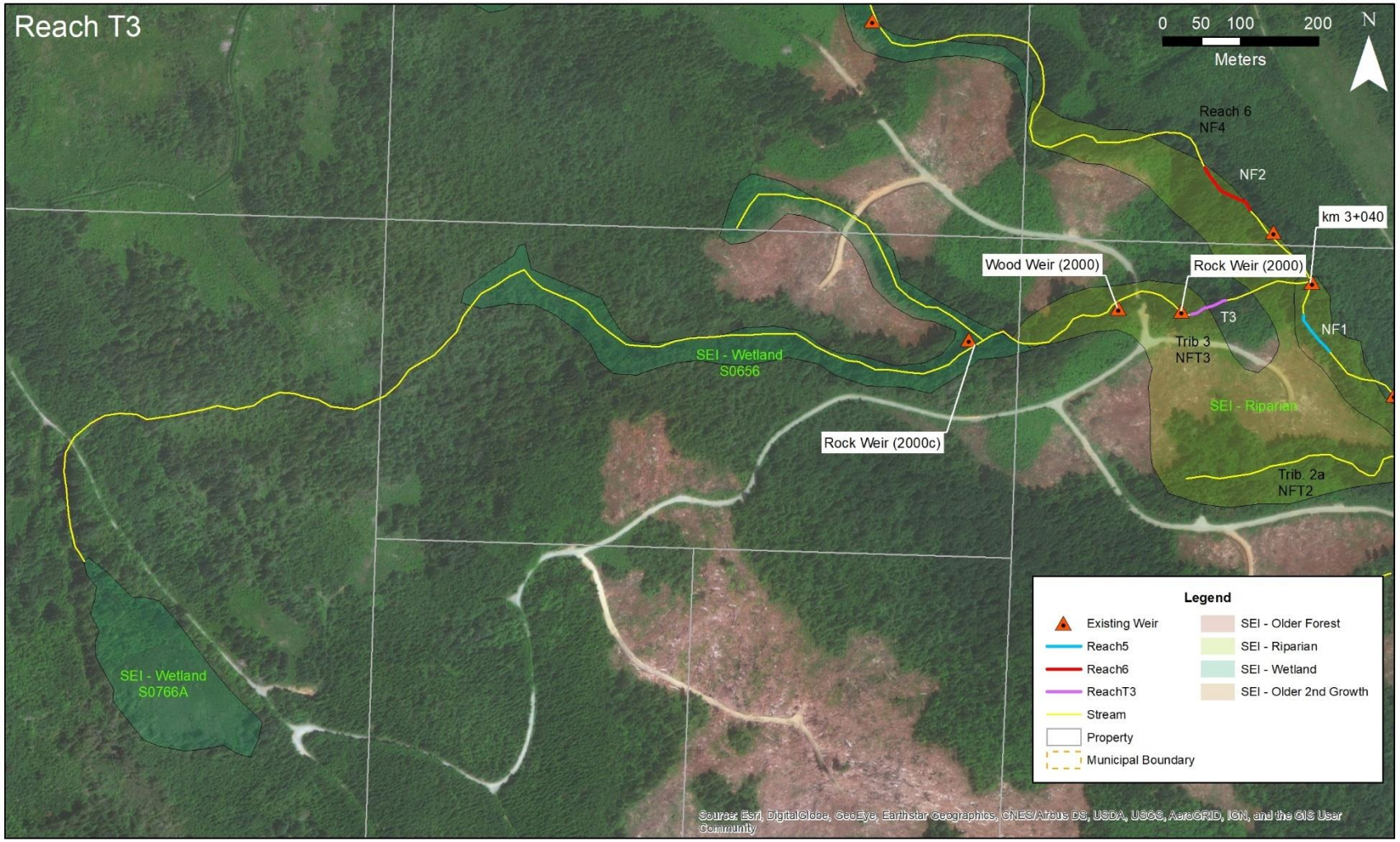


Figure 16. Tributary 3 channel, with its confluence at km 3+040 with the North Fork of Woods Creek showing existing conditions.

5.3 Existing Weirs Condition Assessment

A series of weirs have been installed in the Woods Creek system over the past 20+ years (Section 2.4) for the purposes of engaging summer low flow water retention and percent pool area, augmenting spawning habitat, improving passage, and as infrastructure related to counting fences that have been historically operated near the mouth of the Creek. In the intervening years since their establishment many of these features have fallen into disrepair and a better understanding of their current status and recommendations for the maintenance is warranted. Results of this assessment and recommendations are summarized in Table 15.

Furthermore, the Province of BC holds water licenses over a number of these structures and based on correspondence with MFLNRO Senior Aquatic Ecologist (Jaroslaw Szczot, Pers. Comm.[4]) it is understood that the Province is open to discussing the future maintenance and/or abandonment of these structures as it relates to habitat function, recommendations for future enhancement, and licensing. Nomenclature used in the naming of Weir structures is consistent with mapping from Greenways Land Trust (June 2002) based on SHIM 1998 (Figure 3).

[4] Pers. Comm. Jaroslaw Szczot, MFLNRO Senior Aquatic Ecologist. Email Sept. 19, 2019.

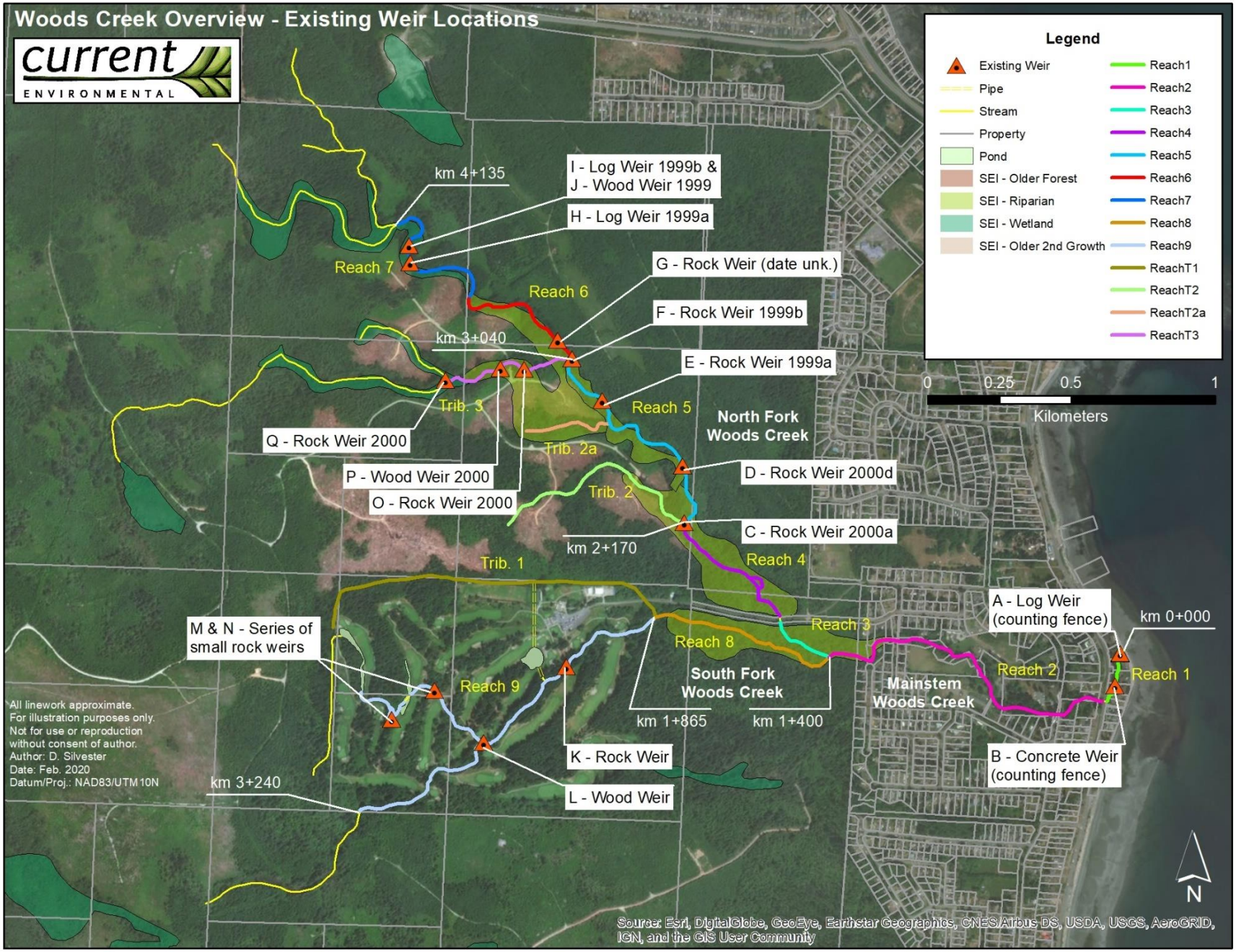


Figure 17. Overview site plan of existing constructed weir locations in the Woods Creek watershed.

