Executive Summary

In the spring of 1997, the Nadina Community Futures Development Corporation (NCFDC) was designated as a proponent for FRBC funding in a Watershed Restoration Program (WRP) project in the Mid-Bulkley Watershed (see figure 1). The NCFDC is a non-profit community economic development corporation based in Houston, British Columbia. The implementing partner in this endeavor was the Ministry of Environment, Lands, and Parks, Skeena Region BC Environment office (MELP).

WRP is a provincial initiative under Forest Renewal BC to restore the productive capacity of forest, fisheries and aquatic resources that have been adversely impacted by past forest harvest practices, and thus to aid in providing long-term employment opportunities in resource-dependent communities (Johnston and Moore, 1995).

The Fish Habitat and Assessment Procedure (FHAP) is a means of assessing watersheds with a history of anthropogenic activity for impacts to fish and fish habitats using a set of integrated physical and biological indicators. The assessment procedure extends from stream and river channels, to the riparian area, to upslope areas in which there is some level of connectivity to the channel. There are two levels of assessment in the FHAP. The first, known as the Overview Assessment, is a reconnaissance-level study compiling background data and using predominately remote-sensing techniques to prioritize sub-basins and waterbodies within those sub-basins for the second level of FHAP. This is known as the Detailed (or Level 1) Assessment, which involves more detailed field surveys of the channel and riparian areas, the end result of which is the formation of restoration prescriptions to restore or rehabilitate fish habitat, or mitigate impacts on that habitat. There are four general steps in both stages of the FHAP:

1. Identification of fish species at risk in the watershed,
2. A quantitative and qualitative description of fish habitat conditions,
3. Evaluation of fish habitat conditions,
4. Identification of opportunities for effective fish habitat rehabilitation.

The British Columbia Conservation Foundation (BCCF) was contracted by NCFDC to carry out a WRP Detailed Level 1 Fish, Fish Habitat and Riparian Assessment in the summer of 1998.

In addition to the FHAP and RAP, BCCF staff also field-tested the Integrated Fish Habitat and Channel Assessment Field Procedures which had been developed for the Ministry of Environment, Lands and Parks Skeena Region WRP. The Channel Assessment Procedures (CAP) provide a continuous description of the stream channel and bank characteristics and impacts. The integrated FHAP/ CAP combined with the RAP result in a far more detailed picture overall and a deeper understanding of the general and specific processes occurring within the reach and the watershed.

The integrated FHAP/ CAP and RAP were conducted in the following sub-basins of the

Mid-Bulkley Watershed (see figure 1):

- Bulkley River
- Buck Creek (including Klo Creek and Dungate Creek)
- Richfield Creek
- McQuarrie Creek
- Byman Creek
- Aitken Creek
- Barren Creek
- Emerson Creek
- Dockrill Creek

The Mid-Bulkley watershed, as defined by the watershed boundaries of the sub-basins listed above, is a 162 729 hectare drainage basin situated on the Nechako Plateau physiographic region. Two sub-basins drain the Telkwa Mountains of the Bulkley Range physiographic region which borders the Nechako Plateau to the Northwest. Elevations range from 570 m (1900 ft.) at the mouth of the Upper Bulkley to 1640 m (5400 ft.) at Tachek Mountain. The majority of land is within 800 and 1500m in elevation (LaRose and Rencoret, 1996). Watershed characteristics, and the fish and fish habitat therein, are defined by a complex and dynamic interaction of climate, hydrology, surficial and bedrock geology, vegetation, and land-use. For detailed descriptions of these characteristics refer to (BCCF, 1997).

Target Species

When fish are defined in the context of this assessment, what is really being referred to are target species. Target species for fish habitat assessment and restoration are economically and/or culturally important salmonids whose abundance has declined following past forest practices, or which are known to be sensitive to the effects of logging (Johnston and Slaney, 1996). The Mid-Bulkley has a complex history of land-use, and a short history of data gathering in relation to fish. In our case, it is difficult to separate the effects of one land-use from another at this level of assessment. Target species are therefore defined here as economically or culturally important salmonids whose abundance has declined following past land-use practices, or which are known to be sensitive to the effects of logging. The following species, in order of priority, are thought to be in decline in the watershed (BCCF, 1997):

- *Oncorhynchus kisutch* (coho salmon)
- *O. tshawytscha* (chinook salmon)
- *O. mykiss* (steelhead trout)

The following species which use the watershed for one or more life stages, are known to be sensitive to the effects of logging (including those listed above) (Johnston and Slaney, 1996):

- *O. gorbuscha* (pink salmon)

- *O. nerka* (sockeye salmon)
- *O. mykiss* (rainbow trout)
- *O. clarki* (cutthroat trout)
- *Salvelinus malma* (Dolly Varden)
- *S. confluentus* (bull trout)

The latter species is also listed as rare and endangered by MELP. These are the target species whose habitats, distributions, and abundance are being investigated in this assessment.

Study Area

The study area for this assessment is presented in figure 1. It delineates the main sub-basins in which detailed assessments were carried out. Other sub-basins identified in the overview FHAP are also shown.

Master Plan for Restoration Activities

The following comprises a set of guiding principles for restoration, a synthesis of impact assessment results, classification of different areas by watershed position for the purpose of grouping restoration priorities, and a set of physical and biological goals. For any given watershed, there are tens to thousands of sites which might exist outside of pre-disturbance conditions, and which could be considered singularly for restoration. The purpose of this plan is to guide sub-basin restoration priorities and timing, and to integrate individual restoration prescriptions with overall watershed-level goals.

Guiding Principles

The following set of eight guiding principles is drawn from the works of the Pacific Rivers Council (1996), Doppelt et al.(1993), Slaney and Zaldokas (1997), and Rhodes et al. (1994):

1) Passive restoration is the least expensive and often the most effective means of restoration, where the principal causes of impact are removed or altered so that they no longer cause an impact. The main cause of failure in active restoration projects is their implementation before the sources of disturbance have been stopped.
2) In some cases, passive restoration alone will not achieve success, as a continued presence of physical or biological limitations may prevent complete recovery. In these cases, active restoration should proceed carefully. Projects should not be based on a misinterpretation of ecosystem needs which result in further degradation, and should focus primarily on addressing the causes rather than the symptoms of degradation.
3) Instream habitat and biota are largely determined by processes occurring in the

drainage basin and riparian and floodplain areas cannot be manipulated independent of this context.

4) Disturbances propagate downstream from headwater sources so that multiple sources can interact and culminate in cumulative impacts. Therefore, restoration should proceed from the upslope areas to the floodplain, and the headwaters to the mainstem where applicable.
5) Restoration should be focused where a minimal investment can secure the maintenance of the largest amount of high quality habitat and diversity of aquatic species. Recovery of highly degraded and therefore biologically impoverished watersheds will require decades to centuries. Restoration in these areas is likely to prove unsuccessful in the short term (<10 years).
6) The current distribution and life history patterns of fish populations, largely governed by the nature and distribution of key habitat refuges (focal and nodal habitats) in the watershed, determine the ability of fish populations to respond to future changes in habitat. Therefore, restoration should be focused on protecting these biological hotspots that are still functioning (functioning-at-risk). Restoration that first secures existing hotspots, then reestablishes similar and proximal habitat that requires little adjustment of life-history patterns, is most likely to provide the kinds of habitat critical to existing fish populations.
7) Aquatic habitat is very patchy and highly variable in space and time. Fish life histories are adapted to these conditions. Restoration must not be focused on producing generic or homogeneous conditions, but on producing spatial diversity and complexity.
8) Restoration must be based on natural templates and unique watershed conditions because they reflect an integration of watershed processes and energy fluxes. This includes channel, upslope and riparian restoration, and should be mindful of how fish populations might have adapted to long-term natural disturbances (i.e.-beavers). It is much less expensive to study the integration of these conditions, than to try to quantify them individually.

Impact Summary and Restoration Priorities

Watershed position, fisheries value, synergistic value (risk to downstream values), land-use, physical and biological impacts, current state of functioning, and land ownership are summarized by reach in appendix H along with a priority for restoration. Sub-basin priority (for planning and funding purposes), restoration priority for each proposed set of works, and assessment/survey/design priorities are presented in section 5 (recommendations) of this report.

Watershed-Level Physical and Biological Goals

Based on watershed position, four physiographic groups were identified to meet the requirements of guiding principles. Within each group, a number of biotic and abiotic functions are held in common which broadly define the nature of habitat and fish species use and connectivity to other groups. Reaches are classified according to these groups, and each group is assigned a set of physical and biological goals for restoration. Within each sub-basin, restoration plans set out in section 4 of this report follow the relative priority of each physiographic group. These groups are as follows:

Headwaters reaches: Headwaters areas in the Mid-Bulkley watershed which support significant salmonid fisheries values and were surveyed in this assessment are all in the Buck sub-basin, and include Upper Buck Creek (reach 11B), and Klo Creek reaches 1 and 2. They do not support anadromous populations due to downstream barriers, but are highly important areas for the maintenance of downstream habitat conditions. They have a very high priority for restoration because there is little upstream land use, because they are often focal or nodal habitats for resident fish, because their landbases are not privately owned, and their restoration will have positive impacts on downstream habitat. This is in consideration of guiding principles 2), 4) and 6). Biological and physical goals include:

1) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability
2) Reestablish sediment storage functions such log jams at geomorphic notch points (natural bedrock constrictions and other points which act to consistently catch and hold debris) where they are lacking
3) Reestablish upstream access to areas which have been blocked for resident fish passage by land-use activities

Mid-elevation reaches: These reaches are depositional reaches above confined canyons which separate upland areas from the Bulkley valley. They act to store sediment, LWD, and water in the floodplain and thus maintain the quality and nature of downstream anadromous and resident salmonid habitat. They also support significant and diverse populations of resident fish. In most cases, these reaches have one or more barriers to upstream migration between them and the valley bottom, and do not support anadromous fish populations. This would include Aitken reach 3A, part of Barren reach 2, and McQuarrie Reach 3. In the case of Buck reaches 4-6, anadromous species have access and both spawn and rear there. These areas typically have medium to wide floodplains and low gradients (<2%). They have a high priority for restoration because their restoration will have a positive impact on downstream reaches, and/or because they are functioning-at-risk but not highly impacted, and/or because the land (in some cases) is not privately owned, and/or because their are high resident and anadromous fisheries values in these reaches. Biological and physical goals include:

I. Reestablish upstream access to resident and anadromous fish species where barriers have been created by land-use.
II. Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probability of success despite upstream sources of disturbance.
III. Reestablish sediment storage functions such as log jams in geomorphic notch points where they are lacking. Maintain anadromous access through these areas in concert with the former goal where applicable.
IV. Carry out passive and active restoration to reduce soil compaction on the active floodplain, reconnect the channel to the active floodplain, and restore key features such as LWD.

Alluvial fan reaches: Owing to the number of upstream barriers to mid-elevation reaches in the watershed, alluvial fans of tributaries to the Bulkley River are focal and nodal habitats for both anadromous and resident fish in the watershed. These include reaches 1 and 2 of Richfield, Buck, and Dungate Creeks, and reach 1 of Byman, McQuarrie, Aitken, Barren, and Emerson Creeks. They are critical for spawning and rearing, particularly for coho salmon and steelhead trout, in an unimpacted state. Although normally a mainstem spawning and rearing species, this reach may also be an important area for chinook salmon considering the extreme low-gradient nature of the Bulkley River in reaches 2 and 4. They ideally provide areas of swifter current and larger substrate, diverse invertebrate communities, complex channel morphology and cooler water temperatures relative to the mainstem. As such they are important for summer rearing and summer and fall spawning habitat. Their proximity to the Bulkley provides access to overwintering habitat, mainstem rearing areas for older juvenile salmonids, and a choice of habitat refugia in either the mainstem or tributary during high water events. Their use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition. They have wide, active floodplains and diverse deciduous-dominated riparian forests which thrive on overbank flood disturbances. They generally have a moderate to high priority for restoration because their restoration will have positive impact on downstream reaches, because they are highly important focal and nodal habitats for some or all fish species present and are in proximity to other high-value habitat (mainstem reaches), because they may be poorly functioning, and/or because they are dominantly on private land. Biological and physical goals include:

1) Reestablish upstream access to resident and anadromous fish species where barriers have been created by land-use.
2) Reestablish spatial habitat diversity and quality, and hydraulic energy dissipation in areas that have been channelized. A long-term goal which requires cooperation between private landowners and regulatory agencies is the de-channelizing of these areas and their reconnection to normal floodplain functioning, which is beyond the scope of this project.
3) Reestablish sediment storage functions such as log jams in geomorphic notch points

where they are lacking. Maintain anadromous access through these areas in concert with the former goal where applicable.
4) Passively restore riparian areas wherever possible with landowner cooperation to limit land-use to areas outside of the riparian zone.
5) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probability of success despite upstream sources of disturbance, and/or when passive restoration needs to be integrated with active restoration.
6) Stabilize extensive bars and promote channel narrowing and deepening where feasible and when upstream sources of disturbance have been alleviated.
7) Actively restore LWD function with the purpose of creating pool habitat and spawning gravel catchments when upstream sources of disturbance and lateral channel instability have been removed.

Mainstem reaches: These are reaches 1 to 3 of the Bulkley River. Mainstem reaches are important for spawning, overwintering, rearing, and migration of anadromous and resident species. They have a lower priority for restoration due to watershed position, upstream impacts, private land ownership, and cost per unit benefit. Biological and physical goals include:

I. Restoring floodplain function and lateral channel movement where feasible to increase spatial habitat diversity and improve overwintering and summer rearing habitat, buffer high and low water levels and water temperatures downstream, and increase overbank sediment storage.
II. Mitigate flood damage by overbank flooding and improve off-channel habitat creation and access to the mainstem on cleared land by revegetating and reconnecting floodplain flood channels and baffling them with LWD in key locations.
III. Increase bank stability through passive and active restoration of root networks at cleared land, and restocking of appropriate site-series specific vegetation when and if upstream disturbances have been alleviated.
IV. Stabilize extensive bars and promote channel narrowing and deepening where feasible and when upstream sources of disturbance have been alleviated.
V. Stabilize upslope point sources of sediment through consideration of surface and groundwater pathways, as well as shear stresses and toe erosion.

Results

Results for channel, riparian, and fish and fish habitat assessments are presented in section 4 of this report for the 24 reaches surveyed. Along with these assessments are a description of land use in and upstream of the reach, a map depicting sample locations, fish presence and distribution, impact prescription sites by number, and areas requiring riparian prescriptions, as well as any barriers. Also included are photos of typical riparian and channel areas, and land-use and impact photos. Graphs and tables showing various diagnostics of the degree of impact and information important for restoration can be found therein. A synopsis of impacts and the nature of prescriptions, as well as a restoration plan for the sub-basin (flowchart) are found at the end of the results for each reach.

Recommendations

Riparian prescriptions are found in appendix F, and impact prescription sites are found in appendix G. Reach priority for restoration, as outlined in section 3 of this report, is presented in appendix H. Sub-basin priority for restoration is presented in table 71a. A prioritized list of restoration work is presented in table 71b, including costs for those sites on crown land. A prioritized list of assessment, survey, and design work is presented in table 72, including cost for work required on crown land. These priorities follow watershed level physical and biological goals for different physiographic groups in each sub-basin, as presented in section 3 of this report.

A general recommendation can be made concerning work on private land. FRBC watershed restoration funds have traditionally been available only for work on public (crown) lands related to forest harvesting impacts. Several exceptions have been made recently where works are shown to be related to upstream forest harvesting impacts, and the net result of carrying out restoration on crown lands only will not be sufficient for watershed restoration objectives to be met. FRBC investments are protected by designating the works as “fish habitat” under the Fisheries Act and Fish Protection Act, and with a signed agreement by the landowner not to alter the works. Should the proponent and/or implementing partners succeed in ratifying such an agreement with both the landowner and FRBC, it is recommended that priority work on private lands proceed. Private land overlaps critical fish habitat and floodplain areas in the watershed, and it is paramount that these areas be addressed fully and in proper sequence in carrying out restoration activities (i.e.- in accordance with sub-basin restoration plans).

Table 71a: Sub-Basin priority for restoration based on ranks assigned for fish values, relative watershed value (basin size, position), level of land-use impacts, and level of cumulative impacts. For the latter, a lower rank is assigned for a lower level of impact. Highest priority is 1 and lowest is 8.

Sub-Basin	Fish Values	Watershed Value	Level of Impact	Cumulative Impacts	Rank
Richfield	6	3	2	1	**1**
Emerson	2	8	1	2	**2**
McQuarrie	7	4	3	3	**3**
Barren	5	6	4	4	**4**
Aitken	8	2	5	6	**5**
Byman	4	5	6	5	**6**
Buck	3	1	7	7	**7**
Bulkley	1	7	8	8	**8**

Table 71b: Prioritized list of riparian and in-stream restoration work by sub-basin.