Table 15. Summary of existing weir status assessed during Overview/Level 1 Woods Creek including maintenance recommendations.

Weir ID	Reach Location	Chainage (km)	Status	Recommendation
A- Log Weir	Reach 1	0+030	Partial obstruction to fry passage	Remove approx. 30 cm of wooden boards to reduce plunge while maintaining upstream bedload retention (Section 6.1.1)
				
B- Concrete Weir	Reach 1	0+125	Partial obstruction to fry passage	Remove and replace with Newbury style riffle (Section 6.1.1)
				

C- Rock Weir 2000a	Reach 4/5 break	2+170	Maintenance required	Rebuild crest and toe. Lengthen downstream face to reduce gradient/velocities. Nourish upstream face with spawning gravel.
				
D- Rock Weir 2000b	Reach 5	2+400	Channel split at upstream side towards right bank. Some gravel exposed on upstream face partially embedded in sandy alluvium.	Leave in existing state.
				

E- Rock Weir 1999a	Reach 5	2+830	Dysfunctional. 3 m of rock blown out on right bank by high velocity flows. Substrates dominated by fines.	Clean-up and remove. Machine labour required.
				
F- Rock Weir 1999b	Reach 5/6 break	3+040	Dysfunctional. Used as ATV crossing. Some gravel remains present upstream.	Abandon.
				

G- Rock Weir (date unk.)	Reach 6	3+120	Rock stable. High flows charge adjacent floodplain. Spawning gravels remain exposed.	Good condition. Nourish with spawning gravel.
				
H- Log Weir 1999a	Reach 7	3+870	Partial barrier to fry migration. High flows avulsing left bank. Good pool maintained upstream. Reach dominated by fine substrates.	Remove and replace with rock weir (will improve passage but spawning potential limited by sandy alluvium) or remove and abandon.
				

I- Log Weir 1999b	Reach 7	3+925	Intended to backwater upstream wood weir that has failed.	No action required or remove in conjunction with J- Wood Weir 1999 and replace using rock weir/riffle.
				
J- Wood Weir 1999	Reach 7	3+935	Dysfunctional. Right bank avulsed. Upstream water level maintained by hardpan control on right bank.	Remove and replace with rock weir/riffle to maintain upstream water levels in wetland.
 View upstream J- Wood weir 1999 avulsion on right bank. (more photos next page)				

View downstream J- Wood weir 1999 avulsion on right bank (background) and control level provided by hardpan (foreground).

Rock berm on left bank (foreground) used to tie in original wood weir (hidden under fallen tree; background) remains intact and can be used to tie in a new rock weir/riffle K - Rock Weir structure to replace failed wooden weir.

(more photos next page)

View of pool habitat upstream of failed J- Wood weir 1999 that is currently maintained by hardpan control.

K- Rock Weir	Reach 9	2+240	Stable with some structural rock movement. Little gravel remains on upstream face partially occluded by sandy sediment alluvium.	Re-establish riffle face. Armour downstream right bank with LWD habitat feature. Excavate upstream pool and nourish with spawning gravel.

L- Wood Weir	Reach 9	2+675	Partial barrier to juvenile fish migration.	Remove and replace with rock weir/riffle. Maintain control elevation. Build tail out min. 10:1. Excavate bedload upstream.
				
M- Series of small rock weirs	Reach 9	2+945	Stable.	Re-nourish with spawning grade gravel on upstream faces. Upstream culvert outlet perched, and partial barrier consider replacing with clear span and re-instate bed (Section 6).
				

N- Series of small rock weirs	Reach 9	3+155	Weirs stable with exception of one creating a plunge drop that is likely partial barrier to juvenile migration (not shown).	Regrade weir causing partial barrier by placing additional rock(s) and re-nourishing with spawning gravel.
				
O- Rock Weir 2000	Trib. 3	3+220	Weir used as trail crossing site. Rock stable with little to no gravel present or obscured by sand.	No action required. Little to no habitat function.
				

P- Wood Weir 2000	Trib. 3	3+320	Wood sill control elevation absent (rotten). No function remains. Backwatered by debris jam downstream and beaver dam upstream serving same purpose.	Abandon.
				
Q- Rock Weir 2000	Trib. 3	3+520	Completely obscured by large beaver dam.	No action required.
				

6 Level 2 - Recommended Habitat Enhancement Summary

The limiting factors for fish production identified in this assessment (Section 5) have been used to identify suitable restoration projects for Woods Creek. Reaches 2, 3, and 6 have been identified as being the best candidates for restoration whereas maintenance to existing weirs has been recommended throughout reaches where historical enhancement has taken place. Recommended restoration/ enhancement works are summarized in Table 16 and detailed in the following sub-sections organized by reach.

Table 16. Summary of recommended restoration/enhancement projects in the Woods Creek watershed based on Overview/Level 1 results.

Reach	Location (km)	Project Type	Objective(s)	Estimated Salmonid Productivity Increase*	Avg. BFW (m)	Avg. Gradient (%)	Property Ownership	Cost Estimate
1	0+018 (Figure 7)	Remove approx. 30 cm of wooden boards from the control elevation of log weir (A) barrier.	Improve migration for all life stages of salmon and provide additional spawning habitat in lowermost reach.	-	4.9	2.5	Private	$5,000
1	0+135 (Figure 7)	Remove dysfunctional concrete weir (B) barrier and replace with a rock weir/riffle. 1 rock weir/riffle 1 LWD feature	Improve migration for all life stages of salmon and provide additional spawning habitat in lowermost reach.	47 Coho smolt 14 Cutthroat smolt	4.9	2.5	Private	$5,000
2	1+090 – 1+144 (Figure 8)	4 rock weir/riffles 4 LWD features	Enhance spawning & rearing habitats.	188 Coho smolt 56 Cutthroat smolt	5.7	3.5	SRD Park	$18,000
3	1+570 – 1+625 (Figure 9)	2 rock weir/riffles 2 LWD features	Enhance spawning & rearing habitats.	94 Coho smolt 28 Cutthroat smolt	5.7	3.5	Mosaic	$9,000
4	1+650 (Figure 10)	1 rock weir/riffle 1 LWD feature	Moderate flow velocities affecting McGimpsey bridge crossing and causing downstream scour. Enhance spawning & rearing habitats.	47 Coho smolt 14 Cutthroat smolt	7	2.7	MOTI (Potential for in-kind $s)	$5,000