Sub-Basin	Project Priority	Reach	Impact Prescription Site	Riparian Prescription Polygon ID	Cost Estimate	Assessment/Survey/ Design Required?	Comments
Richfield	1	1	3	RIC11	N/A	no	
	2	1	-	RIC008/009	N/A	no	
	3	1	2	-	N/A	no	Upstream of highway only
	4	1	1	RIC007	N/A	yes	
	5	1	-	RIC002, 004	N/A	no	
	6	1	2	-	N/A	no	Downstream of highway
Byman	1	1	2	BYM008 to 020	N/A	no	Passive riparian restoration work only
	2	1	1	BYM015, 017	N/A	yes	Slope stabilization part of prescriptions
	3	1	2	BYM008 to 020	N/A	yes	Active riparian restoration if required
	4	1	1	-	N/A	yes	Active in-stream restoration
McQuarrie	1	3	1	MCQ19	$73 000	yes	
	2	1	-	MCQ001/002	N/A	no	
	3	1	-	MCQ003 to 005	N/A	no	
	4	3	-	MCQ015	$5 200	yes	After road work completed under MOF WRP funding
	5	1	-	MCQ009	N/A	no	
	6	1	1	MCQ008	N/A	no	
	7	1	2	-	N/A	yes	
Barren	1	2	-	BAR018 to 023	$29 000	no	Land tenure unknown
	2	4	4	BAR017	$49 800	yes	Land tenure unknown
	3	2	3	-	N/A	no	
	4	2	2	BAR008	N/A	no	
	5	1	1	BAR003	N/A	yes	
Aitken	1	3A	1	AIT025	N/A	no	All work to occur after hydrologic assessment
	2	3A	2 and 3	AIT029, 030 to 033, 035	N/A	no	
	3	3A	4	AIT037	N/A	no	
Buck	1	11B	1	UB008	$29 350	yes	All works to occur after basin-wide hydrologic ass't
	2	11B	-	UB001 to 007	$21 000	yes	
	3	Klo 2	1	KLO021 and 022	N/A	yes	
	4	6		BUC172, 199, 207, 228	N/A	no	
	5	6	-	BUC169, 177, 185, 192, 194	N/A	no	
	6	5	-	BUC139 and 157	N/A	no	

Table 71b: Prioritized list of riparian and in-stream restoration work by sub-basin cont'd.

Sub-Basin	Project Priority	Reach	Impact Prescription Site	Riparian Prescription Polygon ID	Cost Estimate	Assessment/Survey/ Design Required?	Comments
Buck	7	5	-	BUC090, 098-100, 108/109, 112/113, 125, 143/144	N/A	no	
	8	4	1	-	N/A	no	
	9	4	-	BUC064/065, 078, 087	N/A	yes	Land tenure unknown, may need SP
	10	2	-	BUC023, 042/043, 045, 048/049, 055	N/A	no	
	11	Dungate 1	-	DUN001 to 003a	N/A	no	
	12	2	1	-	N/A	no	If active restoration required
	13	1	2	BUC010 to 012	N/A	yes	If active restoration required
	14	1	1	BUC004, 006/007	N/A	yes	If active restoration required
Emerson	1	1	2	EME006/007	N/A	no	Land tenure unknown. To be carried out after upstream sediment source mitigated.
	2	1	-	EME005	N/A	yes	Land tenure unknown.
	3	1	1	EME001/002	N/A	yes	Land tenure unknown.
Bulkley	1	3		BUL262, 267, 268	N/A	no	
	2	2	3		N/A	yes	
	3	1/2/3		All rip-rap planting prescriptions	N/A	no	
	4	2	2	All bank stabilization prescriptions	N/A	no	
	5	2	1	BUL063	N/A	yes	Avulsion reset after upstream bank stabilized
	6	1	1	BUL029 and 032	N/A	yes	
	7	1		All bank stabilization prescriptions	N/A	no	
				Total estimated cost for crown land sites			**$207 350**

Table 72: Priority list of assessment/survey/design work by sub-basin

Sub-Basin	Sub-Basin Priority	Site Priority	Description	Cost
Richfield	1	4	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
Byman	2	2	Consultation and site visit with P. Geo	N/A
		4	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
McQuarrie	3	1	Survey, material sizing, engineering drawings by river and road engineers	$10 200
		4	Silviculture prescription	$1 600
		7	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
Barren	4	2	Survey, material sizing, engineering drawings by river and road engineers	$8 600
		5	Consultation with river engineer/geomorphologist, site survey and prescription drawings. Off-channel assessment (water quality, hydrogeology).	N/A
Buck	6	1	Survey, material sizing, engineering drawings by river and road engineers. Silviculture prescription	$10 200
		2	Silviculture prescription	$1 600
		3	Consultation and site visit with P. Geo. Silviculture prescription	$4 660
		13	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
		14	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
Emerson	7	2	Silviculture prescription required if land tenure is crown	$1 600
		3	Consultation with river engineer/geomorphologist, site survey and prescription drawings.	$8 600
Bulkley	8	2	Consultation with river engineer/geomorphologist, site survey and prescription drawings. Flood channel mapping and site selection.	N/A
		5	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
		6	Site visit and consultation with P.Geo.	N/A
			Total estimated cost for crown land sites	**$47 060**

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48. Major aggradation and instability where channel becomes more confined at top of the alluvial fan. Typical riparian forest community in predicted site series 08 ($58) polygons, Dungate Creek, reach 1.

49. 250metres upstream of Dungate/Buck confluence where channel becomes more stable. Typical riparian forest community in predicted site series 08 ($58) polygons, Dungate Creek, reach 1.

50. Typical riparian forest community in predicted site series 08 ($58) polygons, Dungate Creek, reach 1.

51. Typical riparian forest community in predicted site series 08 ($58) polygons, Dungate Creek, reach 1.

52. Heavy grazing on fan, Area of intensive lateral channel movement and siltation due to loss of riparian vegetation, Dungate Creek, reach 1.

53. Bank erosion at site of old private bridge site, Dungate Creek, reach 1.

54. Upstream of the 1/2 reach break where the channel becomes a bedrock controlled canyon. Note the trapping of wood, Dungate Creek, reach 2.

55. Impassable falls marking the a/b section break, Dungate Creek, reach 2. These falls occur at the end of the survey area.

56. Aggraded section of channel found below channelized area in lower reach. Typical riparian forest community in predicted site series 08 ($58) polygons. Most of the LWD is clumped into jams, Buck Creek, reach 1.

57. Aggraded channel found below channelized area in lower reach. Typical riparian forest community in predicted site series 08 ($58) polygons. Note extensive elevated mid-channel bars, Buck Creek, reach 1.

58. Channelized section of the creek, characterized by minimal complexity, long riffles and a lack of wood, Buck Creek, reach 1.

59. Representative channel and riparian forest community in predicted site series 08 ($59) polygons, typically seen in the upper half of the reach, Buck Creek, reach 1.

60. Canyon section located in the bottom half of the reach, Buck Creek, reach 2.

61. Aggraded channel found in the bottom end of the reach (with some bedrock control), and riparian forest community in predicted site series 08 ($59) polygons, Buck Creek, reach 2.

62. Very aggraded section (A2) above 1170metres, with a lack of overstory on the right bank, Buck Creek, reach 2.

63. Degraded (scoured, low complexity) channel found in the bottom end of the reach, Buck Creek, reach 2.

64. Intersecting powerline corridor crossing the creek between 550-600 metres upsteam of the 1/2 reach break. Rocks and boulder have been placed to allow for water at the pump house, Buck Creek, reach 2.

65. Hay field at approximately 4300 metres upstream of the 1/2 reach break. Note slumping bank, Buck Creek, reach 2.

66. Typical riparian forest community in predicted site series 06 polygons located at bottom end of reach, Buck Creek, reach 4.

67. Typical riparian forest community in predicted site series 08 ($59) polygons located at bottom end of reach, Buck Creek, reach 4.

68. Eroding bank located at bottom end of reach, the result of unstable flow regimes, Buck Creek, reach 4.

69. Typical channel characteristics found ~1400 metres upstream of the 3/4 reach break. Typical riparian forest community in predicted site series 07a ($57) polygons, Buck Creek, reach 4.

70. Large elevated gravel bars located in mid-reach highly aggraded section of creek, Buck Creek, reach 4.

71. Access road to Bob Creek mine claim at 3925 metres upstream of the 3/4 reachbreak, Buck Creek, reach 4.

72. Buck Creek Bridge #1 located at 4100 metres upstream of the 3/4 reachbreak, Buck Creek, reach 4.

73. Rip-rap bank channelizing at 4700 metres upstream of the 3/4 reach break, where the Buck Flats Road parallels the creek, Buck Creek, reach 4.

74. Channelized degraded section in the lower half of the reach. Typical riparian forest community in predicted site series 08 ($58)polygons, Buck Creek, reach 5.

75. Area of high volume LWD jams and lateral channel movement approximately 1 km upstream of the 4/5 reach break, Buck Creek, reach 5.

76. Flooded channel past beaver dam at 1150 metres upstream of 4/5 reach break. Typical ($57) site type riparian forest community in predicted site series 07a polygons on hillside in background, Buck Creek, reach 5.

77. Section of heavy sediment wedge deposits, exposed bedrock, and eroding clay banks 2340 metres upstram of the 4/5 reach break, Buck Creek, reach 5.

78. Clumped LWD in degraded section of channel at 4610 metres upstream of the 4/5 reach break, Buck Creek, reach 5.

79. Old land clearing site at the bottom of the reach, Buck Creek, reach 5.

80. Old skidtrail crossing creek at 3290 metres upstream of the 4/5 reach break, Buck Creek, reach 5.

81. Cleared land and eroding bank at 4969 metres upstream of 4/5 reach break, Buck Creek, reach 5.

82. Aggraded section of the reach with high level of lateral channel movement. Private land cleared for lawn on downstream right at 380metres upstream of the 5/6 reach break, Buck Creek, reach 6.

83. Typical riparian forest community in predicted site series 08 ($58)polygons. Located 500 metres upstream of 5/6 reach break. Note eroding bank on downstream right, Buck Creek, reach 6.

84. Degraded section of channel at 3300 metres upstream of the 5/6 reach break. Typical riparian forest community in predicted site series 08 polygons, Buck Creek, reach 6.

85. Typical riparian forest community in predicted site series 06 ($55) polygons in a selectively logged area of the Swiss Fire, located 3700 metres upstream of the 5/6 reach break, Buck Creek, reach 6.

86. Estimated 20 metre high landslide located below a selectively logged section of the Swiss Fire, on the downstream right side at 870 metres above the 5/6 reach break. A major source of clay input, Buck Creek, reach 6.

87. Rip-rapped channelized section of the reach where the Buck Flats Road parallels the creek located 2750 metres upstream of the 5/6 reach break, Buck Creek, reach 6.

88. Land clearing to the stream bank for cattle grazing associated with loss of bank stability, sediment inputs, and soil compaction. Located 2800 metres above the 5/6 reach break, Buck Creek, reach 6.

89. Large aggraded area 800 metres above the a/b section break. Note willow and alder recolonization on gravel bar deposits. Typical riparian forest community in predicted site series 07b polygons, Buck Creek, reach 11.

90. Log jam 900 metres above the a/b section break, Buck Creek, reach 11.

91. Large point bars in are of moderate-high lateral channel movement, Buck Creek, reach 11.

92. Riffle section in the upper half of the reach, Buck Creek, reach 11.

93. Aggraded section of creek with slumping grass banks. Note close proximity of road in upper left corner backgound, Buck Creek, reach 11.

94. Road related bank slumpage occuring in the upper half of the reach, Buck Creek, reach 11.

95. Mature cottonwood dominated riparian polygon, vital for supplying the largest functional LWD in the reach. Located at the bottom end of the reach in predicted site series 08 ($59) polygons, Bulkley River, reach 1.

96. Outside bank erosion seen below area of histroically cleared land in the lower end of the reach, Bulkley River, reach 1.

97. Typical riparian forest community in predicted site series 07a ($57) polygons seen at 1800 metres above Bulkley/Morice River confluence on the hill in the background, Bulkley River, reach 1.

98. Ideal and typical cottonwood-spruce riparian conditions with functional LWD in foreground, located 1000 metres above Bulkley/Morice confluence, Bulkley River, reach 1.

99. Long riffle section of channel between 1200 - 1300 metres, Bulkley River, reach 1.

100. Typical riparian forest community and gravel bar recolonization at 8800 metres above Bulkley/Morice River confluence, Bulkley River, reach 1.

101. Cleared hayfield with eroding bank in lower half of reach resulting in complete loss of riparian vegetation, soil compaction and sediment input, Bulkley River, reach 1.

102. Flood protection dyking occuring mid reach (just upstream of the Highway 16 bridge enforcements) contributing to stream channelization, Bulkley River, reach 1.

103. Powerline corridor right-of-way paralleling the system at 9000 metres upstream of the Bulkley/Morice River confluence, Bulkley River, reach 1.

104. Typical riparian forest community in predicted site series 08 ($59) polygons with shrub-herb seral stage in foreground, Bulkley River, reach 2.

105. Bank failure below private land clearing and sediment wedge at 2500 metres above the 1/2 reach break, Bulkley River, reach 2.

106. Severely aggraded, braided section just upstream of railway crossing at 4300 metres upstream of 1/2 reach break, Bulkley River, reach 2.

107. Typical riparian forest community in predicted site series 07a polygons at toe of hillside in foreground, Bulkley River, reach 2.

108. Aggraded channel, extensive bank erosion and minimal riparian forest seen above the Knockholt Bridge, Bulkley River, reach 2.

109. Extensive log jam in the upper half of the reach, Bulkley River, reach 2.

110. Deep, low gradient depositional section of channel characterized by long glides and pools and typical riparian forest community. Located 18000 metres above the 1/2 reach break, Bulkley River, reach 2.

111. Typical hillside riparian forest community in predicted site series 07a polygons, Bulkley River, reach 2..

112. Downstream view of the rip-rapped Highway 16 bridge crossing (east of Houston), channelizing that section of the reach, Bulkley River, reach 2.

113. CN railway crossing aggraded section of reach (sediment wedges) approximately 2500 metres upstream of the 1/2 reach break, Bulkley River, reach 2.

114. Livestock watering area and rip-rapped farmer’s field located 3100 metres upstream of the 1/2 reach break, Bulkley River, reach 2.
115. Ford across channel at approximately 22000 metres above the 1/2 reach break, Bulkley River, reach 2.

116. Cattle crossing near the powerline at the top end of the reach, resulting in increased sediment and nutrient input, loss of riparian vegetation, and compacted soils, Bulkley River, reach 2.

117. Small, privately logged patch at the top end of the reach, Bulkley River, reach 2.

118. Typical riparian forest community in predicted site series 08 ($59) polygons, Bulkley River, reach 3.

119. Typical riparian forest community in predicted site series 08 ($59) polygons, Bulkley River, reach 3.

120. Degrading, well inciseds channel upstream of the McQuarry Creek confluence. Typical riparian forest community in predicted site series 08 ($59) polygons, Bulkley River, reach 3.

121. Section of reach complexed with boulders located 4500 metres upstream of the 2/3 reach break, Bulkley River, reach 3.
122. Elevated gravel bars in aggraded section at the top end of the reach, Bulkley River, reach 3.

123. Bank erosion occuring at the head of CN rip-rapped section approximately 440

metres upstream of the 2/3 reach break, Bulkley River, reach 3.

124. Riffle section of lower half of reach, with bank failure on upstream right bank. Typical riparian forest community in predicted site series 08 ($59) polygons, Emerson Creek, reach 1.

1.0 Introduction

In the spring of 1997, the Nadina Community Futures Development Corporation (NCFDC) was designated as a proponent for FRBC funding in a Watershed Restoration Program (WRP) project in the Mid-Bulkley Watershed (see figure 1). The NCFDC is a non-profit community economic development corporation based in Houston, British Columbia. The implementing partner in this endeavor was the Ministry of Environment, Lands, and Parks, Skeena Region BC Environment office (MELP).

WRP is a provincial initiative under Forest Renewal BC to restore the productive capacity of forest, fisheries and aquatic resources that have been adversely impacted by past forest harvest practices, and thus to aid in providing long-term employment opportunities in resource-dependent communities (Johnston and Moore, 1995).

The Fish Habitat and Assessment Procedure (FHAP) is a means of assessing watersheds with a history of anthropogenic activity for impacts to fish and fish habitats using a set of integrated physical and biological indicators. The assessment procedure extends from stream and river channels, to the riparian area, to upslope areas in which there is some level of connectivity to the channel. There are two levels of assessment in the FHAP. The first, known as the Overview Assessment, is a reconnaissance-level study compiling background data and using predominately remote-sensing techniques to prioritize sub-basins and waterbodies within those sub-basins for the second level of FHAP. This is known as the Detailed (or Level 1) Assessment, which involves more detailed field surveys of the channel and riparian areas, the end result of which is the formation of restoration prescriptions to restore or rehabilitate fish habitat, or mitigate impacts on that habitat. There are four general steps in both stages of the FHAP:

1. Identification of fish species at risk in the watershed,
2. A quantitative and qualitative description of fish habitat conditions,
3. Evaluation of fish habitat conditions,
4. Identification of opportunities for effective fish habitat rehabilitation.

The British Columbia Conservation Foundation (BCCF) was contracted by NCFDC to carry out a WRP Detailed Level 1 Fish, Fish Habitat and Riparian Assessment in the summer of 1998. The general steps in conducting a Level 1 Riparian Assessment Procedure (RAP) are similar to those of the FHAP and are as follows:

1. Identification of areas of riparian loss due anthropogenic causes,
2. A quantitative and qualitative description of riparian habitat conditions,
3. Evaluation of riparian habitat conditions and
4. Identification of opportunities for effective riparian habitat rehabilitation.