4	2+170 (Figure 10)	1 rock weir/riffle 2 LWD feature	Repair and enhance rock weir/riffle (C) constructed in 2000.	70 Coho smolt 21 Cutthroat smolt	7	2.7	Mosaic	$5,000
5	2+830 (Figure 11)	Remove dysfunctional weir filter fabric and armour left bank with remnant angular rock.	Deactivate dysfunctional weir (E) and remove waste from stream channel.	-	15.5	1	Mosaic	$2,000
6	3+120-3+220	3 rock weir/riffles	Enhance spawning & rearing habitats in reach with suitable gradient and coarse substrates.	141 Coho smolt	11.3	2	Mosaic	$21,000
6	3+120 (Figure 12)	1 rock weir/riffle	Repair and enhance rock weir/riffle (G) constructed in 2000.	47 Coho smolt 14 Cutthroat smolt	11.3	2	Mosaic	$7,000
7	3+870 (Figure 13)	1 rock weir/riffle or remove and abandon.	Deactivate log weir and replace with rock weir/riffle or remove and abandon.	-	16	1	Mosaic	$7,000
7	3+925 – 3+935 (Figure 13)	Replace dysfunctional wood weir (J) with rock weir/riffle. 1 rock weir/riffle	Deactivate weir prior to complete failure an replace with rock weir/riffle that will maintain control elevation and offer enhanced spawning potential.	47 Coho smolt 14 Cutthroat smolt	16	1	Mosaic	$7,000
8	1+465 - 1+505 (Figure 14)	Remove sections of log/debris jams using hand tools and manual labour.	Improve fish migration and re-expose potential spawning habitat.	94 Coho smolt 28 Cutthroat smolt	2.95	2.25	Mosaic (+ DFO CA Technical Support)	$1,500
9	2+240 (Figure 15)	1 rock weir/riffle	Repair and enhance rock weir/riffle (K). Excavate accumulated bedload from upstream pond to increase rearing capacity.	47 Coho smolt 14 Cutthroat smolt	5.48	1.8	SCGC	$7,000
9	2+670	Replace wood weir (L) with rock weir/riffle. Excavate accumulated bedload from upstream pond.	Improve migration for all life stages of salmon and provide	47 Coho smolt	5.48	1.8	SCGC	$12,000

	(Figure 15)	1 rock weir/riffle	additional spawning habitat in uppermost reach of South Fork.	14 Cutthroat smolt				
9	2+745 (Figure 15) NW Branch	Perched culvert outlet resulting in partial barrier to fish migration.	Replace culvert with clear-span foot bridge crossing to enhance passage for all life stages of salmon.	-	5.48	1.8	SCGC	$5,000
9	2+945 (Figure 15) NW Branch	Series of small rock weirs requiring maintence.	Decommission/replace any relic weirs impeding passage. Enhance potential spawning habitat by re-nourishing existing functional weirs with spawning grade gravel.	-	5.48	1.8	SCGC	$6,000
9	3+155 (Figure 15) NW Branch	Perched weir tail-out resulting in partial barrier to fish migration.	Replace culvert with clear-span foot bridge crossing to enhance passage for all life stages of salmon.	-	5.48	1.8	SCGC	$5,000
9	2+850 – 2+970 (Figure 15)	Deactivate relic beaver dam (2+850) and tote road (2+970) and replace with rock weir/riffle, excavate bedload and replace with spawning gravel. Enhance riparian vegetation.	Improve passage, spawning, and rearing habitat for coho and trout in upper reaches.	94 Coho smolt 28 Cutthroat smolt	5.48	1.8	SCGC	$14,000
Grand Totals	**19 rock weir/riffles** **16 LWD features**	**Grand Totals**		**963 CO smolt** **287 CT smolt**				**$141,500**

* Based on biostandards from Keeley, Slaney, & Zoldokas (1996)

The following subsections provide detailed recommendations of the habitat enhancement/restoration objectives summarized above in Table 16.

6.1.1 Reach 1 (0+018 & 0+135)

The primary limiting factors in this reach are related to a history of disturbance, lack of suitable instream cover from LWD and boulders, low % pool area, and the presence of obstructions to fish passage.

The two weirs located in Reach 1 connected with historical counting fence operations have fallen into disuse and are currently partial barriers to juvenile salmon migration. The wooden weir at km 0+018 is recommended to have approx. 30 cm of wooden boards removed to lower the control elevation to enhance passage for all salmon life stages, while the concrete weir at km 0+135 are recommended to be replaced by Newbury style riffles that will also enhance salmonid passage at all life phases as well as providing additional spawning opportunities in this lowermost reach (Figure 18). The elevations of the upstream weir should be maintained with new riffle crest construction but tailouts extended to facilitate a more gradual downstream face to facilitate migration. The upstream face of the new riffle will be seeded with spawning gravel, and the pool upstream installed with LWD/boulder complexes to provide increased hydraulic complexity and shelter for rearing and migrating adulted spawners (Figures 19 &20).

Riparian reclamation is an important aspect of Reach 1's restoration that will require the removal of a significant amount of invasive plant biomass and replacement with an assemblage of native species able to compete with residual invasive plant presence. A multi-year effort will be required to remove invasive species and provide planted natives with the best chance of survival, with the ultimate goals of providing enhanced overhanging vegetation cover to support salmonid growth and survival through leaf litter and insect drop, shade, and shelter from predation; as well as stream bank resilience against erosive forces.

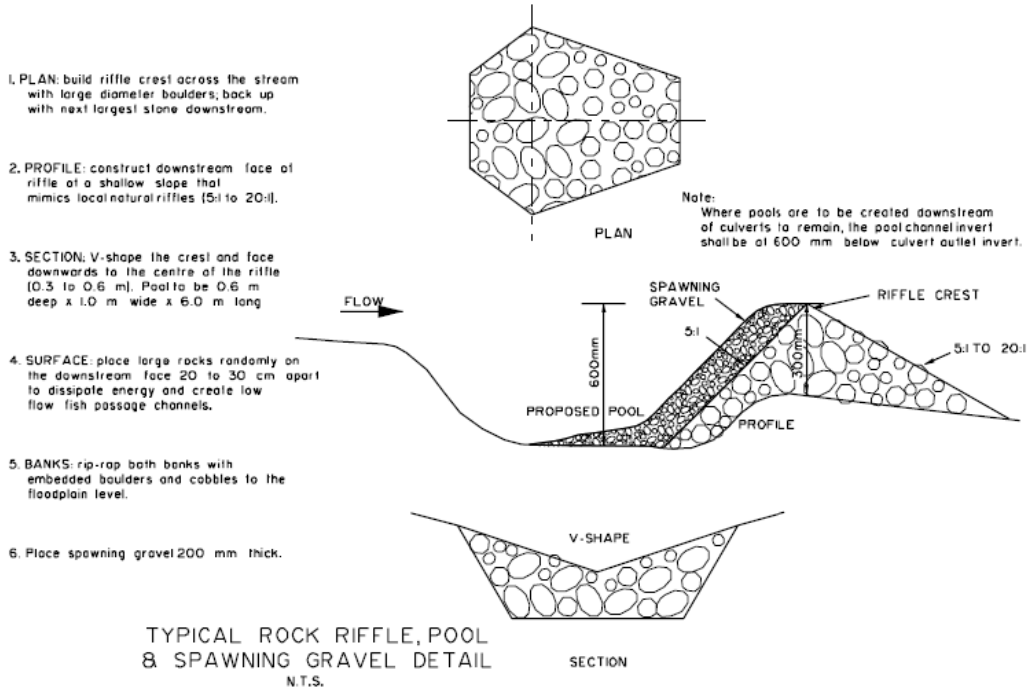
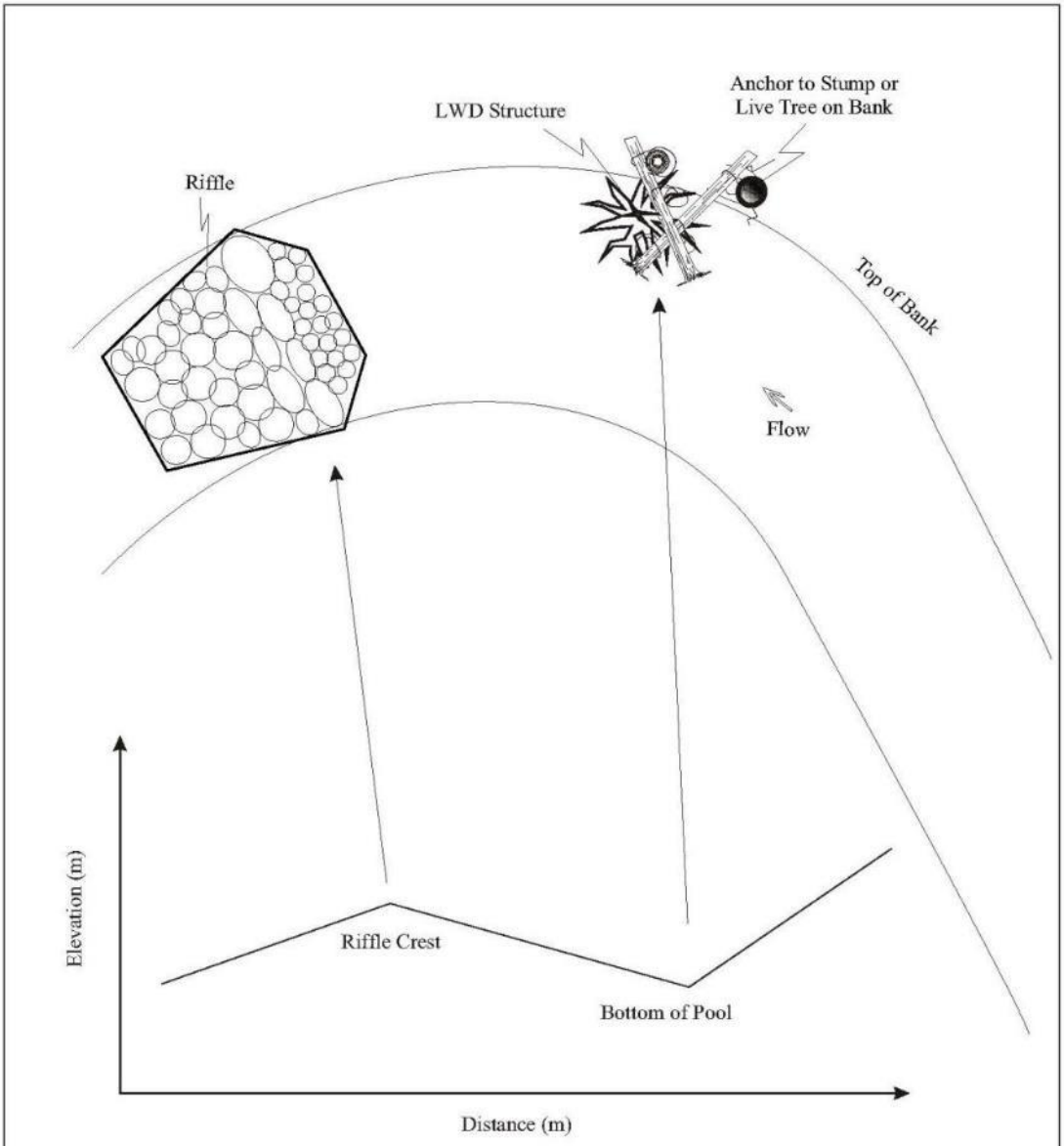


Figure 18. Rock weir/spawning bed conceptual design (adapted from Newbury et al., 1997)



	PLAN AND PROFILE **Typical location of LWD complex installation relative to rock riffle**
adapted from LGL (2002)	Woods Creek Restoration Project

Figure 19. Conceptual layout of rock weir/spawning platform relative to LWD installation.

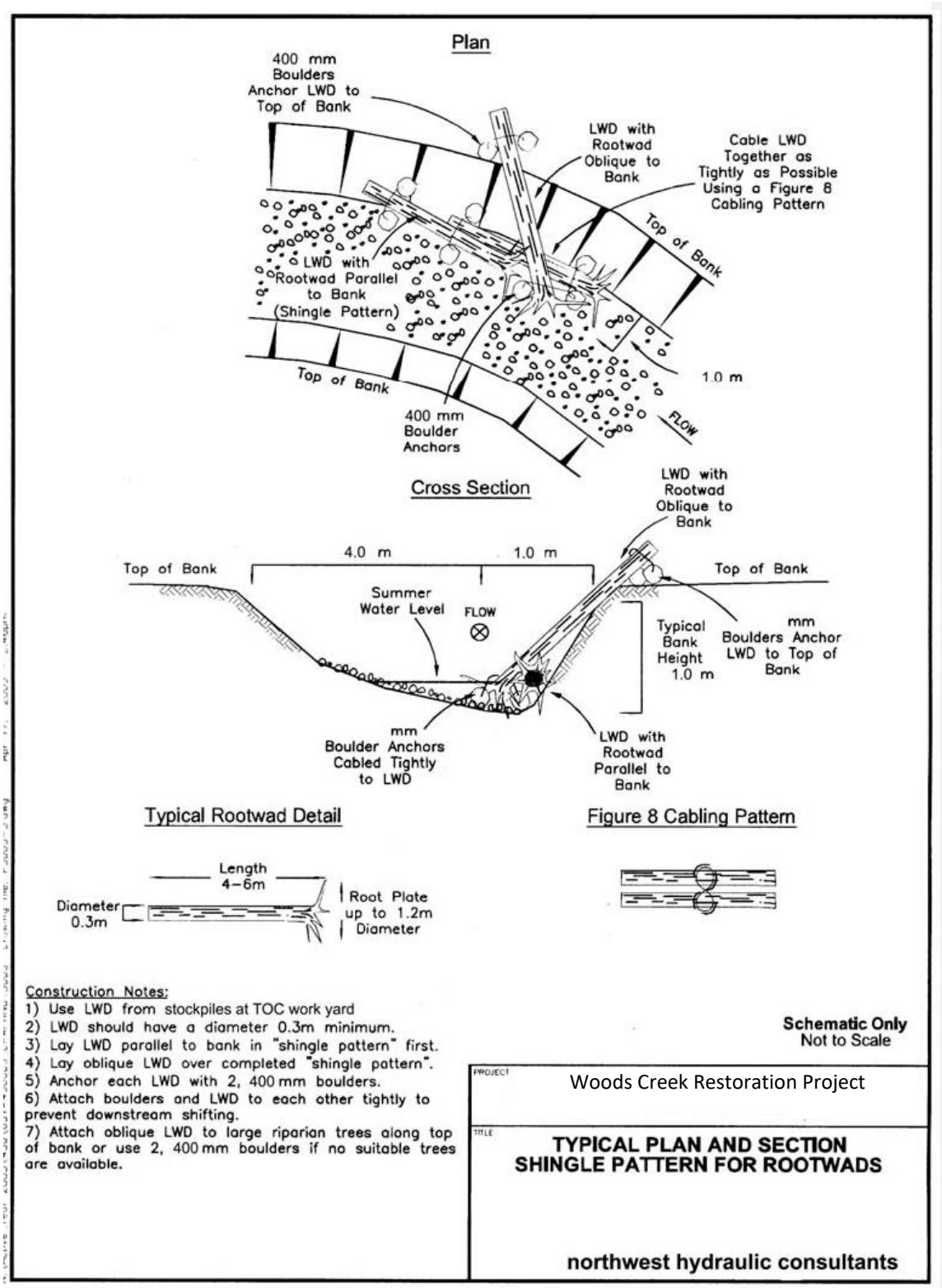


Figure 20. Conceptual design of LWD installation upstream of rock weir/spawning platform shown in Figures 18 & 19 above.

6.1.2 Reach 2 (0+950 - 1+144)

The primary limiting factors to fish productivity in this reach include low summer flows, low % Pool Area, limited LWD frequency and boulder cover, and % wetted area.

These issues can be addressed with enhancement works that include the creation of a well-developed riffle-pool system that will enhance available spawning habitat in a reach that shows sufficient gradient/velocities to maintain a low sediment bedload, include critically lacking LWD/boulder cover within pools, and increase percent pool areas. Constructed Newbury style riffles (Figure 18) provide the added benefit of helping to offset dry-season low flows characterizing the system by impounding water within deeper rearing pools.