In addition to the FHAP and RAP, BCCF staff also field-tested the Integrated Fish Habitat and Channel Assessment Field Procedures which had been developed for the Ministry of Environment, Lands and Parks Skeena Region WRP. The Channel Assessment Procedures (CAP) provide a continuous description of the stream channel and bank characteristics and impacts. The integrated FHAP/ CAP combined with the RAP result in a far more detailed picture overall and a deeper understanding of the general and specific processes occurring within the reach and the watershed.

The integrated FHAP/ CAP and RAP were conducted in the following sub-basins of the Mid-Bulkley Watershed (see figure 1):

- Bulkley River
- Buck Creek (including Klo Creek and Dungate Creek)
- Richfield Creek
- McQuarrie Creek
- Byman Creek
- Aitken Creek
- Barren Creek
- Emerson Creek
- Dockrill Creek

The objectives of the Level 1 Detailed FHAP (Johnston and Slaney, 1996) are:

1. to confirm or revise the identification of the nature, location, extent and severity of land use impacts on fish habitat,
2. to provide sufficient information to identify and prioritize restoration options, and to identify initial project objectives and scope,
3. to identify the need for any Level 2 assessments and
4. to prepare initial budgets and schedules for restoration projects.

The objectives of the Riparian Assessment Procedures (RAP) (Anon. Watershed Restoration Technical Circular No. 6, 1998) are:

1. to confirm the nature , location and extent of land use impacts on riparian habitat,
2. to provide field data for use in prescription development
3. to provide a preliminary list of restoration options for sites with impaired riparian functions and
4. to provide sufficient information to identify and prioritize impaired sites for Level 2 assessments and prescriptions.

1.1 Watershed Characterization

The Mid-Bulkley watershed, as defined by the watershed boundaries of the sub-basins listed above, is a 162 729 hectare drainage basin situated on the Nechako Plateau physiographic region. Two sub-basins drain the Telkwa Mountains of the Bulkley Range physiographic region which borders the Nechako Plateau to the Northwest. Elevations range from 570 m (1900 ft.) at the mouth of the Upper Bulkley to 1640 m (5400 ft.) at Tachek Mountain. The majority of land is within 800 and 1500m in elevation (LaRose and Rencoret, 1996). Watershed characteristics, and the fish and fish habitat therein, are defined by a complex and dynamic interaction of climate, hydrology, surficial and bedrock geology, vegetation, and land-use. For detailed descriptions of these characteristics refer to (BCCF, 1997).

1.2 Target Species

When fish are defined in the context of this assessment, what is really being referred to are target species. Target species for fish habitat assessment and restoration are economically and/or culturally important salmonids whose abundance has declined following past forest practices, or which are known to be sensitive to the effects of logging (Johnston and Slaney, 1996). The Mid-Bulkley has a complex history of land-use, and a short history of data gathering in relation to fish. In our case, it is difficult to separate the effects of one land-use from another at this level of assessment. Target species are therefore defined here as economically or culturally important salmonids whose abundance has declined following past land-use practices, or which are known to be sensitive to the effects of logging. The following species, in order of priority, are thought to be in decline in the watershed (BCCF, 1997):

- *Oncorhynchus kisutch* (coho salmon)

- *O. tshawytscha* (chinook salmon)
- *O. mykiss* (steelhead trout)

The following species which use the watershed for one or more life stages, are known to be sensitive to the effects of logging (including those listed above) (Johnston and Slaney, 1996):

- *O. gorbuscha* (pink salmon)
- *O. nerka* (sockeye salmon)
- *O. mykiss* (rainbow trout)
- *O. clarki* (cutthroat trout)
- *Salvelinus malma* (Dolly Varden)
- *S. confluentus* (bull trout)

The latter species is also blue listed (species considered to be vulnerable) by MELP. These are the target species whose habitats, distributions, and abundance are being investigated in this assessment.

1.3 Study Area

The study area for this assessment is presented in figure 1. It delineates the main sub-basins in which detailed assessments were carried out. Other sub-basins identified in the overview FHAP are also shown.

2.0 Methods

The methods employed during the field portion of Mid-Bulkley Detailed Fish Habitat/ Riparian/ Channel Assessment follow those laid out in the various Watershed Restoration Circulars and Addenda. Detailed descriptions of procedures can be found in the appropriate Technical Circular listed below. Data analysis followed a standardized procedure for each type of data to be analyzed.

2.1 Field Procedures

Field personnel consisted of a Project Leader/ecologist, two Senior Environmental Technicians and a Junior Field Technician. Reaches were assessed by teams of two starting at the mouth or confluence with the mainstem or in several cases at the reach break above a reach not surveyed. Three sets of data along with a tally of all habitat units and a tally of LWD within the channel by size class (small 10-20 cm, large 20-50 cm and extra large >50cm) and functionality were gathered. Observations of point source or Category 1 impacts, broader Category 2 impacts affecting the watershed as a whole and general impressions were also collected.

- Fish and Fish Habitat Assessment Procedures following Watershed Restoration Technical Circular (WRTC) No. 8 (Johnston and Slaney, 1996) were used to assess the quality and quantity of the fish habitat available in the reach.
- Channel Assessment Procedures following WRTC No. 7 (Hogan, et al, 1996) and the Integrated FHAP/CAP field procedure (Skeena Region MELP technical addendum #1) were used to describe the channel and stream banks and to assess the type and degree of impacts occurring within the reach.
- Riparian Assessment followed the overview procedure in WRTC No. 6 (Draft, anon, 1998) which was used as a basis for characterizing the riparian zone and recording the impacts of land-use on the riparian zone and floodplain. Riparian polygons were developed for the reach based on the varying plant communities and land-usage immediately adjacent to the stream. Overstory and shrub/herb species were inventoried to species. In some cases they were only identified to genus where identification to species was not plausible (i.e.- *salix* (willow) species).

All forms of field data were gathered concurrently allowing various impacts, sites and potential prescriptions for rehabilitation to be cross-referenced to each other and to riparian polygons, channel disturbance indicators and to fish habitat descriptions.

The Integrated Fish Habitat/ Channel Assessment Field Procedure (Skeena Region WRP Technical Addendum (Mackay, 1998)) was field tested during this contract. The Integrated Procedure is based on the FHAP, CAP (Anon, 1996) and the Channel Conditions and Prescriptions Assessment (WRTC No. 7). Forms 4 and 7 were used to record FHAP data and Channel Disturbance data respectively.

A systematic random sampling method was used to determine habitat units to be sampled. Five types of habitat units were differentiated to stratify the stream reach. These units consisted of glides, riffles, pools, cascades and “others”. Off-channel and beaver ponds were classified as “other” units. A randomly generated start interval and sampling interval was determined for each type of unit using a random number generator. The fourth glide from the mouth of the stream or the reach break was sampled (start interval) and every 18th glide from then on was sampled (sampling interval). The start interval for riffles was 10 and the sampling interval was 12. The third pool upstream from the reach break was sampled followed by every 16th. Cascades had a start interval of five and a sampling interval of 12. The first other unit was examined and every 16 after that. This yielded some variability in actual subsampling, as the end of surveys did not always see the completion of all unit sampling for a particular interval. Furthermore, some units which fell as the next interval were not always have good conditions for sampling (ie-water levels, water quality). In some complex (and usually smaller streams) the sample interval for habitat units was doubled. This expedited sampling effort while still maintaining the inherent randomness of the survey design.

Discharge was estimated once daily using methods suggested in WRTC#8 by each field crew for all reaches except the mainstem Bulkey River which has a permanent monitoring station near Houston. Air and water temperatures were taken hourly using a pocket alcohol thermometer to develop a temperature differential for the reach. Coffelt BP-4 battery powered backpack electroshockers and dip nets were used to capture fish in the units sampled. Unclosed units were electroshocked in a single pass. Channel widths and depths were recorded using Eslon tape measures and stadia rods respectively. A Suunto clinometer and an Abney hand level were used to determine gradients. Several gradients were taken over representative sections of the reach. Field chains mounted on hip-belts were used to record all distances. Garmin GPS 12XL handheld GPS units were used to acquire UTM coordinates (not differentially corrected) to assist in the mapping phases of the contract and to confirm general location in the field.

2.2 Data Analysis

Data analysis procedures were developed for each type of data gathered. FHAP survey data and CAP data was entered into an MS Access database using the WRP data entry system (WRP DES). The results of data analysis are presented on a reach basis. Types of data analysis and their descriptions are listed below.

1. **FHAP habitat survey data analysis**:

Habitat survey data was analyzed for quantitative parameters (length, bankfull/wetted depths, bankfull/wetted widths, pool depths, and D (largest stone moved by flowing water) using the weighted reach mean calculations for randomly subsampled survey data. This procedure is set out in TC#8. These values were useful in determining, among other things, LWD and pool frequencies, in-stream design data, and bankfull:wetted depth and width ratios. Modal results were calculated for nominal data such as substrate type.

2. **FHAP habitat unit data analysis:**

The total habitat unit tallies for the reach were used to calculate unit richness (the number of unit categories), complexity index (a measure of habitat complexity based on habitat unit class proportion and unit richness), pool frequency (number of bankfull widths between pools), and metres between pools (indicator parameters of salmonid rearing habitat condition) for each reach.

The complexity index was invented using a modified Simpson's Diversity Index. This ecological parameter is normally used as a descriptor of community biodiversity. It reflects both species richness and proportional abundance. The complexity of habitat units, or lack thereof, is an important indicator of the overall fish habitat value of a reach. Complexity is defined here as the degree of equability amongst the range of habitat unit types expected for a given type of channel. A diversity of habitat means an ability to support a diverse range and abundance of species and age classes. The calculation for Simpson's Diversity Index was modified to arrive at an index of complexity by replacing the biotic terms with those for habitat unit richness and proportions of habitat by unit category. Unit richness was in most cases static, based on the usual habitat unit categories present. The complexity index value is directly proportional to the equability of habitat unit types.

3. **FHAP wood data analysis:**

The LWD tallies were used to determine ratios of functional to non-functional LWD, and numbers of pieces of functional LWD per bankfull width. These ratios give an indication of the role LWD plays in complexing the stream and creating diverse habitat.

4. **FHAP temperature data analysis**:

Temperature differential was calculated by subtracting the mean ambient water temperatures from the mean ambient air temperatures sampled. Temperature differential was only calculated for those reaches which were surveyed during the high summer temperatures/summer low flow critical period and when weather conditions were not overcast and/or raining. These conditions were placed on the analysis of temperature measurements because it would be unreasonable to assume that this parameter would respond in a linear fashion to different amounts of solar loading. Only summer critical period measurements would yield a clear impact signal based on the timing of our surveys. Thermal maxima were also reported in the results, and compared to known thermal thresholds for different salmonid species.

5. **FHAP channel and riparian data analysis**:

Length of moderately to severely disturbed channel was calculate using the methods set out in the integrated CAP/FHAP field procedure. Disturbed riparian polygons requiring prescriptions were mapped on 1:20 000 scale TRIM map sheets.

Predicted ecological site series and associated soil regimes were assigned to riparian polygons requiring rehabilitation prescriptions using Banner et al, 1993, Oikos Ecological Services Ltd., 1998 and Haeussler, 1998. These designations are to be field checked in the 1999 field season prior to finalizing silviculture prescriptions.

6. **FHAP design data analysis:**

Following procedures in Newbury and Gaboury, 1993, median particle size, tractive force and bankfull discharge estimates were calculated. These parameters are helpful in designing instream works and sizing their construction materials.

7. **FHAP fish data analysis:**

Age-class analysis and determination was conducted by generating fork length histograms based on class-widths of 0.5 to 1 cm. Age cohorts were determined by analyzing peaks and distributions of classes, and with the aid of other extensive studies of growth rates (Scott and Crossman, 1973) and local, more intensive studies which have been carried out in the watershed (Tredger, 1982, Bustard, 1984). Volumnar densities (fish/m^3) by species and age class were calculated for each habitat unit sampled based on measurements of unit dimensions and numbers of fish sampled. Mean densities by species and age class for each habitat unit category were arrived at by averaging the results of density calculations.

8. **Impact Analysis:**

All of the data generated above had to be integrated in a meaningful way into an interpretation of impact. Since regional habitat standards for many of the variables collected in the FHAP do not exist, procedures set out in the FHAP for carrying out this step could not be used. Instead, a set of parameters indicating channel and habitat disturbance were integrated with channel assessment data and field observations, as well as relative abundance/densities of species present in different habitat units. These parameters, in order to indicate a degree of cumulative impact or not, had to be compared to a standard set of values. Having surveyed a wide spectrum of reaches with varying levels of land-use, it was decided that using the parameters Complexity Index, Functional LWD Frequency, Pool Frequency, the Bankfull Width:Wetted Width ratio and the Bankfull Depth:Wetted Depth ratio, that a set of benchmark reaches would be set up to compare all other reaches to for these parameters. (see table 1). A measure of impact was provided by the number of standard deviations (the standard deviation of all reaches surveyed for a given parameter) from the average benchmark value that the resultant parameter for that

Table 1: Comparison of reach results for selected parameters to benchmark conditions as an indication of impacts by land-use activities.

Reach	Complexity Index	SD	Functional LWD per W_B	SD	Pool Frequency	SD	Wb:Ww Ratio	SD	Db:Dw Ratio	SD
Low-Gradient/Depositional Reaches										
Richfield1	3.41	0.6	0.34	1.8	5.92	0.6	2.05	0.8	3.15	1.8
Byman1	3.06	1.8	0.23	2.2	7.06	0.9	1.85	0.6	2.92	1.5
McQuarrie1	3.39	0.6	0.14	2.6	3.38	0.1	2.48	1.4	2.29	0.6
McQuarrie3	3.39	0.6	0.83	0.1	4.42	0.2	1.52	0.1	2.13	0.3
Aitken1	3.76	0.6	0.25	2.1	15.54	3.2	1.68	0.3	3.01	1.6
Aitken3	3.88	1.0	0.58	0.8	3.32	0.1	1.29	0.2	1.60	0.5
Barren1	2.84	2.5	0.16	2.5	5.2	0.4	4.42	4.1	1.33	0.9
Barren2	2.96	2.1	0.17	2.4	7.71	1.1	1.93	0.7	2.70	1.2
Buck1	3.02	1.9	0.39	1.6	9.57	1.6	2.50	1.5	2.74	1.2
Buck2	3.31	0.9	0.14	2.6	7.68	1.1	1.71	0.4	2.83	1.4
Buck4	3.32	0.9	0.59	0.8	6.04	0.6	1.84	0.6	2.48	0.8
Buck5	3.35	0.8	0.39	1.6	8.82	1.4	1.72	0.4	2.83	1.4
Buck6	3.13	1.5	0.1	2.7	15.73	3.3	1.36	0.1	4.23	3.4
Buck11	3.46	0.4	0.98	0.7	3.26	0.1	1.50	0.1	2.00	0.1
Klo1	3.22	1.2	0.49	1.2	6.91	0.9	2.33	1.2	2.51	0.9
Dungate1	3.84	0.9	0.22	2.3	9.26	1.5	1.69	0.4	2.42	0.7
Emerson1	3.38	0.7	0.58	0.8	9.69	1.6	1.46	0.0	1.71	0.3
Max	3.88		0.98		15.73		4.42		4.23	
Min	2.84		0.10		3.26		1.29		1.33	
Mean	**3.34**		**0.39**		**7.62**		**1.96**		**2.52**	
SD	0.29		0.26		3.70		0.73		0.68	
Benchmark Low-Gradient Depositional Reaches										
Buck11	3.46	0.4	0.98	0.7	3.26	0.1	1.50	0.1	2.00	0.1
McQuarrie3	3.39	0.6	0.83	0.1	4.42	0.2	1.52	0.1	2.13	0.3
Aitken3	3.88	1.0	0.58	0.8	3.32	0.1	1.29	0.2	1.60	0.5
Benchmark	**3.58**		**0.80**		**3.67**		**1.44**		**1.91**	
High-Gradient/Confined Reaches (Richfield 2=Benchmark)										
Richfield2	3.55		0.16		6.36		1.82		2.33	
Klo2	3.06	1.3	0.2	0.2	9.27	2.2	2.24	1.6	2.41	0.2
Dungate2	3.97	1.1	0.23	0.3	9.1	2.0	1.96	0.5	2.54	0.5
Dockrill1	3.62	0.2	0.63	2.2	8.03	1.2	1.63	0.7	1.55	1.8
Max	3.97		0.63		9.27		2.24		2.54	
Min	3.06		0.16		6.36		1.63		1.55	
Mean	**3.55**		**0.305**		**8.19**		**1.91**		**2.21**	
SD	0.37		0.22		1.34		0.26		0.45	

reach fell. Although natural variability could not be estimated using these assessment procedures, parameters were tested for normality, and parameters all approximated a normal distribution. The standard deviation is a useful descriptor because it illustrates incremental variability from the sample mean, or in this case a set of benchmark values. In this way, a measure of impact could be assigned to those values which fell outside of one standard deviation from the benchmark value, with those values that fell within considered unimpacted and within the range of natural variability. Reaches were grouped into two types so that differences in channel processes would not lead to erroneous conclusions. These were unconfined ("alluvial") and confined reaches. Benchmarks reaches were chosen for each of these types of groupings, and an average was taken of their results for each parameter, and this was the resultant benchmark value. Benchmark reaches were chosen based on the degree of land use and overall rank in the spectrum of values for all indicator parameters.