Searidge Park, located at the north end of Searidge Plc. between mainstem stations km 1+090 – 1+144, is a 0.12 ha Strathcona Regional District Park surrounding an approximate 54 m mainstem length in Reach 2. Downstream of Searidge Park is a 0.59 ha parcel roughly following the creek alignment with unknown ownership status[5] (Figure 8). The Park and stream parcel with unknown ownership are well suited to enhancement with riffle/pool/spawning platform and LWD complex installations as this section of the subject reach contains low % fines and good gravel recruitment. Seardige Park is conveniently located to provide stream access by machinery for riffle and LWD complex construction, including importation of materials via Searidge Plc.

Furthermore, public support from surrounding landowners may be derived by the ancillary benefits of reduced erosion potential by enhancing hydraulic complexity to limit scour and with riparian enhancement plantings to support the banks. A large, 3.8 ha privately owned lot bearing municipal address 3891 Castle Dr. (PID: 009528431), is located adjacent to the proposed enhancement reach with access from both banks that would be ideal for gaining access at multiple points to the parcel with unknown ownership immediately downstream of Searidge Park.

Given existing bank heights and streambed gradient, a series of four riffle/pool/spawning platforms can be constructed in the approximate 194 m mainstem length between station km 0+950 - 1+144. At a minimum each rock riffle will be preceded by a LWD complex composed of four log/stump members ballasted by boulders at minimum 1.0 m ø (Figures 19-20). Depending on the distance between riffles and need to mitigate areas of bank erosion with revetment structures, additional LWD complexes will likely be field fit during the process of enhancement works.

6.1.3 Reach 3 (1+570 – 1+625)

The primary limiting factors to fish productivity in this reach include low % pool area and % wetted area, the limited suitable instream cover from LWD and boulders, and lack of suitably spawning habitat.

The upper habitat unit from km 1+570 – 1+625 is a higher gradient channel (3-5 %) dominated by coarse substrates and exposed hardpan resulting from higher velocity flows passing through the bridge structure of the McGimpsey Road crossing. Pool frequency and spawning grade gravels are nearly non-existent in this upper half of the reach.

Proposed enhancement works include a series of two spawning riffle/pool/LWD complexes that will function to reduce erosive force by creating a more gently sloping bed profile and moderating velocities

[5] iMap BC. Object ID 376313763. No Crown Parcel ID. No LTSA Parcel ID. Accessed from <https://maps.gov.bc.ca/ess/hm/imap4m/>.

with increased hydraulic complexity in pool/LWD features. Spawning opportunities are lacking in this section of the reach that will be enhanced with spawning grade gravel platforms located at the crest of each riffle. Access is good off McGimpsey road towards the right bank of the subject reach, a location that will also facilitate removal of a log jam causing channel braiding and scour to hardpan near km 1+615. Each riffle will have a LWD complex installed in its upstream pool.

6.1.4 Reach 4 (1+650 & 2+170)

The upstream end of the McGimpsey Road clear span bridge is subject to high velocity flows constricted by rock armouring bridge abutments (Photo 39). The construction of a spawning riffle/pool/LWD complex upstream of the bridge abutments will function to reduce flow velocities passing under the bridge and enhance availability of spawning habitat. Slower flow velocities will help reduce scour affecting the downstream side of the bridge crossing at the upstream end of Reach 3 where bed substrates are currently being scoured down to hardpan. The installation of a riffle complex upstream of the bridge can effectively be linked with the downstream series of riffle complexes in Reach 3, forming an unbroken series of spawning and rearing habitat features.

A rock weir established in 2000 (Greenways Land Trust, 2002; Figure 3) is showing signs of stress where some of the angular rock used to construct the weir has been displaced by high velocity flows and no gravel remains present (Photo 40). Maintenance work on the existing weir should include rebuilding the crest using larger diameter round rock imbedded into stream substrates and keyed in on either bank immediately upstream of the existing crest. The face of the riffle will be extended an additional 5 m downstream and keyed in with larger rock ~ 1 m ø to reduce the slope of the existing rock that appears to be contributing to increased flow velocities that have undermined the weir's stability. The finished restructuring should provide an overall riffle length of approximately 12 m, compared to the existing 5 m length, while the crest elevation will be maintained. The upstream face will be nourished with spawning grade gravel to produce a spawning platform, and the upstream pool will receive two LWD/boulder complexes.

Photo 39 & 40. View downstream of angular rock associated with the McGimpsey Road crossing at the site of proposed spawning riffle enhancement near km 1+650 (above left), and view upstream of Rock Weir #3 constructed in 2000 that has been identified for enhancement/maintenance (above right).

6.1.5 Reach 6 (km 3+120 – 3+220)

An existing rock weir present at km 3+120 is in a state of good repair that would benefit from spawning gravel re-nourishment on its upstream face. Some gravels remain present, but the majority has either been transported downstream or is partially embedded in fine sediment.

Upstream of the existing weir (G – date unknown) a section of higher gradient 2-3 % channel profile with areas of exposed gravels is a good candidate site for enhancement with a series of 3 rock weir/riffles and LWD pool complexes. Enhanced spawning and rearing habitat in this reach in the upper watershed will provide unique spawning potential that is lacking elsewhere in the upper watershed (Photo 41).

Photo 41. Example of native gravel substrates present in the subject section of Reach 6 recommended for enhancement.

6.1.6 Reach 7 (km 3+925 - 3+935)

Replace dysfunctional wood weir (J- 1999) prior to complete failure using rock weir/riffle constructed to maintain control elevation of upstream pool habitat, while enhancing spawning opportunity in this upper watershed reach otherwise lacking spawning opportunities. An existing finger of rock extending from the left bank that was originally used to anchor the left side of the wood weir can be maintained and tied into new weir construction. The right bank, site of wood weir avulsion, must be tied into hardpan of the right bank and armoured with rock to avoid additional scour. Beaver activity in this upper reach is common and there is a risk that the weir will provide an additional site for beaver dam construction, however, the current wood weir does not currently show presence of dam construction and since control elevation will be maintained the risk will not change significantly.

Log weir (I- 1999) is located immediately downstream of the failed wood weir (J- 1999) and although it is not creating a negative impact to fish habitat, its original purpose was to backwater wood weir (J- 1999) and should be replaced as part of the larger wood weir replacement works that will include locating the toe of a rock riffle near the log weir's current position.

6.1.7 Reach 8 (km 1+465 - 1+505)

A series of log/debris jams that are detaining fine sediments causing them to build up on their upstream sides, and acting as partial barriers to fish migration have resulted from tree windthrow connected with forest harvesting practices near the right (south) bank in an approximately 50 m long section of this reach of the South Fork. A combination of hand labour and manual/power tools is recommended to

remove instream sections of LWD from the channel to flush sediment and reduce obstructions to fish migration, including juvenile and adult salmon. Once alluvium is re-mobilized it is anticipated that a certain amount of native gravels will be re-exposed that will have a positive effect for available areas of spawning habitat in this reach.

6.1.8 **Reach 9 (km 2+240 – 3+155)**

Historical enhancements in Reach 9 have been completed with assistance and support from Storey Creek Golf Course, Pacific Salmon Foundation (PSF), and the Campbell River Salmon Foundation (CRSF) that have included rock and wood weirs in the South Fork channel as well as a series of smaller rock weirs in the NW Branch tributary which runs through two ponds on the Golf Course and has its confluence with the South fork near km 2+670. A series of enhancements and restoration recommendations have been identified to improve or replace historical enhancement measures, in addition to identification of new sites (Table 16).

An existing rock riffle (K in Table 15) at km 2+240 is stable but requires maintenance to improve its habitat function, including excavating accumulated bedload on its upstream face and replacing with spawning grade gravels. The structure of the weir is relatively intact and would benefit from only minor upgrading.