Cumulative and point-source impacts were also ascertained from an interpretation of fish habitat, riparian and channel analysis results, field observations, and photos. Prescriptions for impact sites were determined using Slaney, 1997, Newbury and Gaboury, 1993, Anonymous, 1998, Chatwin et al., 1994, Donat, 1995, various articles in the WRP technical bulletin streamline, and supporting information presented in the references section. All prescriptions were linked to a set of guiding principles and a master plan for restoration activities (section 3 of this document). A restoration plan was developed for each sub-basin indicating the timing and priority of restoration activities. Prescription and survey and design costs are presented only for those sites on crown land.

3.0 Master Plan for Restoration Activities

The following comprises a set of guiding principles for restoration, a synthesis of impact assessment results, classification of different areas by watershed position for the purpose of grouping restoration priorities, and a set of physical and biological goals. For any given watershed, there are tens to thousands of sites which might exist outside of pre-disturbance conditions, and which could be considered singularly for restoration. The purpose of this plan is to guide sub-basin restoration priorities and timing, and to integrate individual restoration prescriptions with overall watershed-level goals.

3.1 Guiding Principles

The following set of eight guiding principles is drawn from the works of the Pacific Rivers Council (1996), Doppelt et al.(1993), Slaney and Zaldokas (1997), and Rhodes et al. (1994):

1) Passive restoration is the least expensive and often the most effective means of restoration, where the principal causes of impact are removed or altered so that they no longer cause an impact. The main cause of failure in active restoration projects is their implementation before the sources of disturbance have been stopped.
2) In some cases, passive restoration alone will not achieve success, as a continued presence of physical or biological limitations may prevent complete recovery. In these cases, active restoration should proceed carefully. Projects should not be based on a misinterpretation of ecosystem needs which result in further degradation, and should focus primarily on addressing the causes rather than the symptoms of degradation.
3) Instream habitat and biota are largely determined by processes occurring in the drainage basin and riparian and floodplain areas cannot be manipulated independent of this context.
4) Disturbances propagate downstream from headwater sources so that multiple sources can interact and culminate in cumulative impacts. Therefore, restoration should proceed from the upslope areas to the floodplain, and the headwaters to the mainstem where applicable.
5) Restoration should be focused where a minimal investment can secure the maintenance of the largest amount of high quality habitat and diversity of aquatic species. Recovery of highly degraded and therefore biologically impoverished watersheds will require decades to centuries. Restoration in these areas is likely to prove unsuccessful in the short term (<10 years).
6) The current distribution and life history patterns of fish populations, largely governed by the nature and distribution of key habitat refuges (focal and nodal habitats) in the watershed, determine the ability of fish populations to respond to future changes in habitat. Therefore, restoration should be focused on protecting these biological hotspots that are still functioning (functioning-at-risk). Restoration that first secures existing hotspots, then reestablishes similar and proximal habitat that requires little

adjustment of life-history patterns, is most likely to provide the kinds of habitat critical to existing fish populations.

7) Aquatic habitat is very patchy and highly variable in space and time. Fish life histories are adapted to these conditions. Restoration must not be focused on producing generic or homogeneous conditions, but on producing spatial diversity and complexity.
8) Restoration must be based on natural templates and unique watershed conditions because they reflect an integration of watershed processes and energy fluxes. This includes channel, upslope and riparian restoration, and should be mindful of how fish populations might have adapted to long-term natural disturbances (i.e.-beavers). It is much less expensive to study the integration of these conditions, than to try to quantify them individually.

3.2 Impact Summary and Restoration Priorities

Watershed position, fisheries value, synergistic value (risk to downstream values), land-use, physical and biological impacts, current state of functioning, and land ownership are summarized by reach in appendix H along with a priority for restoration. Sub-basin priority (for planning and funding purposes), restoration priority for each proposed set of works, and assessment/survey/design priorities are presented in section 5 (recommendations) of this report.

3.3 Watershed-Level Physical and Biological Goals

Based on watershed position, four physiographic groups were identified to meet the requirements of guiding principles. Within each group, a number of biotic and abiotic functions are held in common which broadly define the nature of habitat and fish species use and connectivity to other groups. Reaches are classified according to these groups, and each group is assigned a set of physical and biological goals for restoration. Within each sub-basin, restoration plans set out in section 4 of this report follow the relative priority of each physiographic group. These groups are as follows:

Headwaters reaches: Headwaters areas in the Mid-Bulkley watershed which support significant salmonid fisheries values and were surveyed in this assessment are all in the Buck sub-basin, and include Upper Buck Creek (reach 11B), and Klo Creek reaches 1 and 2. They do not support anadromous populations due to downstream barriers, but are highly important areas for the maintenance of downstream habitat conditions. They have a very high priority for restoration because there is little upstream land use, because they are often focal or nodal habitats for resident fish, because their landbases are not privately owned, and their restoration will have positive impacts on downstream habitat. This is in consideration of guiding principles 2), 4) and 6). Biological and physical goals include:

1) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability

2) Reestablish sediment storage functions such log jams at geomorphic notch points (natural bedrock constrictions and other points which act to consistently catch and hold debris) where they are lacking
3) Reestablish upstream access to areas which have been blocked for resident fish passage by land-use activities

Mid-elevation reaches: These reaches are depositional reaches above confined canyons which separate upland areas from the Bulkley valley. They act to store sediment, LWD, and water in the floodplain and thus maintain the quality and nature of downstream anadromous and resident salmonid habitat. They also support significant and diverse populations of resident fish. In most cases, these reaches have one or more barriers to upstream migration between them and the valley bottom, and do not support anadromous fish populations. This would include Aitken reach 3A, part of Barren reach 2, and McQuarrie Reach 3. In the case of Buck reaches 4-6, anadromous species have access and both spawn and rear there. These areas typically have medium to wide floodplains and low gradients (<2%). They have a high priority for restoration because their restoration will have a positive impact on downstream reaches, and/or because they are functioning-at-risk but not highly impacted, and/or because the land (in some cases) is not privately owned, and/or because their are high resident and anadromous fisheries values in these reaches. Biological and physical goals include:

I. Reestablish upstream access to resident and anadromous fish species where barriers have been created by land-use.
II. Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probability of success despite upstream sources of disturbance.
III. Reestablish sediment storage functions such as log jams in geomorphic notch points where they are lacking. Maintain anadromous access through these areas in concert with the former goal where applicable.
IV. Carry out passive and active restoration to reduce soil compaction on the active floodplain, reconnect the channel to the active floodplain, and restore key features such as LWD.

Alluvial fan reaches: Owing to the number of upstream barriers to mid-elevation reaches in the watershed, alluvial fans of tributaries to the Bulkley River are focal and nodal habitats for both anadromous and resident fish in the watershed. These include reaches 1 and 2 of Richfield, Buck, and Dungate Creeks, and reach 1 of Byman, McQuarrie, Aitken, Barren, and Emerson Creeks. They are critical for spawning and rearing, particularly for coho salmon and steelhead trout, in an unimpacted state. Although normally a mainstem spawning and rearing species, this reach may also be an important area for chinook salmon considering the extreme low-gradient nature of the Bulkley River in reaches 2 and 4. They ideally provide areas of swifter current and larger substrate, diverse invertebrate communities, complex channel morphology and cooler water temperatures relative to the mainstem. As such they are important for summer rearing and summer and fall spawning habitat. Their proximity to the Bulkley provides access to overwintering habitat, mainstem rearing areas for older juvenile salmonids, and a choice of habitat refugia in either the mainstem or tributary during high water events. Their use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition. They have wide, active floodplains and diverse deciduous-dominated riparian forests which thrive on overbank flood disturbances. They generally have a moderate to high priority for restoration because their restoration will have positive impact on downstream reaches, because they are highly important focal and nodal habitats for some or all fish species present and are in proximity to other high-value habitat (mainstem reaches), because they may be poorly functioning, and/or because they are dominantly on private land. Biological and physical goals include:

1) Reestablish upstream access to resident and anadromous fish species where barriers have been created by land-use.
2) Reestablish spatial habitat diversity and quality, and hydraulic energy dissipation in areas that have been channelized. A long-term goal which requires cooperation between private landowners and regulatory agencies is the de-channelizing of these areas and their reconnection to normal floodplain functioning, which is beyond the scope of this project.
3) Reestablish sediment storage functions such as log jams in geomorphic notch points where they are lacking. Maintain anadromous access through these areas in concert with the former goal where applicable.
4) Passively restore riparian areas wherever possible with landowner cooperation to limit land-use to areas outside of the riparian zone.
5) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probability of success despite upstream sources of disturbance, and/or when passive restoration needs to be integrated with active restoration.
6) Stabilize extensive bars and promote channel narrowing and deepening where feasible and when upstream sources of disturbance have been alleviated.
7) Actively restore LWD function with the purpose of creating pool habitat and spawning gravel catchments when upstream sources of disturbance and lateral channel instability have been removed.

Mainstem reaches: These are reaches 1 to 3 of the Bulkley River. Mainstem reaches are important for spawning, overwintering, rearing, and migration of anadromous and resident species. They have a lower priority for restoration due to watershed position, upstream impacts, private land ownership, and cost per unit benefit. Biological and physical goals include:

I. Restoring floodplain function and lateral channel movement where feasible to increase spatial habitat diversity and improve overwintering and summer rearing habitat, buffer high and low water levels and water temperatures downstream, and increase overbank sediment storage.
II. Mitigate flood damage by overbank flooding and improve off-channel habitat creation

and access to the mainstem on cleared land by revegetating and reconnecting floodplain flood channels and baffling them with LWD in key locations.

III. Increase bank stability through passive and active restoration of root networks at cleared land, and restocking of appropriate site-series specific vegetation when and if upstream disturbances have been alleviated.

IV. Stabilize extensive bars and promote channel narrowing and deepening where feasible and when upstream sources of disturbance have been alleviated.

V. Stabilize upslope point sources of sediment through consideration of surface and groundwater pathways, as well as shear stresses and toe erosion.

4.0 Results and Discussion

4.1 Richfield Creek Reach 1

Land Uses

Moving upstream from the mouth, land uses include hay land and cattle ranching for the first 400 metres. This area is dissected by the railway corridor at 200 metres, and a railway bridge which channelizes the creek. Richfield Creek flows across the westernmost edge of higher density housing on the left bank between 400 and 980 metres. Most of the houses or their yards are on the floodplain directly adjacent to the creek. Consequently, a good deal of bank armouring has been done in this area. Along with human habitation inevitably comes inputs of garbage and debris into the creek, of which there is a good deal. At 980 metres upstream from the mouth, the creek is crossed by Highway 16, where it flows through two pipe-arch culverts. During low flow periods, flow is consistent only through one of these. The banks upstream and downstream of the highway bridge are channelized for roughly 100 metres each way to prevent lateral channel movement. The right bank continues to be used for agricultural purposes up to 1800 metres upstream from the mouth. It is dominantly hay fields downstream of the highway, and cattle pasture upstream. At two points on the right bank, the main channel of the creek has been physically altered for watering purposes, one for a cattle watering hole, and the other for a water pump. On the left bank above the highway crossing, there are a number of dwellings and cleared land in the riparian area up to roughly 1400 metres. From this point, old land clearing and intermittent openings for pasture are the dominant land-use to the reach break on both banks. The large powerline corridor which follows Highway 16 to the north also intercepts the creek at approximately 1400 metres and is associated with regular removal/suppression of vegetation which might cause or potentially damage the wires. Nutrient loading from cattle faeces is expected to be highly detrimental to water quality, and is evidenced by field observations of odour and primary productivity in the creek. Water quality measurements are unfortunately beyond the scope of this study. Upstream land uses include forestry (in the headwaters of Redtop Creek and in the Holmes Creek basin along the Granisle Highway corridor), as well as some small-scale mining exploration and extraction in the Richfield Creek basin near Nez Lake. The Equivalent Clearcut Area of the reach is 14% (BCCF, 1997). Land-use in the headwaters is not expected to have altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 11 polygons occupying a total area of 14.9 hectares with a riparian zone width of 30 metres (see Richfield Creek entry,

Reach Impact and Restoration Diagnostics

Table 2: Summary of habitat quality indicators by habitat unit category for Richfield Creek, reach 1.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	G	H	AR	L	0
Other	S		M	AR	N	0
Pool	C	G	H	AR	L	1
Riffle	C	G	H	AR	H	1

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	0	0	0	C, OV	1
Other	0	0	1	OV	2
Pool	0	1	1	OV	1
Riffle	0	1	0	LWD	1

Table 3: Reach summary of other indicators of impacts to watershed function and fish habitat for Richfield Creek, reach 1.

Functional pieces of LWD/bankfull width	**0.34**
Pool frequency	**5.92**
Bankfull : wetted width ratio	**2.05**
Bankfull : wetted depth ratio	**3.15**
Average temperature differential at summer low flows (^{O}C)	**1.67**
Area of disturbed riparian forest (ha)	**13.5**
Length of disturbed channel (m)	**1935**

Table 4: Mean values for selected parameters which may assist in designing instream restoration works, Richfield Creek, Reach 1.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	0.50	0.60	10.73	10.67	40.76	3.00
Riffle	0.60	0.64	10.46	13.20	40.19	3.85
Pool	0.50	0.81	6.20	9.33	65.39	4.03
				Reach Mean Estimated Bankfull Discharge	48.78	

appendix D). Land-use has modified 90%, or 13.5 hectares of this. The BEC classification for this reach is sub-boreal spruce, dry-cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations. On the alluvial fan of Richfield Creek, the dominant plant community is predicted to be the cottonwood-twinberry ($58) seral association with areas of black cottonwood-dogwood ($59) on lower-bench areas with more frequent overbank flooding. It may be possible that prior to agricultural land development that pacific willow-mountain alder-lady fern (TEM code=ML) communities existed in low-bench regularly flooded sidechannels of the Bulkley or Richfield Creek but these seem to be absent due to either decreased overbank disturbance, or being filled in for hayland, or both. These are floodplain (08) site series. The wetland area which lies between the confluence of Robert Hatch and Richfield Creek is mostly a shrub carr non-forested site series (32), dominated by *Salix* (willow) and *Carex* (sedge) species. Higher bench spots in this area are influenced by alluvium from Richfield Creek, and appear directly adjacent to it in many cases. The most upstream end of the reach is confined on the right bank by steep valley walls of morainal and glacio-fluvial materials with an easterly aspect. The presence of abundant *Populus tremuloides* (trembling aspen) and 0-40% slopes indicates spruce-horsetail (07a) and/or spruce-twinberry-coltsfoot (06) sites. These sites are seral associations, and are predicted as aspen-twinberry ($57) and aspen-rose-peavine ($55) based on species presence and aspect.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest and soil compaction in areas used for hay farming/grazing/powerline corridor.
- Loss of the shrub/herb layer and associated root system and soil compaction from cattle grazing carried out in areas where the overstory still exists
- Removal of riparian forest and disconnection of the channel from the riparian zone due to channelizing in transportation corridors and at housing developments on the floodplain.
- Past harvesting of spruce and cottonwood by landowners preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (white clover, Canada thistle), the possible modification of floodplain and channel features (diversions, landfilling), and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.

Typical riparian polygon photos are found in plates #2.

Channel Assessment

Reach 1 is a 2478 metre long RPgw and RPcw channel flowing between the elevations of 660 and 672 metres a.s.l., with an average gradient of 0.54 %, bankfull width of 8.4 metres, and bankfull depth of 0.7 metres. It is a depositional alluvial fan reach whose dominant channel-forming mechanism is LWD. Streambanks are composed of erodible, unconsolidated sands, gravels and cobbles. The channel is irregularly wandering with a low to moderate degree of lateral stability. Upslope areas are disconnected from the active channel except in the upper end of the reach where it is confined on the left bank and partially confined on the right bank by steep valley walls. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 1 indicated that 78 % (1935 metres) of channel is moderately to severely disturbed. In all channel disturbance polygons, the channel was classified as aggrading (A2). Dominant indicators of disturbance include extensive bars, minimal pool frequency/extent, and eroding banks. Elevated mid-channel bars occur for the first 930 metres upstream. Avulsions were noted just below the channelized section at the railway crossing, in the vicinity of the Robert Hatch wetland area, and near the top of the alluvial fan just below the semi-confined stretch. Localized areas of sediment wedges and extensive riffles occur at the bottom of the reach. Compacted floodplain soils and riparian modification causing eroding banks and channel incision are illustrated by the departure of the bankfull:wetted width and bankfull:wetted depth ratios (2.05 and 3.15 respectively) from benchmark conditions. See plates 1-3 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 1 can be characterized as high value fish habitat. Coho (0+) salmon, and resident prickly sculpins (1+), and long-nosed dace (0+/1+/2+) were present in the creek at the time of survey. Coho were not present in units sampled above the highway crossing. Rainbow/steelhead trout (0+/1+/2+) were also caught in this reach. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout (Tredger, 1984). Chinook salmon (0+) also have a documented presence in the reach (FISS, 1995, FHIIP, 1991, Tredger, 1982). Anecdotal information from a local rancher suggested the presence of Dolly Varden and cutthroat trout (BCCF, 1997). No cutthroat trout were captured in the watershed during the survey, and it is doubtful that they are or were present in this reach, although it is possible they exist in Nez Lake and might occasionally survive a downstream migration through several cataracts and waterfalls. Dolly Varden and bull trout were captured in similar areas of the watershed (dominantly canyon areas), and may be present during different seasons, or have a historic presence. Twenty or more adult chinook and numerous chinook jacks were observed holding in a large pool at the mouth of Richfield Creek at the time of survey. It is assumed they were awaiting slightly lower water temperatures and higher flows prior to moving up the creek to spawn.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is a critical and productive area for spawning and rearing, particularly for coho salmon and steelhead trout, in an unimpacted state. Although normally a mainstem spawning and rearing species, this reach may also be an important area for chinook salmon considering the extreme low-gradient nature of the Bulkley

River in reach 4. The alluvial fans of tributaries to the upper Bulkley River, as discussed in section 3 of this report, ideally provide areas of swifter current and larger substrate, diverse invertebrate communities, complex channel morphology and cooler water temperatures relative to the mainstem. As such they are important for summer rearing and summer and fall spawning habitat. Their proximity to the Bulkley provides access to overwintering habitat, mainstem rearing areas for older juvenile salmonids, and a choice of habitat refugia in either the mainstem or tributary during high water events. Their use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits degraded habitat relative to benchmark conditions. Habitat complexity falls within 1 standard deviation of the benchmark with a complexity index of 3.41, and is greater than the average of all reaches surveyed (see table 1(page 9) and figure 9). Riffles dominate the spectrum of habitat units, and there are very few off-channel (“other”) units present. Compaction was high in all units except “other” units. Spawning gravels were usually low to absent in all units except riffles, which had both anadromous and resident gravels. Several redds (likely steelhead trout) were noted at 1730 and 2075 metres upstream. Many suitable areas of spawning gravels were noted just upstream of a large log jam at approximately 2200 metres upstream from the mouth. This indicates the tendency of LWD (particularly log jams) to store spawning gravels and create hydraulic conditions where they are deposited by decreasing local gradients. LWD function is less than 50% in all size classes, and functional LWD frequency is 0.34 pieces/bankfull width (see figure 8 and table 3). The latter value is 1.6 standard deviations below the benchmark value, and as such is considered a significant departure from benchmark conditions. On average, functional LWD (affecting cover, morphology) is only found in riffles and pools, and no small functional LWD was present in any of the units sampled. Pool frequency is 5.92 bankfull widths between pools, less than 1 standard deviation from the benchmark of 3.67, and is above the survey average. Cover elements showed less complexity, with very little in-stream cover. Cover usually consisted of overhead deciduous vegetation, except in glides where cutbanks also added cover, and in riffles where LWD was the only cover available. Canopy closure was 0-20% on average due to a high bankfull:wetted width ratio and the frequently removal of riparian canopy. The average temperature differential of 1.67 ^{o}C reflected this, with water temperatures (22 ^{o}C) exceeding thermal maxima for coho/chinook juvenile lethal temperatures, and chinook migration temperatures, as well as temperatures for successful growth and reproduction in rainbow/steelhead at the time of survey.

Use of habitat by different fish species can be characterized as follows (see figures 4 to 7):

- Pools yielded the lowest densities of fish of all types of units sampled, but the greatest species richness. The dominant species/age-classes were 0+ and 1+ rainbow/steelhead (0.36 fish/m^3). The least dominant were long-nosed dace and 2+ rainbow steelhead. Coho salmon and prickly sculpins were present in moderate densities. Coho and rainbow/steelhead are expected to compete for similar habitats and food, and coho may be preyed upon by larger rainbow/steelhead and prickly sculpins (Scott and Crossman, 1973). In this reach, prickly sculpins were only present in pools with larger substrate (usually rip-rap). The high diversity of age-classes suggests the importance of pools in the context of the reach and watershed.

- Riffles were used dominantly by 0+ rainbow/steelhead trout (2.8 fish/m^3). Moderate densities of coho and 1+ dace were captured, and 1+ rainbow/steelhead accounted for the smallest proportion of the catch. Intersitial spaces of riffle substrate appeared to control habitat area with the frequent absence of most cover elements. Coho present in larger numbers in riffles is likely a function of competition with rainbow/steelhead for pool habitat at summer low flows, rather than a habitat preference.
- Only dace and rainbow/steelhead were present in glides, although they provided good diversity of age-structure. Three age-classes of each species were present. Long-nose dace showed highest densities in the 1+ age-class, and rainbow in the 0+ age-class. Very high densities of both these species were noted, being more than an order of magnitude greater than that in pool habitat.
- Other (off-channel) habitat provided rearing habitat for both 0+ (primarily) and 2+ rainbow/steelhead. Relatively moderate densities of fish were present (1.7-1.8 fish/m^3). Habitat quality in these units was very poor at the time of survey, indicating the condition of the floodplain in general.

Impact Synopsis

Land-use in this reach has damaged fish habitat quantity and quality. Of particular concern is the poor LWD function, high summer water temperatures, extensive eroding banks and associated sediment load, and the consistently high compaction and embeddedness of substrate. Impact sources are dominantly isolated to this particular reach, but are cumulative in nature. Poor LWD function is likely due to a combination of poor bank stability (anchoring), high sediment load (increased lateral pressure and/or burial), and artificially increased water velocities below the highway crossing (channelizing and culverts). High summer water temperatures are a function of lower summer baseflows, a wider and shallower channel, and a decrease in stream shading. Baseflows are generally influenced by the water infiltration and storage capacity of floodplain soils, as well as the influence of transpiration by vegetation. Bank erosion is related to a loss of soil cohesion as the root system of riparian vegetation is lost (overstory and/or shrub layer), bank calving from repeated cattle trampling, migration of the thalweg as sediment load and bar size increases, and increases in water velocities due to channelizing and culverts. Substrate embeddedness and compaction is caused by an elevated fine sediment load which penetrates the matrix of bed paving materials.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Rancher's road and excavation of a cattle watering hole adjacent to the creek causing increased bank erosion and lateral channel movement.
2) Channelizing at the railway bridge without any form of vertical energy dissipation.

3) Undersized and poorly designed culverts for fish passage in lower flow conditions at the highway crossing. No coho salmon were caught above the highway crossing at the time of survey, indicating that the one perched (dry/blocked by debris) and one shallow pipe-arch culvert are a barrier, at least during the summer low-flow period.
4) Channelizing and loss of riparian function at the highway crossing without any form of vertical energy dissipation..
5) Rotational slump and surface erosion of fine-textured morainal materials at the reach break related to land clearing and cattle passage. This is a fairly substantial sediment source which is probably acting to perpetuate bank erosion downstream.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) The frequent removal and/or alteration of riparian forest canopy and subsequent loss of stream shading and functional riparian microclimate. This in turn causes stressful to lethal summer rearing temperatures, poor water quality, and exacerbates the nutrient loading/eutrophication problem through accelerated primary productivity.
2) The frequent removal and/or alteration of riparian forest canopy and subsequent loss of root system, soil cohesion and streambank stability. The positive feedback nature of this impact leads to an increased sediment load which further perpetuates bank erosion. Channel widening and sediment load in turn are related to higher water temperatures, loss of habitat complexity through in-filling of pools, poor LWD function and loss of channel sinuosity and off-channel habitat, and penetration of spawning gravel matrices by fine sediments causing compaction and smothering of redds.
3) The alteration of floodplain function by removal of LWD and riparian forest, as well as compaction of floodplain soils leading to a decreased groundwater recharge and water storage capacity, and a disconnection of the floodplain from the channel. The latter includes the formation of off-channel features, the buffering of overbank flood flows by riparian LWD, and an increase in surface erosion during overbank flood events as surface roughness is minimized. Spinoff effects include decreased rearing and overwintering habitat quality and quantity for salmonids (particularly juvenile coho) in off-channel areas, lower summer and winter baseflows and subsequently greater extremes in temperature, and channel impacts (loss of sinuosity, increased sediment load and associated effects on fish habitat).

Prescriptions

All prescription sites are on private land in reach 1, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 1 are summarized in appendix F. They relate to slope stabilization, bank stabilization, stream shading and creating future sources of LWD. The prescription for polygon RIC11 is integrated with impact prescription site #3, and the prescription for RIC005 is tied into impact prescription site #1 (appendix G).

Three impact prescription sites have been identified based on impacts outlined above, and physical and biological goals for alluvial fan reaches presented in section 3 of this report. They relate to habitat complexing and energy dissipation in the uniform channelized section at the highway (impact prescription #1), the revegetation of aggraded areas throughout the reach (impact prescription #2), and slope stabilization of a large rotational slump at the reach 1/2 break (impact prescription #3) (see appendix G).

Priority and sequence of prescriptions is presented in figure 10. This reach has a high priority for restoration as indicated by the reach prioritization table in appendix H.

Richfield Creek Sub-Basin Restoration Plan

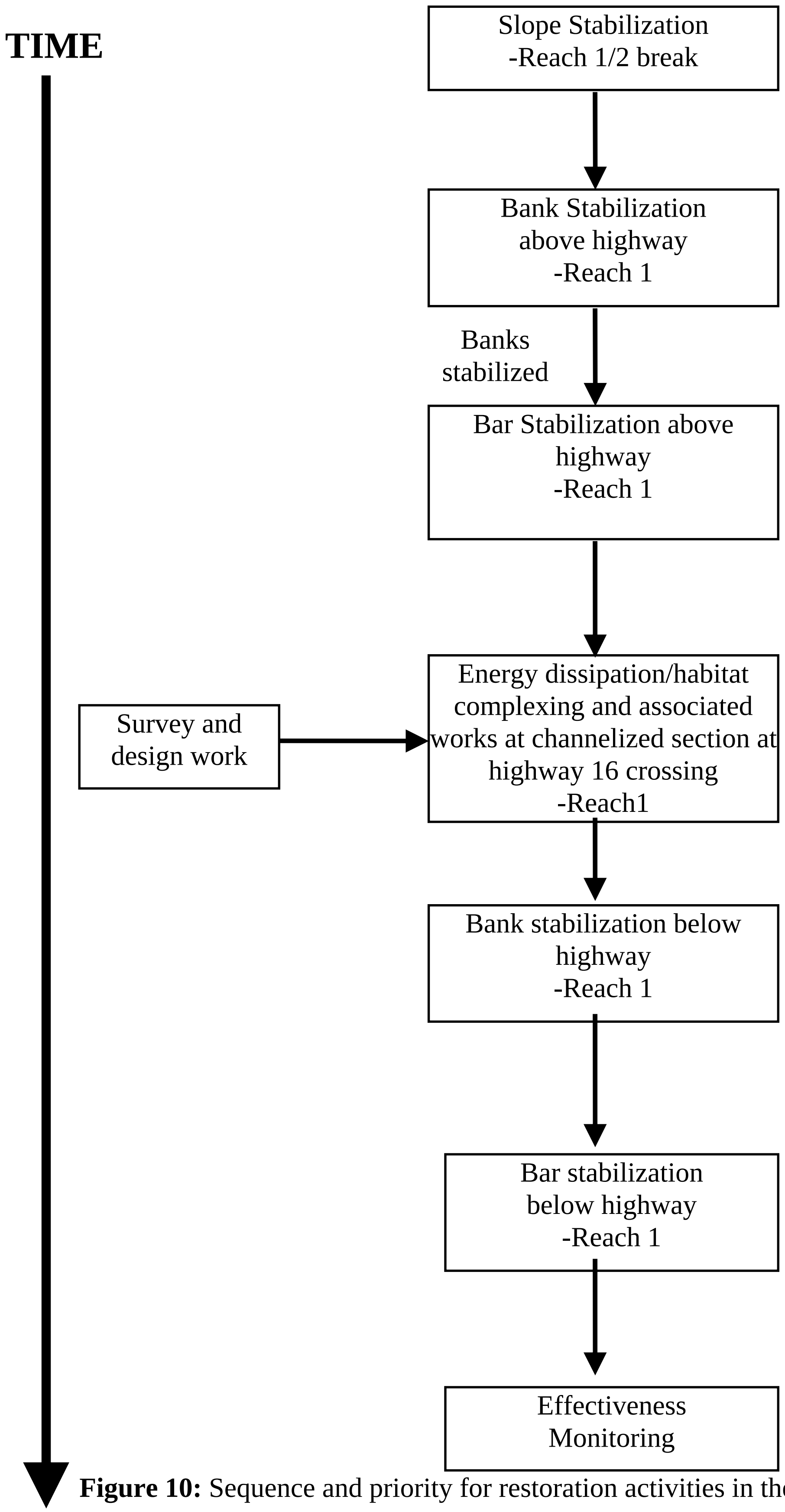

Figure 10: Sequence and priority for restoration activities in the Richfield Creek sub-basin.

4.2 Richfield Creek Reach 2A

Land Uses

The only land-uses in this reach are presently cattle grazing, and historic logging, probably for railroad ties and building materials. Cattle grazing occurs at relatively lower intensities throughout this section to its termination at the first falls. Cattle graze selectively on the upslope areas in this reach, instead of the narrow and brushy floodplain. Upstream land uses include forestry (in the headwaters of Redtop Creek and in the Holmes Creek basin along the Granisle Highway corridor), as well as some small-scale mining exploration and extraction in the Richfield Creek basin near Nez Lake. The Equivalent Clearcut Area of the Richfield sub-basin is 14% (BCCF, 1997). Land-use in the headwaters is not expected to have altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 16 polygons occupying a total area of 7.38 hectares with a riparian zone width of 30 metres (see Richfield Creek entry, appendix D). Land-use has modified 9%, or 0.7 hectares of this. Upslope areas are much more highly modified by both cattle-grazing and past timber harvesting. The BEC classification for this reach is sub-boreal spruce-dry/cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

Due to a long history of ranching and homesteading in the watershed, most of the riparian forest in this confined reach is altered 06 (spruce-twinberry-coltsfoot) or 07a (spruce-horsetail) site series in polygons without, or with minimal floodplain. Much of the hillslope area in this reach has either been logged, and/or cleared to improve cattle forage in the understory. These sites are dominantly deciduous seral associations, with aspen-rose-peavine ($55) and aspen-twinberry ($57) sites. Floodplain (08) sites are subject to regular disturbance in unconfined sections, and are predicted as $58 (black cottonwood-dogwood) seral associations.

There are no significant land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone. Nutrient loading during the spring freshet is expected to be significant due to upslope runoff in cattle grazing areas, but organic pollution impacts are beyond the scope of this study.

Reach Impact and Restoration Diagnostics

Table 5: Summary of habitat quality indicators by habitat unit category for Richfield Creek, reach 2.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Cascade	B	C	H	AR	N	0
Glide	C	G	H	AR	L	2
Pool	R	C	H	AR	H	0
Riffle	B	C	H	AR	N	0

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Cascade	0	0	0	B	2
Glide	2	0	0	OV, B	1
Pool	0	0	0		2
Riffle	0	0	0	B	1

Table 6: Reach summary of other indicators of impacts to watershed function and fish habitat for Richfield Creek, reach 2.

Functional pieces of LWD/bankfull width	**0.16**
Pool frequency	**6.36**
Bankfull : wetted width ratio	**1.82**
Bankfull : wetted depth ratio	**2.33**
Average temperature differential at summer low flows (^{O}C)	**1.10**
Area of disturbed riparian forest (ha)	**0.68**
Length of disturbed channel (m)	**183**

Table 7: Mean values for selected parameters which may assist in designing instream restoration works, Richfield Creek, Reach 2.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.67	0.80	8.10	44.67	88.33	13.33
Riffle	1.83	0.55	7.53	38.67	38.82	10.08
Pool	1.50	0.93	7.35	27.50	169.08	13.88
		Reach Mean Estimated Bankfull Discharge			98.74	

Channel Assessment

Reach 2 is a 1230 metre long RPcw and CPcw channel flowing between the elevations of 687 and 722 metres a.s.l., with an average gradient of 1.75%, bankfull width of 7.74 metres, and bankfull depth of 0.71 metres. Only section A was surveyed. The end of this section is an 18m high impassable falls. It is a confined intermediate canyon reach whose dominant channel-forming mechanism is bedrock, with LWD playing an intermediate role at the downstream end of the reach. Streambanks are composed of either mixed alluvium/smaller colluvium (sand to boulders), or non-erodible colluvium/bedrock. The channel is irregularly meandering with a moderate degree of lateral stability. There is a fair amount of movement within the narrow floodplain due to high stream power and transient log jams. Upslope areas are connected the active channel except at the bottom end of the reach where connectivity is intermittent and the floodplain is somewhat wider.. The floodplain plays a minor role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities. Colluvium, bedrock, log jams at bedrock notches and natural mass movements are much more important in this respect.

Channel assessment in reach 2A indicated that 15% (180 metres) of channel is moderately to severely disturbed. In all channel disturbance polygons, the channel was classified as aggrading (A2). Dominant indicators of disturbance include poor pool frequency, extensive riffles, eroding banks, and poor LWD function. Bankfull:wetted width and bankfull:wetted depth ratios (1.82 and 2.33 respectively) indicate a moderately significant (approximately 1 standard deviation) relative to benchmark conditions. Sediment and flow regimes are expected to be highly variable in channel-forming events, and can be attributed to natural sources. The first 180 metres of disturbed channel in the reach appeared to be caused by a large natural slide at the end of the polygon (field observations).