A large wood weir (L in Table 15) located near km 2+670 is a partial barrier to juvenile salmon migration and is recommended for replacement with a rock weir/riffle that will also provide spawning habitat that is otherwise lacking in Reach 9. Fine sediment bedload will be excavated from the upstream side of the weir and replaced with spawning grade gravel.

There are two branches that have their confluence at the upstream side of the existing wood weir near 2+670: the NW branch, and SW branch. Both chainages for these branches are a continuation from km 2+670.

Beginning with the NW Branch, there is a perched culvert at km 2+745 that is recommended for replacement with a clear-span bridge and reinstatement of natural bed materials suing gravel, and two sites of historical enhancement that include a series of relatively small rock weirs with upstream gravel placements (km 2+945 & 3+155). It is recommended that any relic weirs that pose a potential barrier be decommissioned and replaced with a new passable rock weir structure and gravel nourishment be added where deficient.

The SW Branch contains a relic beaver dam near km 2+850 that is recommended to be removed and replaced by a rock weir/riffle including excavation of the upstream pools bedload to reinstate the ponds capacity and replacement with spawning grade gravel. Tis work can be tied in with replacement of a relic tote road upstream towards km 2+970 that can be removed, and natural bed profile reinstated with a series of two rock weir/riffles, and 2 LWD complexes. Riparian enhancement planting should be included wherever instream works are carried out in accordance with the owner's land use requirements.

7 Conclusions

Overall, the primary limiting factors to productivity in the Woods Creek watershed are the lack of summertime base flows and prevalence of fine sandy alluvium. These innate conditions define the potential for successful reproduction of coho salmon that require year-round rearing to support juvenile survival, while chum salmon juveniles are expected to experience better survival success since they egress to the marine environment in spring, prior to onset of the dry season.

According to the results of this *Fish Habitat Assessment*, three of the assessed reaches received a *Fair* rating and six received a *Poor* overall rating. Habitat parameters commonly missing across all assessed reaches include lack of off-channel habitat, low % boulder cover, low % spawning gravel, high % fine substrates, and impacts to riparian vegetation related to clearing on private property and forest harvesting practices.

Habitats that includes suitable spawning gravel are concentrated in Reaches 2 & 3 upstream of Highway 19A and in Reach 6 in the upper North Fork of Woods Creek. These reaches are ideal candidates for spawning habitat enhancement projects as they are proven to show natural recruitment of coarse materials, whereas lower gradient reaches are commonly dominated by fine sediment that have impaired weir function in some historically enhanced reaches.

Beaver activity is common throughout the watershed but appears to be concentred in Reach 5, 7 and Trib. 3. The presence of beaver dams has effectively enhanced water retention within extensive wetland type habitats that will help to reduce the negative impacts of seasonal drying by extending the hydroperiod in reaches that might otherwise dry in the absence of dams. This natural water retention function provided by beaver dams was also one of the original objectives behind many of the weirs installed in 1999-2000, and based on a survey of weir function (Section 5.3) the effort expended to build wooden weirs has been overshadowed by the natural function provided by beavers.

In addition, beaver dams have also created a series of partial barriers to fish migration where juvenile salmon are unlikely to move upstream, and in some circumstances spawning habitat has been impaired where constructed weirs have been completely enclosed or backwatering from dams and have detained fine sediments that have occluded spawning grade gravels.

Restoration opportunities are recommended in light of the above conditions that are known to support or challenge salmon productivity. Based on the presence of suitable spawning habitat located in both lower and upper reaches, and substantial flow through the spawning season, both coho and chum salmon and cutthroat trout are likely to have spawning success with appropriate access to these areas. Rearing survival, however, is dependent on wetted areas through the dry summer season and will remain dependent upon natural attenuation in large part contributed by beaver dams.

Restoration recommendations include the construction of 19 rock weir/riffles including integrated spawning gravel platforms and upstream pools that will contain at least 16 LWD complexes. These measures are included within the inventory of recommended maintence/enhancement works for existing weirs (Section 5.3) and other habitat features that have been historically implemented in the Woods Creek watershed (Section 2.4). Based on existing biostandards these habitat enhancements will give rise to an overall estimated increase of 963 coho and 287 cutthroat smolts annually.

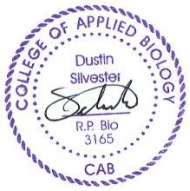
In 2006, a report summarizing repair work completed on a series of weirs in the North Fork stated that "our goal is to be able to restore these streams to a self sustaining wild salmon watershed and one that will stand the human encroachment and development surrounding the drainage area". This sentiment remains relevant today and has guided the objectives and outcomes of this report.

8 Closure

We trust that this report has met the project objectives for a comprehensive review and assessment of existing salmonid habitat conditions in the overall Woods Creek watershed, and that the recommendations made herein will serve to continue enhancing and restoring the system.

Please contact the undersigned with any queries.

Current Environmental Ltd.



Dusty Silvester, R.P.Bio.
Feb. 21, 2020
(Revised June 9, 2020)

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Appendix A. Raw Quantitative Data of Assessed Reaches

Reach 1

Unit	Habitat Type	Start (chainage at start)	Finish (chainage at end)	Unit Length	Wetted Width	Pool Area	Wetted Reach Area	%Pool Area	Habitat unit Depth (m)	Percent Gradient	Bankfull Width (m)	Average Percent Wetted Area	Substrate Percent						Percent Instream Cover						Percent Crown Cover	Large Woody Debris	LWD/bank-full channel width	Erosion Sites (length)	Altered Stream Sites (length)	Obstructions (number)	Off-Channel Habitat (length)	Off-Channel Habitat (width)	Off-Channel Habitat (bank side)	Land Use		Vegetation Type		Riparian Slope		Stability		Vegetation Depth		Photos	Comments
													Bed	Bld	Cob	Grv	Fine	Bold	LWD	Cutbk	OverVg	InVg												Right	Left	Right	Left	Right	Left	Right	Left	Right	Left		
Mouth	Glide	0.00	57.00	57.00	3.70	35.00	210.90	16.60	0.32	2.50	4.90	75.51	0	0	10	60	30	5	0	0	15	0	20.00	1	0.09	10	20	2	0	0	0	R	R	SH	SH	10	10	H	H	3	3	X	Disturbance from retaining walls, bridge abutments, vegetation clearing, invasive species, remnants of counting fences.
	Reach Totals and Averages		57.00	57.00	3.70	35.00	210.90	16.60	0.32	2.50	4.90	75.51	0	0	10	60	30	5	0	0	15	0	20.00	1	0.09	18	35	2	0	0	0							0	0	3.00	3.00		

Reach 2

Unit	Habitat Type	Start (chainage at start)	Finish (chainage at end)	Unit Length	Wetted Width	Pool Area	Wetted Reach Area	%Pool Area	Habitat unit Depth (m)	Percent Gradient	Bankfull Width(m)	Average Percent Wetted Area	Substrate Percent						Percent Instream Cover						Percent Crown Cover	Large Woody Debris	LWD/bank-full channel width	Erosion Sites (length)	Altered Stream Sites (length)	Obstructions (number)	Off-Channel Habitat (length)	Off-Channel Habitat (width)	Off-Channel Habitat (bank side)	Land Use		Vegetation Type		Riparian Slope		Stability		Vegetation Depth		Photos	Comments
													Bed	Bld	Cob	Grv	Fine	Bold	LWD	Cutbk	OverVg	InVg												Right	Left	Right	Left	Right	Left	Right	Left	Right	Left		
M1U4	Glide	880.00	951.00	71.00	3.10	51.75	220.10	23.51	0.34	2.00	4.90	63.27	0	0	10	70	20	0	0	5	60	0	30.00	3	0.21	0	0	1	0	0	0	Res	Res	Mx	Mx	2	2	M	M	16	13	X	BD/log jam at G500, sinuous channel
M1U3	Riffle	1092.00	1158.00	66.00	6.40	31.20	422.40	7.39	0.17	3.00	8.00	80.00	10	0	60	20	0	5	0	0	15	0	70.00	1	0.12	0	1	0	0	0	0	Res	Res	Mx	Mx	5	2	M	L	15	0	X	Cobble and some erosion on LB w heer clearing has taken place and high flow s top bank.
M1U2	Riffle	1193.00	1258.00	65.00	3.40	54.00	221.00	2.00	0.22	5.00	4.70	72.34	0	10	60	30	0	5	0	0	15	0	10.00	7	0.51	1	1	0	0	0	0	Res	Res	Mx	Mx	4	4	M	M	7	30	X	High gradient, dominated by cobble and boulder
M1U1	Riffle	1300.00	1397.00	97.00	2.50	50.35	242.50	10.00	0.18	3.00	5.20	48.08	15	10	40	20	5	2	0	0	5	0	40.00	28	1.50	0	0	0	0	0	0	Log	Log	Mx	Mx	10	10	M	M	15	15	X	Loggging increased w indthrow resulting in LWD recruitment in strem and debris jams
	Reach Totals and Averages		530.00	299.00	3.85	187.30	1151.15	16.27	0.23	3.25	5.70	67.54	6	5	43	35	6	3	0	1	24	0	37.50	39	0.74	1	2	1	0	0									13.25	14.50		