Fish and Fish Habitat Assessment

Reach 2 can be characterized as high value fish habitat. Chinook salmon (0+), and resident long-nose dace (1+) were present at the time of survey. Rainbow/steelhead trout (0+/1+/2+) were also caught in this reach. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout (Tredger, 1984). Chinook salmon were only captured at the bottom 500m of the reach . Anecdotal information from a local rancher suggested the presence of Dolly Varden and cutthroat trout (BCCF, 1997). No cutthroat trout were captured in the watershed during the survey, and it is doubtful that they are or were present in this reach, although it is possible they exist in Nez Lake and might occasionally survive a downstream migration through several cataracts and waterfalls. Dolly Varden and bull trout were captured in similar areas of the watershed (dominantly canyon areas), and may be present during different seasons, or have a historic presence.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is an important area for adult resident fish and steelhead and chinook juveniles in an unimpacted state in the context of overall watershed productivity and diversity of fish. It is also important due to the fact that it remains relatively undeveloped and pristine, with little upstream influence on sediment/runoff regimes by land-use. As such, it provides stable summer rearing and overwintering habitat for those species/age-classes preferring large cobble/boulder cover elements and swifter water velocities. Water temperatures are expected to be significantly lower than reach 1, making this section an important refuge in periods of extreme thermal loading. Although normally a mainstem spawning and rearing species, this reach/section may also be a moderately important area for chinook salmon considering the extreme low-gradient nature of the Bulkley River in reach 4. Its use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits excellent habitat relative to average higher gradient/canyon reach conditions. Habitat complexity is equal to the average conditions with a complexity index of 3.55 (see figure 15 and table 1 (page 9). Glides dominate the spectrum of habitat units, and there are fewer pool and cascade units present. Compaction was high in all units, but is thought to be attributed to substrate geometry as much as fine sediments. This is supported by the size class of dominant/subdominant substrates. Spawning gravel amounts are low in glides, absent in riffles/cascades, but high in pool tailouts. All gravels present in sampled units, when present, are suitable for both resident and anadromous spawners. LWD function is low in all size classes except the extra large category, and functional LWD frequency is 0.16 pieces/bankfull width (see figure 16 and table 7). The latter value is significantly lower than the benchmark value, but is not considered a departure from benchmark conditions due to the expected minor role of LWD in channel morphology. On average, functional LWD (affecting cover, morphology) is only found in glides, and on average, no functional LWD was present in any of the other units sampled. Pool frequency is 6.36 bankfull widths between pools, greater than 1 standard deviation lower (more frequent) than the average of 8.19. Cover elements showed little complexity, but consisted mostly of in-stream cover (boulders). Cover elements were completely absent in pools in most cases. Canopy closure was 20 to 40% on average. Temperature data at the time of survey does not indicate the capacity of the creek to buffer itself from high summer thermal load, due to prevailing cloudy/rainy weather conditions. The behaviour of the temperature differential parameter is not expected to be linear.

Use of habitat by different fish species can be characterized as follows (see figures 12 to 14):

- Pools in this reach yielded fish from two species and four age-classes at the time of survey. These include chinook (0+) and rainbow/steelhead (0+/1+/2+) species. Low (~0.1-0.3 fish/m^3 on average) densities of all species/age classes were encountered . The most abundant species/age-class 0+ rainbow/steelhead, although they were at their lowest densities in pools. This was the only unit category where chinook were encountered, indicating their importance to this species.
- Riffles exhibited average species richness, but only two age-classes were present. The fork length range of these age classes indicates that interstitial spaces of substrate on

the margins of the units are probably preferred micro-habitats. Riffles yielded the highest densities of the two species, indicating their relative importance to rearing 0+ rainbow/steelhead and dace juveniles.

- Two species and four age-classes were present in glides, including rainbow/steelhead (0+/1+/2+) and long-nose dace (1+). Average densities of 0+ and 1+ rainbow/steelhead were sampled, but relatively low densities of 2+ RB and 1+ LNC indicate that glides are probably not critical habitat for these species/age-classes. The corollary of this might be that glide habitat is not fully seeded by these age-classes, which is possible considering that it is the most frequent type of unit.

Impact Synopsis

Land-use in this reach has not damaged fish habitat quantity and quality significantly. Of particular concern is the level of nutrient loading from cattle manure, but such concerns are beyond the scope of this study.

Prescriptions

As indicated by low levels of impact, this reach has no restoration work prescribed at this time.

Richfield Creek Sub-Basin Restoration Plan

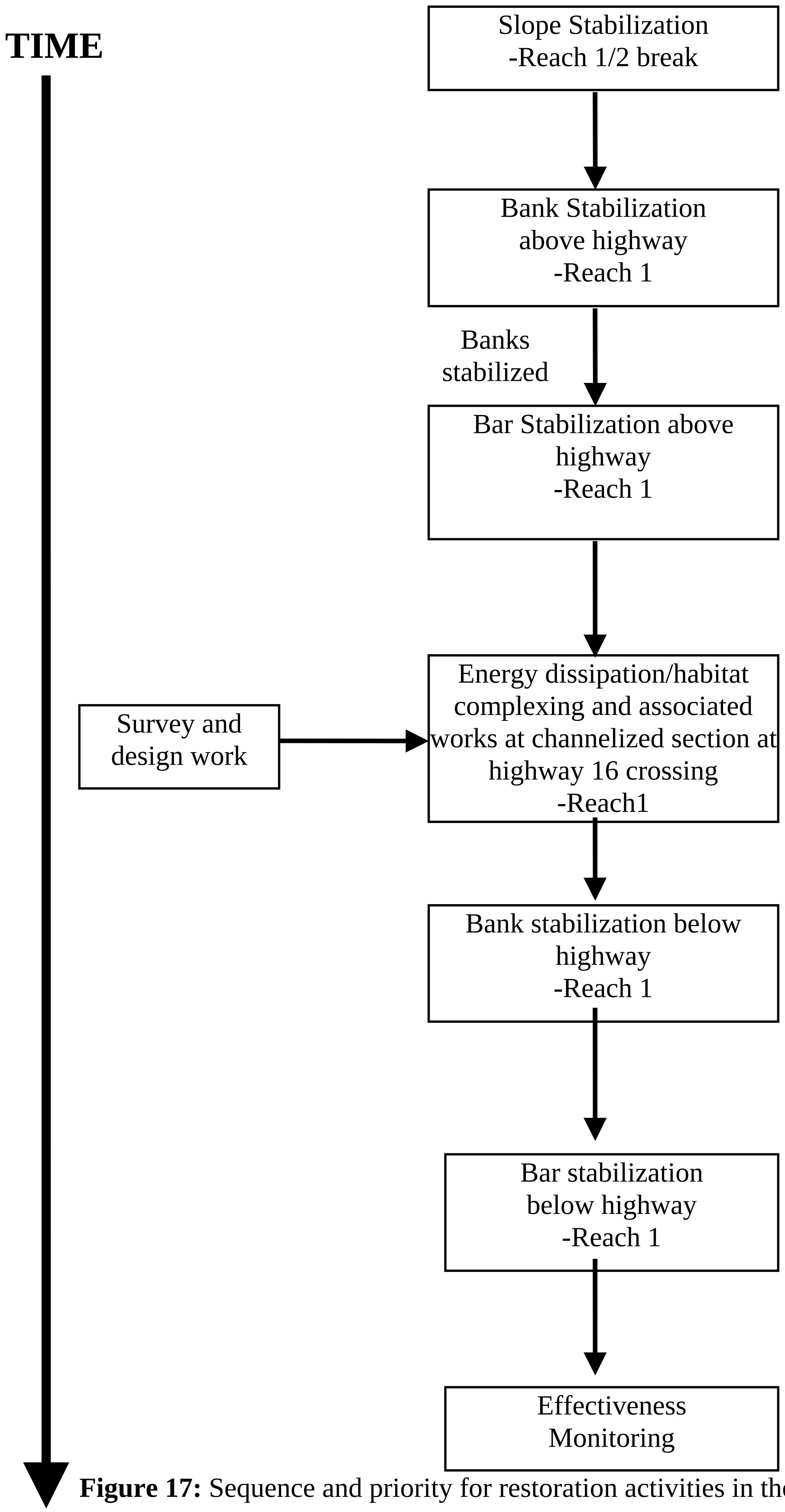

Figure 17: Sequence and priority for restoration activities in the Richfield Creek sub-basin.

4.3 Byman Creek Reach 1

Land Uses

Moving upstream from confluence with the Bulkley River, land uses consists of private land dwellings at 250 metres (adjacent to the Perow Creek confluence), where the owner appears to have removed LWD from the stream and has several ATV trails crossing the creek. A railway bridge follows at 345 metres, where the creek has been channelized but not straightened. Above this, the creek parallels the highway corridor and runs through the middle of a ranch. This section of the channel was straightened and diverted circa 1948, and the channel thread was trained to join up with Perow Creek. Assumedly flooding posed a threat to the homestead at the junction of the creek and highway (where the creek was diverted), and/or it was diverted to create more land for cultivation/grazing. The creek is dyked on the left bank throughout this section until the highway crossing at 1675 metres upstream from the mouth. Heavy cattle grazing occurs on both sides of the creek throughout this 635 metre straight stretch. At the highway crossing, a single round culvert facilitates creek (and fish) passage. Above the highway, range land continues on the left bank until 2500 metres upstream where it moves to both banks. At 2300-2500 metres, the creek is again diverted to the west side of the alluvial fan against the valley wall by a dyke and away from the alluvial fan which has been converted to pasture. At 2550 metres the riparian area is dissected by a powerline corridor. Open pasture persists up to 2770 metres, and cattle grazing persists in the riparian zone to 3570 metres upstream. The creek is diverted away from the alluvial fan at one other point at approximately 3900 metres. Nutrient loading from cattle faeces is expected to be highly detrimental to water quality, and is evidenced by field observations of odour and primary productivity in the creek. Water quality measurements are unfortunately beyond the scope of this study. Upstream land-uses include forest harvesting and roads, particularly salvage logging in the Row Fire area. The equivalent clearcut area of the Byman Creek watershed is 25%, and Perow Creek is 14% (BCCF, 1997). There is a concern that forestry in the headwaters may be affecting runoff regime due to the high ECA.

Riparian Assessment

The riparian area of this reach was divided into 23 polygons occupying a total area of 24.9 hectares with a riparian zone width of 30 metres (see Richfield Creek entry, appendix D). Land-use has modified 74.3%, or 18.5 hectares of this. The BEC classification for this reach is SBSdk, with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

Reach Impact and Restoration Diagnostics

Table 8: Summary of habitat quality indicators by habitat unit category for Byman Creek, reach1.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	G	H	A	H	0
Other	S	G	L	R	L	12.5
Pool	S	C	M	AR	L	3.33
Riffle	C	G	H	A	L	1

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	0	0	0	B, OV	1
Other	9	4	0	OV	3
Pool	1	1	1	LWD, OV	1
Riffle	0	1	0	B, OV	1

Table 9: Reach summary of other indicators of impacts to watershed function and fish habitat for Byman Creek, reach 1.

Functional pieces of LWD/bankfull width	**0.23**
Pool frequency	**7.06**
Bankfull : wetted width ratio	**1.85**
Bankfull : wetted depth ratio	**2.92**
Average temperature differential at summer low flows (^{O}C)	**2.30**
Area of disturbed riparian forest (ha)	**18.5**
Length of disturbed channel (m)	**3832**

Table 10: Mean values for selected parameters which may assist in designing instream restoration works, Byman Creek, Reach 1.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	0.92	0.52	8.60	22.75	28.92	4.78
Riffle	1.06	0.51	9.36	21.00	32.98	5.42
Pool	1.08	0.90	7.50	15.33	141.40	9.79
				Reach Mean Estimated Bankfull Discharge	67.77	

On the alluvial fan of Byman Creek, the dominant plant community is predicted to be the cottonwood-twinberry ($58) seral association with areas of black cottonwood-dogwood ($59) on mid-bench areas with less frequent overbank flooding. These are 08 floodplain site series seral associations. It may be possible that prior to agricultural land development that pacific willow-mountain alder-lady fern (TEM code=ML) communities often existed in low-bench regularly flooded sidechannels of the Bulkley or Byman Creek but these seem to be mostly absent due to either decreased overbank disturbance, or being filled in for hayland, or both. One instance was noted where a side-channel of the Bulkley intercepted the mouth of Byman Creek. Above the highway, the reach is confined on the right bank by steep valley walls of morainal and glacio-fluvial materials with an easterly aspect. The presence of abundant *Populus tremuloides* (trembling aspen) and 0-40% slopes indicates spruce-horsetail (07a) and/or spruce-twinberry-coltsfoot (06) sites. These sites are seral associations, and are predicted as aspen-twinberry ($57) and aspen-rose-peavine ($55) based on species presence and aspect.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest, and soil compaction in areas used for hay farming/grazing/powerline corridor.
- Loss of the shrub/herb layer and associated root system and soil compaction from cattle grazing carried out in areas where the overstory still exists
- Removal of riparian forest and disconnection of the channel from the riparian zone due to channelizing and straightening.
- Past harvesting of spruce and cottonwood by the private landowner preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (white clover, Canada thistle), the modification of floodplain and channel features (diversions, landfilling), and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.

Typical riparian polygon photos are found in plates 5-8.

Channel Assessment

Reach 1 is a 4243 metre long RPgw and RPcw channel flowing between the elevations of 639 and 712 metres a.s.l., with an average gradient of 0.98%, bankfull width of 8.35 metres, and bankfull depth of 0.65 metres. It is an alluvial fan reach whose dominant channel-forming mechanism is LWD. Streambanks are composed of well sorted and fine textured cohesive silt/clay fluvial materials on the Bulkley River floodplain near the mouth. Three hundred metres upstream, this shifts to an unconsolidated and generally unsorted mix of sand to cobble alluvium, with dominant particle size increasing towards the end of the reach. Frequent but sparse boulders appear in the matrix here as stream energies and sources of colluvium increase in proximity to reach 2. The channel is presently regularly meandering with a low degree of lateral stability. This channel geometry is reinforced at several points by diversions of the creek to maintain its position adjacent to the western valley wall, and to maintain its present direction below the highway. It is unlikely that the creek maintained such a channel pattern prior to extensive diversions. Upslope areas are highly connected to the active channel except below the highway and near the top of the reach where it is disconnected. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 1 indicated that 90% (3832 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2-A3). Dominant indicators of disturbance include extensive bars, elevated mid-channel bars, minimal pool frequency, eroding banks, abandoned channels, and poor LWD function. In the straightened/diverted section below Highway 16, disturbance indicators also include extensive riffles. Bankfull:wetted width and bankfull:wetted depth ratios (1.85 and 2.92 respectively) indicate a significant departure relative to benchmark conditions of 1.73 standard deviations. Causal mechanisms of channel disturbance include dyking and channel straightening leading to higher stream energies which increase bank erosion and slope instability. The latter impact is related to toe erosion, slumping and sliding of surface layers, and subsequent surface erosion of the western valley wall. This is composed of dominantly fine textured post-glacial fluvial terrace materials which are highly erodible. Combined with heavy grazing and land clearing and associated loss of bank strength/lateral channel stability over most of the reach, this accounts for much of the channel disturbance. Other sources of channel impact include upstream mass movements at the Row fire area, and natural colluvial activity in the canyon.. See plates 4 and 6 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 1 can be characterized as very high value fish habitat. Coho (0+) and chinook salmon (0+), and resident bull trout (adult), mountain whitefish (1+), lake chub (0+/1+), and long-nose dace (0+/1+) were present in the creek at the time of survey. Rainbow/steelhead trout (0+/1+/2+) were also caught in this reach. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout due to a lack of barriers upstream from the mainstem (Tredger, 1984). Most species occurred throughout, with the exception of mountain whitefish and lake chub which were only captured below the highway crossing, and bull trout, of which only one adult was caught at the top of the reach in a pool. Several adult chinook were observed holding at the mouth and migrating upstream at the time of survey.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is a critical and productive area for spawning and rearing, particularly for coho salmon and steelhead trout, in an unimpacted state. Although normally a mainstem spawning and rearing species, this reach may also be an important area for chinook salmon considering the extreme low-gradient nature of the Bulkley

River in reach 4. The alluvial fans of tributaries to the upper Bulkley River, as discussed in part 3 of this report, ideally provide areas of swifter current and larger substrate, diverse invertebrate communities, complex channel morphology and cooler water temperatures relative to the mainstem. As such they are important for summer rearing and summer and fall spawning habitat. Their proximity to the Bulkley provides access to overwintering habitat, mainstem rearing areas for older juvenile salmonids, and a choice of habitat refugia in either the mainstem or tributary during high water events. Their use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits extremely degraded habitat relative to benchmark conditions. Habitat complexity is 1.6 standard deviations lower than the benchmark with a complexity index of 3.06, and is greater than 1 standard deviation below the average of all lower gradient reaches surveyed (see figure 24 and table 1 (page 9)). Riffles and glides dominate the spectrum of habitat units, and there are very few “other” units present. Pools occurred almost 50% less frequently than riffles or glides. Compaction was high in riffle and glide units, moderate in pools and low in “other” units. Spawning gravels were usually low except in glides where they were abundant. Spawning gravel sizes varied a great deal, with resident gravels in suitable areas of “other” units, anadromous gravels in glides and riffles, and anadromous and resident-suitable spawning gravels in the tailouts of pools. No redds were noted at the time of survey, and particular section of the creek exhibited much better spawning conditions than other areas. LWD function is low in the small size class, but moderate in larger sizes. Wood from the latter size classes was not abundant, probably due to extensive land clearing of the floodplain. Functional LWD frequency is 0.23 pieces/bankfull width (see figure 23 and table 9). The latter value is more than 2 standard deviations lower than the benchmark value, and as such is considered a significant departure from benchmark conditions. On average, functional LWD (affecting cover, morphology) is not found in glides, but is abundant in “other units (mean of 12.5 pieces) and infrequent in pools (3 pieces) and riffles (1 piece). Pool frequency is 7.06 bankfull widths between pools, which is approximately 1 standard deviation from the benchmark of 3.67, and is below (pools are closer together) the survey average. Fines were the dominant substrate in pools, indicating a high sediment load and subsequent effects on spawning and rearing habitat quality. Cover elements showed good complexity, with at least one element in the in-stream cover category. Cover usually consisted of boulder and/or overhead vegetation. Canopy closure was 0-20% on average due to channel widening and loss/modification of riparian forest canopy. The average temperature differential of 2.3 ^{o}C reflected this, with maximum water temperatures (20.5 ^{o}C) at the time of survey exceeding thermal maxima for successful growth/reproduction in chinook and coho salmon, and was sufficiently close to the rainbow/steelhead threshold to be of concern. Sufficient metabolic stress would certainly have resulted for all species, and chronically high water summer temperatures may be lethal.