Reach 3

Unit	Habitat Type	Start (chainage at start)	Finish (chainage at end)	Unit Length	Wetted Width	Pool Area	Wetted Reach Area	%Pool Area	Habitat unit Depth (m)	Percent Gradient	Bankfull Width(m)	Average Percent Wetted Area	Substrate Percent						Percent Instream Cover						Percent Crown Cover	Large Woody Debris	LWD/bank-full channel width	Erosion Sites (length)	Altered Stream Sites (length)	Obstructions (number)	Off-Channel Habitat (length)	Off-Channel Habitat (width)	Off-Channel Habitat (bank side)	Land Use		Vegetation Type		Riparian Slope		Stability		Vegetation Depth		Photos	Comments
													Bed	Bld	Cob	Grv	Fine	Bold	LWD	Cutbk	OverVg	InVg												Right	Left	Right	Left	Right	Left	Right	Left	Right	Left		
N1U0	Riffle	1415.00	1490.00	75.00	3.30	24.50	247.50	9.90	0.23	5.00	5.70	57.89	10	5	20	60	5	2	2	0	50	0	30.00	6	0.46	0	0	0	0	0	0	N	N	M	M	10	20	H	H	20	20	X	Logging w ithin 30 m
N1U1	Riffle	1500.00	1585.00	85.00	2.40	22.54	204.00	11.05	0.07	2.00	5.70	42.11	10	5	50	20	15	2	2	5	0	0	60.00	25	1.68	0	0	1	25	2	0	N	N	M	M	10	5	H	L	30	30	X	Relic sidechannel overflow high w ater, log jams
	Reach Totals and Averages		300.00	160.00	2.85	47.04	456.00	10.32	0.15	3.50	5.70	50.00	10	5	35	40	10	2	2	2	25	0	45.00	31	1.10	0	0	1	8									0	0	25.00	25.00		

Reach 4

Unit	Habitat Type	Start (chainage at start)	Finish (chainage at end)	Unit Length	Wetted Width	Pool Area	Wetted Reach Area	%Pool Area	Habitat unit Depth (m)	Percent Gradient	Bankfull Width(m)	Average Percent Wetted Area	Substrate Percent						Percent Instream Cover						Percent Crown Cover	Large Woody Debris	LWD/bank-full channel width	Erosion Sites (length)	Altered Stream Sites (length)	Obstructions (number)	Off-Channel Habitat (length)	Off-Channel Habitat (width)	Off-Channel Habitat (bank side)	Land Use		Vegetation Type		Riparian Slope		Stability		Vegetation Depth		Photos	Comments
													Bed	Bld	Cob	Grv	Fine	Bold	LWD	Cutbk	OverVg	InVg												Right	Left	Right	Left	Right	Left	Right	Left	Right	Left		
N2U1	Glide	1665.00	1750.00	85.00	4.85	19.53	412.25	4.74	0.07	2.00	5.85	82.91	0	0	0	35	65	0	5	0	10	0	70.00	8	0.55	0	0	1	0	0	0	N	N	M	M	5	5	M	M	60	60	X	Seasonal canopy
N2U2	Riffle	1750.00	1790.00	40.00	3.90	55.10	156.00	35.32	0.06	5.00	5.00	78.00	80	0	20	0	0	0	5	0	5	0	40.00	6	0.75	0	0	0	0	0	0	N	N	M	M	5	5	M	M	60	60	X	Seasonal canopy
N2U3	Glide	1790.00	1830.00	40.00	5.40	66.00	216.00	30.56	0.26	1.00	10.00	54.00	0	0	0	5	95	0	10	0	15	0	40.00	11	2.75	0	0	0	77	2	0	N	N	M	M	5	5	M	M	60	20	X	Relic sidechannel on left bank 77 m length
	Reach Totals and Averages		595.00	165.00	4.72	140.63	778.25	18.07	0.13	2.67	6.95	67.87	27	0	7	13	53	0	7	0	10	0	50.00	25	1.05	0	0	1	13	1	0							3	3	0	0	60.00	46.67		

Reach 5

Unit	Habitat Type	Start (chainage at start)	Finish (chainage at end)	Unit Length	Wetted Width	Pool Area	Wetted Reach Area	%Pool Area	Habitat unit Depth (m)	Percent Gradient	Bankfull Width(m)	Average Percent Wetted Area	Substrate Percent						Percent Instream Cover						Percent Crown Cover	Large Woody Debris	LWD/bank-full channel width	Erosion Sites (length)	Altered Stream Sites (length)	Obstructions (number)	Off-Channel Habitat (length)	Off-Channel Habitat (width)	Off-Channel Habitat (bank side)	Land Use		Vegetation Type		Riparian Slope		Stability		Vegetation Depth		Livestock Access		Photos	Comments
													Bed	Bld	Cob	Grv	Fine	Bold	LWD	Cutbk	OverVg	InVg												Right	Left	Right	Left	Right	Left	Right	Left	Right	Left		
NF1	Glide	1930.00	1985.00	55.00	11.00	302.50	605.00	50.00	0.42	1.00	15.50	70.97	0	0	0	0	100	0	10	0	5	5	50.00	27	7.61	0	0	0	0	0	0	N	Log	M	M	5	5	M	M	20	60	0	0	X	Logging on right bank
	Reach Totals and Averages		55.00	55.00	11.00	302.50	605.00	50.00	0.42	1.00	15.50	70.97	0	0	0	0	100	0	10	0	5	5	50.00	27	7.61	0	0	0	0	0	0									20.00	60.00	0	0		

Reach 6

Unit	Habitat Type	Start (chainage at start)	Finish (chainage at end)	Unit Length	Wetted Width	Pool Area	Wetted Reach Area	%Pool Area	Habitat unit Depth (m)	Percent Gradient	Bankfull Width(m)	Average Percent Wetted Area	Substrate Percent						Percent Instream Cover						Percent Crown Cover	Large Woody Debris	LWD/bank-full channel width	Erosion Sites (length)	Altered Stream Sites (length)	Obstructions (number)	Off-Channel Habitat (length)	Off-Channel Habitat (width)	Off-Channel Habitat (bank side)	Land Use		Vegetation Type		Riparian Slope		Stability		Vegetation Depth		Livestock Access		Photos	Comments
													Bed	Bld	Cob	Grv	Fine	Bold	LWD	Cutbk	OverVg	InVg												Right	Left	Right	Left	Right	Left	Right	Left	Right	Left		
NF2	Riffle	3165.00	3220.00	55.00	4.40	0.00	242.00	0.00	0.30	2.00	11.30	38.94	0	0	10	30	30	0	5	0	5	0	30.00	16	3.29	0	0	0	0	0	0	Nat	Nat	MF	MF	10	10	M	M	60	60	0	0	X	Beaver dams dow nstream
	Reach Totals and Averages			55.00	4.40	0.00	242.00	0.00	0.30	2.00	11.30	38.94	0	0	10	30	30	0	5	0	5	0	30.00	16	3.29																	60.00	60.00				