Use of habitat by different fish species can be characterized as follows (see figures 19 to

22):

- Pools yielded all 7 species and 10 age classes. The high diversity of age-classes suggests the importance of pools in the context of the reach and watershed. Typically, higher densities of 0+ rainbow/steelhead were present, with much lower densities of other species. Coho were found in highest densities in pool units, and as such they are considered a critical habitat type for this species. All other species exhibited lower densities than in some other types of units. For mountain whitefish and chinook, pools are known to be important habitat in other systems in the watershed, and lower densities are probably due to poor habitat quality in this reach. Although bull trout were only found in pools in reach 1, pools are not likely a critical habitat. Adult bull trout are commonly found in more confined reaches with larger substrate, typical of canyon reaches in the mid-Bulkley watershed. Reach 1 only exhibits such features at its upper end. Bull trout are thought to inhabit the lower end of reach 2 more extensively, although it has not been sampled at this point.
- Riffles exhibited low species richness, but yielded six age classes. Rainbow/steelhead were the only salmonid species captured. Highest densities of 1+ and 2+ RB were sampled in riffles, and as such are considered a critical habitat for these species/age-classes. Most fish were caught within the substrate or at the margins of riffles, and therefore hydraulic complexity and a lack of compaction within riffle units is also important.
- Six species and 9 age-classes were present in glide units. Highest densities of 0+ RB, 0+ CH and 1+ MW were sampled. The latter two species have likely seeded glides in higher densities due to a lack of good quality pool habitat in the reach. Glides are considered to be critical habitat for 0+ rainbow/steelhead due to their extraordinarily high densities (6 fish/m^3). Again, most fish were using the substrate as the dominant form of cover, and therefore a lack of compaction and embeddedness is important.
- "Other" habitat. (off-channel units) yielded 3 species and 4 age classes. Densities were the lowest of all units sampled for these species. "Other" units were in extremely poor condition at the time of survey due to low water levels and high temperatures, as well as high primary productivity and associated oxygen depletion. Generally poor condition of the floodplain due to extensive soil compaction and land clearing is correlated to habitat condition. Off-channel areas are known to be important to coho for overwintering and rearing in other watersheds, and low densities here are likely related to land-use impacts and/or extreme summer temperatures (evaporation, drought).

Impact Synopsis

Land-use in this reach has damaged fish habitat quantity and quality. Of particular concern are high water temperatures, poor LWD frequency, extensive channel and slope disturbance and high sediment load, substrate embededdness and pool frequency and quality. Impact sources are dominantly isolated to this particular reach, but are partially related to upstream sediment sources and possibly an altered runoff regime due to extensive cleared land in the headwaters. Impacts are mostly cumulative in nature. Poor LWD function is likely due to a combination of poor bank stability (anchoring), high sediment load (increased sheer stress and/or burial), and artificially increased water velocities below the highway crossing (channelizing and culverts). High summer water temperatures are a function of lower summer baseflows, a wider and shallower channel, and a decrease in stream shading. Baseflows are generally influenced by the water infiltration and storage capacity of floodplain soils, as well as the influence of transpiration by vegetation. Bank erosion is related to a loss of soil cohesion as the root system of riparian vegetation is lost (overstory and/or shrub layer), bank calving from repeated cattle trampling, migration of the thalweg as sediment load and bar size increases, and increases in water velocities due to channelizing and culverts. Substrate embeddedness and compaction is caused by an elevated fine sediment load which penetrates the matrix of bed paving materials.

Category 1 Impacts

There are no point-source, isolated impacts in this reach which are not influenced by other cumulative upstream impacts, and/or do not require overall, integrated prescriptions.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) The frequent removal and/or alteration of riparian forest canopy and subsequent loss of stream shading and functional riparian microclimate. This in turn causes stressful to lethal summer rearing temperatures, poor water quality, and exacerbates the nutrient loading/eutrophication problem through accelerated primary productivity.
2) The frequent removal and/or alteration of riparian forest canopy and subsequent loss of root system, soil cohesion and streambank stability. The positive feedback nature of this impact leads to an increased sediment load which further perpetuates bank erosion. Channel widening and sediment load in turn are related to higher water temperatures, loss of habitat complexity through in-filling of pools, poor LWD function and loss of channel sinuosity and off-channel habitat, and penetration of spawning gravel matrices by fine sediments causing compaction and smothering of redds.
3) The alteration of floodplain function by removal of LWD and riparian forest, as well as compaction of floodplain soils leading to a decreased groundwater recharge and water storage capacity, and a disconnection of the floodplain from the channel. The latter relates to the formation of off-channel features, the buffering of overbank flood flows by riparian LWD, and an increase in surface erosion during overbank flood events as surface roughness is minimized. Spinoff effects include decreased rearing and overwintering habitat quality and quantity for salmonids (particularly juvenile coho) in off-channel areas, lower summer and winter baseflows and subsequently greater extremes in temperature, and channel impacts (loss of sinuosity, increased sediment load and associated effects on fish habitat).
4) The diversion of the channel at three points in the reach leading to an altered channel geometry, increased bank erosion, habitat simplification and in-filling of pools, and

toe erosion of the western valley wall causing mass wasting.

Prescriptions

All prescription sites are on private land in reach 1, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 1 are summarized in appendix F. They relate to slope stabilization, bank stabilization, stream shading and creating future sources of LWD. Most of these aim to achieve these goals with passive restoration by excluding cattle access from riparian areas. The prescription for polygons BYM8 to BYM10 are integrated with impact prescription #2, and the prescription for slopes in BYM13 and BYM 15 are tied into impact prescription #1 (appendix G).

Two impact prescription sites have been identified based on impacts outlined above, and physical and biological goals for alluvial fan reaches presented in section 3 of this report. They relate to habitat complexing and energy dissipation in the uniform diverted and straightened section below the highway (impact prescription #2), and slope stabilization of eroding valley walls above the highway (impact prescription #1) (see appendix G).

Priority and sequence of prescriptions is presented in figure 25. This reach has a high priority for restoration as indicated by the reach prioritization table in appendix H

Byman Creek Sub-Basin Restoration Plan

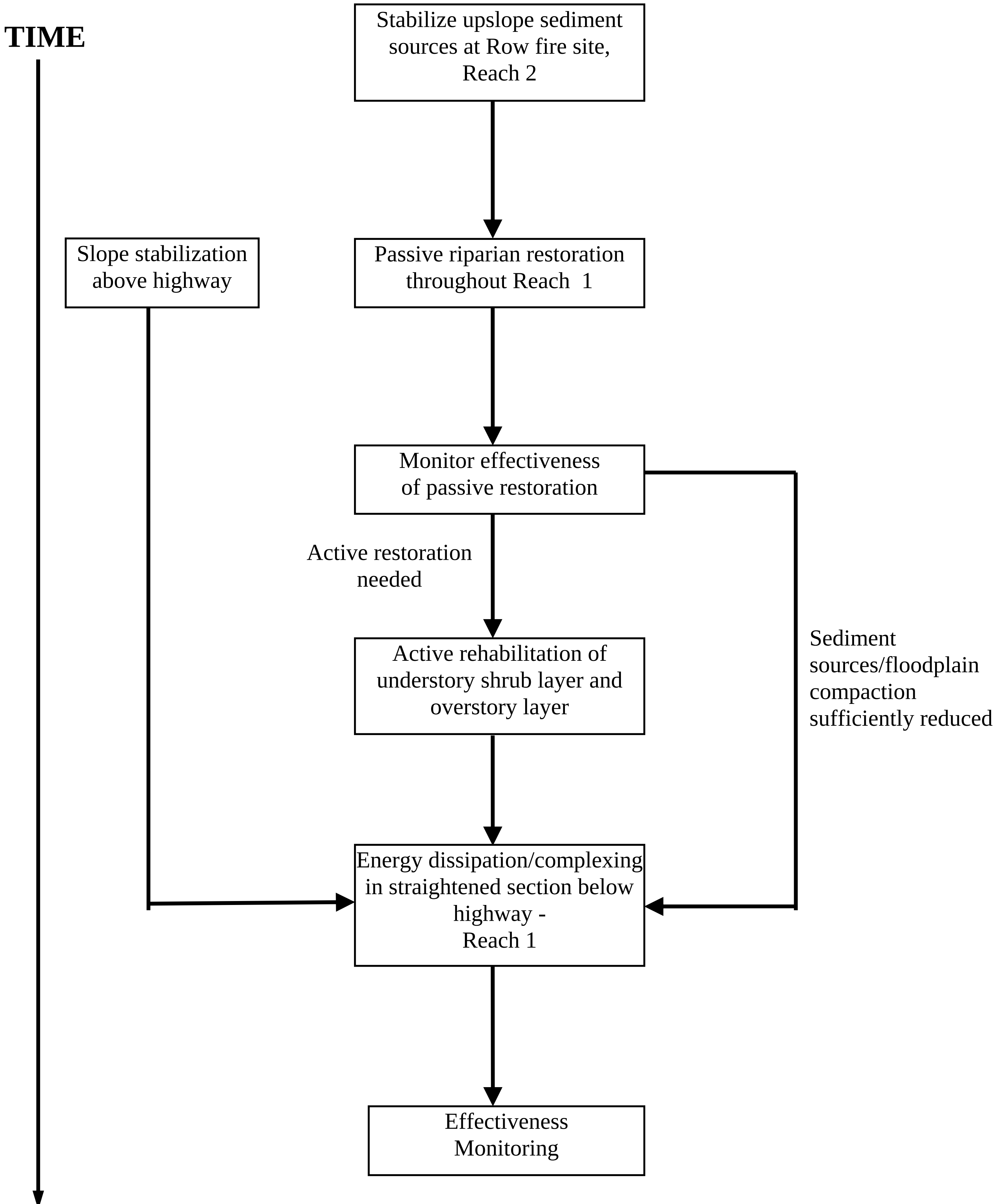

Figure 25: Sequence and priority for restoration activities in the Byman Creek sub-basin.

4.4 McQuarrie Creek Reach 1

Land Uses

Moving upstream from the mouth, land-use includes the railway and highway corridor, agricultural land (hay framing and cattle grazing), and past forestry. The creek is channelized for the first 340 metres on both banks, and channelizing continues on the left bank up to 820 metres upstream. A paved access road occupies the right bank within the first 340 metres, and a dirt road continues up to approximately 500 metres upstream. Beyond this, a large hay field occupies the left bank riparian zone to 800 metres, and cattle grazing land occupies the right bank from just above the highway to approximately 850 metres. Above 850 metres, grazing continues in upslope areas to the end of the reach on the right bank. On the left bank an old (5-10+ years old) clearcut intermittently dissects the riparian zone on the left bank, and at one point was logged to the streambank. This has lead to significant bank erosion in the vicinity of the reach 1/2 break. Nutrient loading from cattle faeces is expected to be highly detrimental to water quality, and is evidenced by field observations of odour and primary productivity in the creek. Water quality measurements are unfortunately beyond the scope of this study. Upstream land uses include forest harvesting and roads. The Equivalent Clearcut Area of the McQuarrie sub-basin is 14% (BCCF, 1997). Land-use in the headwaters is not expected to have altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 9 polygons occupying a total area of 9.48 hectares with a riparian zone width of 30 metres (see McQuarrie Creek entry, appendix D). Land-use has modified 74%, or 7.05 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool, with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

On the alluvial fan of McQuarrie Creek, the dominant plant community is predicted to be the cottonwood-twinberry ($58) seral association with areas of black cottonwood-dogwood ($59) on lower-bench areas with more frequent overbank flooding. These are 08 floodplain site series seral associations. It may be possible that prior to agricultural land development that pacific willow-mountain alder-lady fern (TEM code=ML) communities often existed in low-bench regularly flooded sidechannels of the Bulkley or McQuarrie Creek but these seem to be mostly absent due to either decreased overbank disturbance, or being filled in for hayland, or both. Above 900 metres, the reach is confined on the left bank by steep valley walls of morainal materials with a south easterly to easterly aspect. The presence of abundant *Populus tremuloides* (trembling aspen) and

Reach Impact and Restoration Diagnostics

Table 11: Summary of habitat quality indicators by habitat unit category for McQuarrie Creek, reach 1.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	G	H	AR	L	0
Other	S	C	M	None	None	4
Pool	G	C	M	A	L	1
Riffle	C	B	H	AR	L	0

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	0	0	0		2
Other	4	0	0	OV	1
Pool	0	1	0		1
Riffle	0	0	0	B, OV	1

Table 12: Reach summary of other indicators of impacts to watershed function and fish habitat for McQuarrie Creek, reach 1.

Functional pieces of LWD/bankfull width	**0.14**
Pool frequency	**3.38**
Bankfull : wetted width ratio	**2.48**
Bankfull : wetted depth ratio	**2.29**
Average temperature differential at summer low flows (^{O}C)	**4.75**
Area of disturbed riparian forest (ha)	**7.05**
Length of disturbed channel (m)	**1580**

Table 13: Mean values for selected parameters which may assist in designing instream restoration works, McQuarrie Creek, Reach 1.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	0.88	0.45	15.65	27.00	48.64	3.89
Riffle	1.17	0.48	13.03	31.33	44.19	5.64
Pool	0.92	0.67	7.60	17.67	81.69	6.14
				Reach Mean Estimated Bankfull Discharge	58.17	

0-40% slopes indicates spruce-horsetail (07a) and/or spruce-twinberry-coltsfoot (06) sites. These sites are seral associations, and are predicted as aspen-twinberry ($57) and aspen-rose-peavine ($55) based on species presence and aspect.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest and soil compaction in areas used for hay farming/grazing/powerline corridor.
- Loss of the shrub/herb layer and associated root system and soil compaction from cattle grazing carried out in areas where the overstory still exists
- Removal of riparian forest and disconnection of the channel from the riparian zone due to channelizing and straightening.
- Past harvesting of spruce and cottonwood by the private landowner preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (white clover, Canada thistle), the modification of floodplain and channel features (diversions, landfilling), and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.

Typical riparian polygon photos are found in plates 13.