Reach 7

Unit	Habitat Type	Start (chainage at start)	Finish (chainage at end)	Unit Length	Wetted Width	Pool Area	Wetted Reach Area	%Pool Area	Habitat unit Depth (m)	Percent Gradient	Bankfull Width(m)	Average Percent Wetted Area	Substrate Percent						Percent Instream Cover						Percent Crown Cover	Large Woody Debris	LWD/bank-full channel width	Erosion Sites (length)	Altered Stream Sites (length)	Obstructions (number)	Off-Channel Habitat (length)	Off-Channel Habitat (width)	Off-Channel Habitat (bank side)	Land Use		Vegetation Type		Riparian Slope		Stability		Vegetation Depth		Livestock Access		Photos	Comments
													Bed	Bld	Cob	Grv	Fine		Bold	LWD	Cutbk	OverVg	InVg										Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left		
NF3	Glide	3645.00	3700.00	55.00	3.00	132.00	165.00	80.00	0.28	1.00	16.00	18.75	10	0	0	10	80		0	15	0	10	0	40.00	27	7.85	0	0	3	0	0	0	N	N	MF	MF	1	1	M	M	15	30	0	0	X	Beaver dam and log jam obstructions. Not completely inventoried
	Reach Totals and Averages		0.00	55.00	3.00	132.00	165.00	80.00	0.28	1.00	16.00	18.75	10	0	0	10	80		0	15	0	10	0	40.00	27	7.85			3												15.00	30.00				

Reach 8

Unit	Habitat Type	Start (chainage at start)	Finish (chainage at end)	Unit Length	Wetted Width	Pool Area	Wetted Reach Area	%Pool Area	Habitat unit Depth (m)	Percent Gradient	Bankfull Width(m)	Average Percent Wetted Area	Substrate Percent						Percent Instream Cover						Percent Crown Cover	Large Woody Debris	LWD/bank-full channel width	Erosion Sites (length)	Altered Stream Sites (length)	Obstructions (number)	Off-Channel Habitat (length)	Off-Channel Habitat (width)	Off-Channel Habitat (bank side)	Land Use		Vegetation Type		Riparian Slope		Stability		Vegetation Depth		Photos	Comments
													Bed	Bld	Cob	Grv	Fine		Bold	LWD	Cutbk	OverVg	InVg										Right	Left	Right	Left	Right	Left	Right	Left	Right	Left		
S1U1	Glide	1470.00	1543.00	73.00	2.10	47.40	153.30	30.92	0.12	1.50	3.20	65.63	0	0	5	10	70		0	8	0	5	0	40.00	21	0.92	0	0	3	0	0	0	Log	N	M	M	20	10	H	H	15	30	X	Logging up to 15 m on RB resulting in w indthrow & log jams
S1U2	Glide	1543.00	1610.00	67.00	1.90	20.00	127.30	15.71	0.20	3.00	2.70	70.37	0	0	0	0	100		0	2	0	20	0	40.00	18	0.73	0	0	1	0	0	0	Log	N	M	M	20	10	H	H	15	30	X	Debris jams
	Reach Totals and Averages		300.00	140.00	2.00	67.40	280.00	24.07	0.16	2.25	2.95	67.80	0	0	3	5	85		0	5	0	13	0	40.00	39	0.82	0	0	4	0									0	0	15.00	30.00		

Reach 9

Unit	Habitat Type	Start (chainage at start)	Finish (chainage at end)	Unit Length	Wetted Width	Pool Area	Wetted Reach Area	%Pool Area	Habitat unit Depth (m)	Percent Gradient	Bankfull Width(m)	Average Percent Wetted Area	Substrate Percent						Percent Instream Cover						Percent Crown Cover	Large Woody Debris	LWD/bank-full channel width	Erosion Sites (length)	Altered Stream Sites (length)	Obstructions (number)	Off-Channel Habitat (length)	Off-Channel Habitat (width)	Off-Channel Habitat (bank side)	Land Use		Vegetation Type		Riparian Slope		Stability		Vegetation Depth		Photos	Comments
													Bed	Bld	Cob	Grv	Fine		Bold	LWD	Cutbk	OverVg	InVg										Right	Left	Right	Left	Right	Left	Right	Left	Right	Left		
GC1	Glide	1865.00	1970.00	105.00	2.60	0.00	273.00	0.00	0.37	2.50	4.60	56.52	0	0	20	10	70		0	1	0	40	0	40.00	5	0.22	0	0	0	0	0	0	GC	GC	Mix	Mix	10	10	M	M	30	30	X	Natural form. Sandy alluvium
GC2	Glide	2045.00	2150.00	105.00	8.10	0.00	850.50	0.00	0.22	1.00	10.00	61.00	0	0	0	0	100		0	0	0	10	5	30.00	5	0.48	0	0	0	0	0	0	GC	GC	D	D	10	10	M	M	30	20	X	Rock w eir dysfunctional
GC3	Glide	2215.00	2265.00	50.00	2.60	0.00	130.00	0.00	0.37	2.00	4.30	60.47	0	0	0	30	70		0	5	0	5	0	60.00	8	0.69	1	0	0	0	0	0	GC	GC	Mix	Mix	10	10	L	M	15	20	X	Weir juvenile barrier
GC4	Glide	2640.00	2735.00	95.00	4.70	800.00	446.50	179.17	0.25	2.00	6.70	70.15	0	0	0	10	90		0	0	0	5	10	20.00	8	0.56	0	0	0	0	0	0	GC	GC	D	D	5	5	M	M	20	15	X	Backw atered by w ood w eir
GC5N	Glide	2680.00	2750.00	70.00	1.60	0.00	112.00	0.00	0.25	1.50	1.80	88.89	0	0	0	20	80		1	0	0	10	0	0.00	0	0.00	0	0	0	0	0	0	GC	GC	Gr	Gr	5	5	M	M	3	3	X	Impacted by fairw ay veg maintenace. Some small constructed rock w eirs.
	Reach Totals and Averages		530.00	425.00	3.92	800.00	1666.00	48.02	0.29	1.80	5.48	71.53	0	0	4	14	82		0	1	0	14	3	30.00	26	0.34	1	0	0	0	0	0									19.60	17.60		

Trib. 3

Unit	Habitat Type	Start (chainage at start)	Finish (chainage at end)	Unit Length	Wetted Width	Pool Area	Wetted Reach Area	%Pool Area	Habitat unit Depth (m)	Percent Gradient	Bankfull Width(m)	Average Percent Wetted Area	Substrate Percent						Percent Instream Cover						Percent Crown Cover	Large Woody Debris	LWD/bank-full channel width	Erosion Sites (length)	Altered Stream Sites (length)	Obstructions (number)	Off-Channel Habitat (length)	Off-Channel Habitat (width)	Off-Channel Habitat (bank side)	Land Use		Vegetation Type		Riparian Slope		Stability		Vegetation Depth		Livestock Access		Photos	Comments
													Bed	Bld	Cob	Grv	Fine		Bold	LWD	Cutbk	OverVg	InVg										Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left		
T3	Glide	3155.00	3207.00	52.00	3.00	0.00	156.00	0.00	0.28	2.00	16.00	18.75	0	0	0	40	60		0	15	0	10	0	40.00	27	8.31	0	0	0	0	0	0	Log	Log	MF	MF	20	20	H	H	18	18	0	0	X	Beaver dams dominate starting at upstream end of reach.
	Reach Totals and Averages		0.00	52.00	3.00	0.00	156.00	0.00	0.28	2.00	16.00	18.75	0	0	0	40	60		0	15	0	10	0	40.00	27	8.31			0												18.00	18.00				