Channel Assessment

Reach 1 is a 1580 metre long RPgw and RPcw channel flowing between the elevations of 637 and 656 metres a.s.l., with an average gradient of 0.98%, bankfull width of 10.16 metres, and bankfull depth of 0.49 metres. It is an alluvial fan reach whose dominant channel-forming mechanism is LWD. Streambanks are composed of rip-rap for the first 340 metres, and above this, an unconsolidated and moderately sorted mix of sand, gravel and cobble alluvium on those banks which are not channelized (left bank channelized to 800 metres upstream). The channel is sinuous to straight with a low degree of lateral stability in areas which are not channelized. Upslope areas are disconnected to the active channel except between 1100 and 1450 metres where the channel is confined by steep valley walls on the left bank. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 1 indicated that 100% (1580 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as both aggrading (A2-A3 above channelizing on both banks) and degrading (D2- within area channelized on both banks) (see appendix C). Dominant indicators of disturbance include poor LWD function, minimal pools, and extensive riffle in both aggrading and degrading areas. Areas of scouring were noted within degraded areas. More severely aggraded areas exhibited elevated mid-channel bar, sediment wedge, abandoned channel, braiding, and avulsion indicators of disturbance as well. Bankfull:wetted width and bankfull:wetted depth ratios (2.48 and 2.29 respectively) indicate a departure from benchmark conditions. The width ratio is the second highest of all reaches surveyed, and is 3 standard deviations greater (wider bankfull width) than the benchmark value, pointing to a definite bank erosion, channel widening and extreme summer low-flow problem. The depth ratio is within 1 standard deviation of the mean and thus the channel is not considered significantly incised. See plate 12 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 1 can be characterized as high value fish habitat. Chinook (0+)and coho salmon (0+), and resident long-nose dace (0+/1+) were present at the time of survey. Rainbow/steelhead trout (0+/1+/2+/3+) were also caught in this reach. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout due to a lack of barriers upstream from the mainstem (Tredger, 1984). Rearing coho and chinook salmon were only caught near the end of the reach (above 1000 metres upstream) where habitat conditions had improved relative to downstream areas, but dace and rainbow/steelhead were caught throughout.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is a critical and productive area for spawning and rearing, particularly for coho salmon and steelhead trout, in an unimpacted state. Although normally a mainstem spawning and rearing species, this reach may also be an important area for chinook salmon considering the extreme low-gradient nature of the Bulkley River in reaches 2 and 4. The alluvial fans of tributaries to the upper Bulkley River, as discussed in part 3 of this report, ideally provide areas of swifter current and larger substrate, diverse invertebrate communities, complex channel morphology and cooler water temperatures relative to the mainstem. As such they are important for summer rearing and summer and fall spawning habitat. Their proximity to the Bulkley provides access to overwintering habitat, mainstem rearing areas for older juvenile salmonids, and a choice of habitat refugia in either the mainstem or tributary during high water events. Their use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits degraded habitat relative to benchmark conditions. Habitat complexity falls within 1 standard deviation of the benchmark with a complexity index of 3.39, and is slightly higher than the average of all reaches surveyed (see figure 32 and table 1 (page 9)). No particular type of unit is particularly dominant among the main riffle, pool, and glide categories. Off-channel areas, although present and tallied, were usually dry. Compaction was high in riffle and glide units, and moderate in pool and “other” units. Spawning gravels were low to absent in most units sampled. Gravel sizes suitable to anadromous and resident species were present in glides and riffles, and in pool tailouts for anadromous species only. LWD function is very low in all size classes despite abundant wood supply in the active channel, and functional LWD frequency is

0.14 pieces/bankfull width (see figure 31 and table 12). The latter value is more than 2 standard deviations below the benchmark value, and as such is considered a significant from benchmark conditions. On average, functional LWD (affecting cover, morphology) is only found only in pool and "other" units, and no functional LWD was present in any of the glide or riffle units sampled. Pool frequency is 3.38 bankfull widths between pools, which falls within 1 standard deviation of the benchmark of 3.67, and is well below the survey average (this reach had more frequent pools than the survey average). Cover elements showed poor complexity, with very little in-stream cover. Cover usually consisted of overhead vegetation in "other" and riffle units. The only in-stream cover present was boulder cover in riffles. Pools and glides did not normally have any cover for rearing fish. Canopy closure was 0-20% on average due to channel widening and loss of/modified riparian forest canopy. The average temperature differential was 4.75 ^{o}C at the time of survey (peak summer temperatures, lowest water levels), with maximum water temperatures (22 ^{o}C) exceeding thermal maxima for the lethality of coho and chinook salmon (lower end of lethal temperatures reported in literature review), and successful growth and reproduction (high metabolic stress) in rainbow/steelhead at the time of survey.

Use of habitat by different fish species can be characterized as follows (see figures 27 to 30):

- Pools contained all species of fish present in the reach, and six different age classes. Pool habitat was much more prevalent above 800 metres where channelizing ended. 0+ chinook were present only in pools, and thus they are considered critical habitat for this species. Both chinook and coho are expected to be in competition with 1+ rainbow/steelhead for space and resources, and the presence of coho in higher densities in riffles may reflect this competition. Pools were also important for 1+ rainbow/steelhead, which were only found in higher densities in "other" units. Low densities of other species/age-classes were encountered. The high diversity of age-classes also suggests the importance of pools in the context of the reach and watershed.
- Riffles exhibited lower diversity of species/age classes, but higher densities of fish. Riffles had the highest densities of 2+ rainbow/steelhead, and the only units where 3+ rainbows were caught. Coho were present in their highest densities within glides, possibly for reasons outlined above. Most younger fish were noted using substrate and calmer areas at the margins of riffles as cover, indicating the importance of maintaining uncompacted bed paving materials.
- Dace and rainbow/steelhead were present in glides, with a good diversity of age-classes between these two species (5 age-classes). The highest densities of long-nose dace were captured in glides, but salmonids did not appear to preferentially select glide habitat in this reach. Densities of rainbow/steelhead were average in all age classes.
- Other (off-channel) habitat which was wetted at the time of survey provided rearing area for relatively high numbers of 0+ and 1+ rainbow/steelhead. Cover elements in sampled units were much better than in other habitat unit categories, which may account for the high densities of fish. As discussed above, most off-channel habitat

was dry at the time of survey.

Impact Synopsis

Land-use in this reach has damaged fish habitat quantity and quality. . Of particular concern are high water temperatures, poor LWD frequency, poor cover in pool habitat, extensive channel disturbance (both aggradation and degradation), high sediment load, and substrate embededdness. Impact sources are dominantly isolated to this particular reach, and mostly cumulative in nature. Poor LWD function is likely due to a combination of poor bank stability (anchoring), high sediment load (increased sheer stress and/or burial), and artificially increased water velocities below the channelized area and the highway crossing (channelizing and culverts). High summer water temperatures are a function of lower summer baseflows, a wider and shallower channel, and a decrease in stream shading. Baseflows are generally influenced by the water infiltration and storage capacity of floodplain soils, as well as the influence of transpiration by vegetation. Bank erosion is related to a loss of soil cohesion as the root system of riparian vegetation is lost (overstory and/or shrub layer), bank calving from repeated cattle trampling, migration of the thalweg as sediment load and bar size increases, and increases in water velocities and erosive force due to channelizing and straightening on the left bank. Degradation of channel materials and poor LWD function in the lower end of the reach can be directly attributed to gradient increase from excavation of the dyked area, removal of LWD and LWD jams, straightening, and the loss of the energy dissipating effects of vertical and lateral hydraulic complexity. Substrate embeddedness and compaction is caused by an elevated fine sediment load which penetrates the matrix of bed paving materials.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Dyking on both banks for 340 metres above and through the highway and railway corridor to the mouth. This is artificially increasing stream energies, simplifying and degrading habitat, and eliminating the riparian stream shading function.
2) Sediment delivery from a rotational slump of fine-textured materials at approximately 900 metres. Impact vectors are thought to be cattle trampling/grazing and removal of overstory/shrub vegetation at the top of the slope altering surface and subsurface drainage patterns in the slope, and removing the stabilizing and strengthening effect of plant roots.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) The frequent removal and/or alteration of riparian forest canopy and subsequent loss

of stream shading and functional riparian microclimate. This in turn causes stressful to lethal summer rearing temperatures, poor water quality, and exacerbates the nutrient loading/eutrophication problem through accelerated primary productivity.

2) The frequent removal and/or alteration of riparian forest canopy and subsequent loss of root system, soil cohesion and streambank stability. The positive feedback nature of this impact leads to an increased sediment load which further perpetuates bank erosion. Channel widening and sediment load in turn are related to higher water temperatures, loss of habitat complexity through in-filling of pools, poor LWD function and loss of channel sinuosity and off-channel habitat, and penetration of spawning gravel matrices by fine sediments causing compaction and smothering of redds.
3) The alteration of floodplain function by removal of LWD and riparian forest, as well as compaction of floodplain soils leading to a decreased groundwater recharge and water storage capacity, and a disconnection of the floodplain from the channel. The latter relates to the formation of off-channel features, the buffering of overbank flood flows by riparian LWD, and an increase in surface erosion during overbank flood events as surface roughness is minimized. Spinoff effects include decreased rearing and overwintering habitat quality and quantity for salmonids (particularly juvenile coho) in off-channel areas, lower summer and winter baseflows and subsequently greater extremes in temperature, and channel impacts (loss of sinuosity, increased sediment load and associated effects on fish habitat).

Prescriptions

All prescription sites are on private land in reach 1, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 1 are summarized in appendix F. They relate to slope stabilization, bank stabilization, stream shading and creating future sources of LWD. Many of these prescriptions aim to achieve these goals with passive restoration by excluding cattle access from riparian areas. The prescription for polygons MCQ1 and MCQ2 are integrated with impact prescription #2, and the prescription for slopes in MCQ7 is tied into impact prescription #1 (appendix G).

Two impact prescription sites have been identified based on impacts outlined above, and physical and biological goals for alluvial fan reaches presented in section 3 of this report. They relate to habitat complexing and energy dissipation in the uniform channelized section at and above the highway/railway corridor (impact prescription #2), and slope stabilization below heavy cattle trampling at 0+760 metres (impact prescription #1) (see appendix G).

Priority and sequence of prescriptions is presented in figure 33. This reach has a high priority for restoration as indicated by the reach prioritization table in appendix H

McQuarrie Creek Sub-Basin Restoration Plan

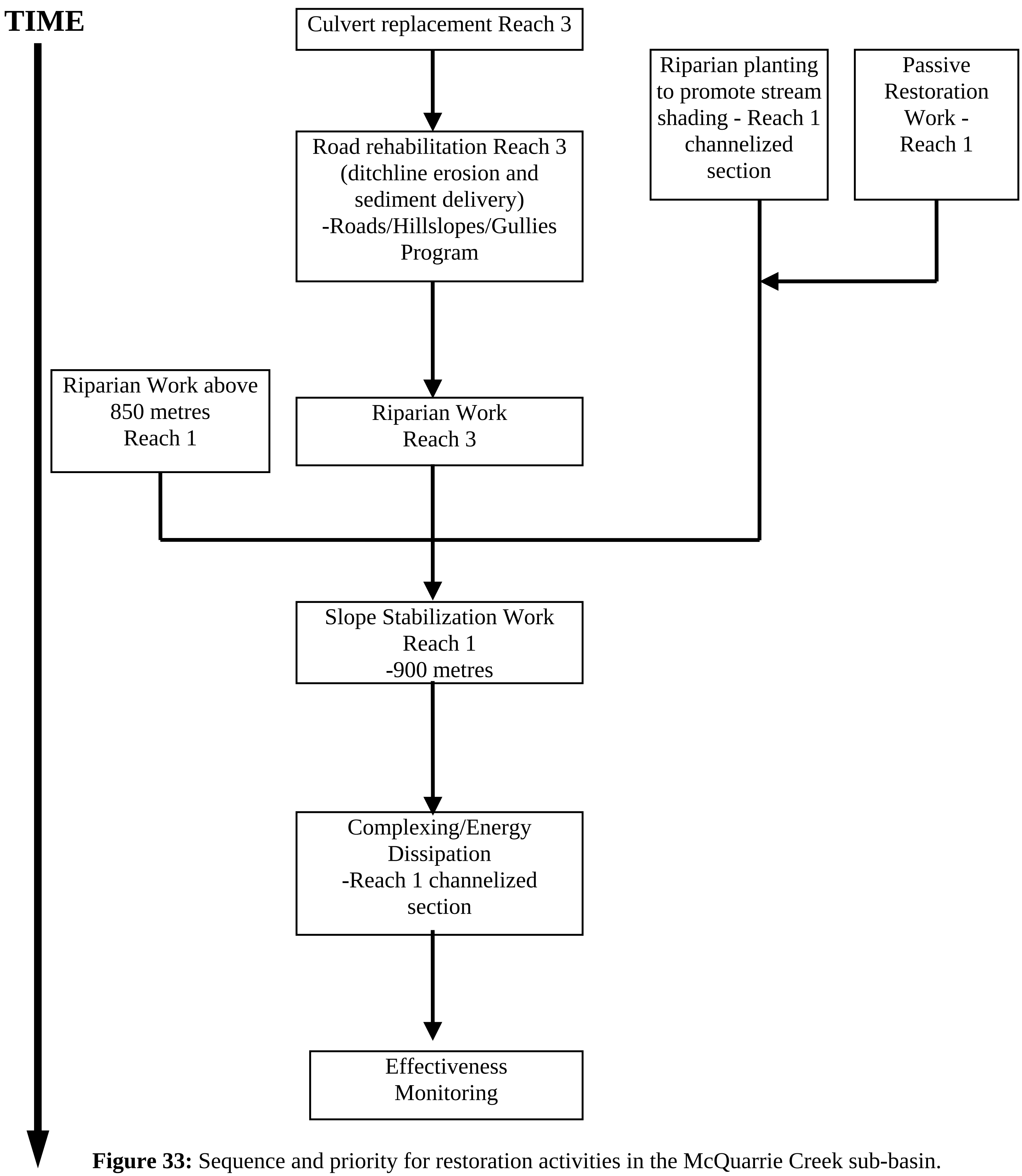

Figure 33: Sequence and priority for restoration activities in the McQuarrie Creek sub-basin.

4.5 McQuarrie Creek Reach 3

Land Uses

The only land use in this reach is the Michelle Bay FSR corridor. The road parallels the creek about 50-100 metres upslope on the right bank for the length of the reach. It crosses the creek at the terminus of the survey area (1828 metres). At this point a long pipe-arch culvert was installed to facilitate creek passage. Upstream land uses include minor levels of forestry and forest access roads on tributaries, and a single small clearcut on the mainstem just below McQuarrie Lake. The Equivalent Clearcut Area of the McQuarrie sub-basin is 14% (BCCF, 1997). Land-use in the headwaters is not expected to have altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 9 polygons occupying a total area of 17.5 hectares with a riparian zone width of 30 metres (see McQuarrie Creek entry, appendix D). Land-use has modified 9%, or 1.59 hectares of this. The BEC classification for this reach is sub-boreal spruce/moist-cold (Babine variant) (SBSmc2), with one site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations. The proximity to water, position at the base of slopes, species composition, and presence of mountain alder and willows indicate that riparian polygons in reach 3A are likely all spruce-horsetail (10a) site series.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- a loss of stream shading and bank stability at the two points where the Michelle Bay FSR enters the riparian zone.
- possible alteration of surface/subsurface flow patterns in the riparian zone on the right bank due to ditching and soil compaction upslope in the road corridor.

Typical riparian polygon photos are found in plates 17-18.

Channel Assessment

Reach 3 is an 1828 metre long RPcw channel flowing between the elevations of 880 and 910 metres a.s.l., with an average gradient of 1 %, bankfull width of 8.1 metres, and bankfull depth of 0.56 metres. It is a short transitional and partially confined reach with a moderately wide floodplain whose dominant channel-forming mechanisms is LWD. Streambanks are composed of sand and gravel alluvium, with sporadic sections of fine-textured deposits at the lower end of the reach above areas which consistently catch LWD, and subsequently act to store sediment. Occasionally colluvial materials below

Reach Impact and Restoration Diagnostics

Table 14: Summary of habitat quality indicators by habitat unit category for McQuarrie Creek, reach 3.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	G	M	A	L	1
Other	S	G	M			2
Pool	G	C	H	AR	H	8
Riffle	C	G	H	A	H	1

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	0	1	0	OV, LWD	2
Other	2			OV, LWD	4
Pool	4	1	3	LWD, DP	2
Riffle	1	0	0	OV, B	1

Table 15: Reach summary of other indicators of impacts to watershed function and fish habitat for McQuarrie Creek, reach 3.

Functional pieces of LWD/bankfull width	**0.83**
Pool frequency	**4.42**
Bankfull : wetted width ratio	**1.52**
Bankfull : wetted depth ratio	**2.13**
Average temperature differential at summer low flows (^{O}C)	**5.00**
Area of disturbed riparian forest (ha)	**1.90**
Length of disturbed channel (m)	**1076**

Table 16: Mean values for selected parameters which may assist in designing instream restoration works, McQuarrie Creek, Reach 3.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m
Glide	1.00	0.56	8.83	19.75	34.82	5.60
Riffle	1.00	0.39	9.07	20.00	19.83	3.90
Pool	1.00	0.87	6.93	14.33	66.50	8.73
				Reach Mean Estimated Bankfull Discharge	40.38	

bedrock outcrops will also dominate bank materials at the bottom of the reach. The channel is regularly meandering (very short meander wavelength) with a moderate to high degree of lateral stability. Upslope areas are infrequently connected to the active channel except near the bottom of the reach as it becomes more confined and valley walls steepen. The floodplain plays a median role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement. In some cases, bedrock and valley wall controls dictate channel morphology and thus fish habitat. Occasionally, colluvium will form functional habitat features, and in some cases, LWD is recruited from upslope areas (blowdown, mass movement) rather than bank erosion, flooding, and lateral movement.

Channel assessment in reach 3 indicated that 59% (1076 metres) of channel is moderately disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2) (see appendix C). Dominant indicators of disturbance include extensive bars and recently formed LWD jams. Occasionally sediment wedges and elevated mid-channel bars were noted. Bankfull:wetted width and bankfull:wetted depth ratios (1.52 and 2.13 respectively) indicate a minor departure from benchmark conditions. Channel disturbance vectors are thought to be dominantly related to chronic sediment sources from the Michelle Bay FSR particularly from cross-ditches draining downslope, and erosion of road and culvert fill and bank erosion at the Michelle Bay FSR crossing. Flood damage and erosion was thought to have been accelerated by overbank flood conditions in the spring of 1997, and that focusing the creek through a single undersized culvert lead to artificial increases in water velocities and stream power downstream. Many of the elevated mid-channel bars and log jams noted are probably attributable to changes in the position of log jams during the flood which existed for several years prior, and were storing significant sediment wedges. See plates 16-18 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 3 can be characterized as high value resident fish habitat. Resident rainbow trout (0+/1+/2+/3+/adult) were the only species present at the time of survey. They were captured throughout the reach, and above the FSR culvert as well. Although the overview FHAP report (BCCF, 1997) indicated that anadromous fish may be able to navigate the canyon to use this reach, it was discovered that a 4 to 5 metre high impassable falls (significant overhanging section, lack of plunge pool) exists in the canyon in reach 2 at UTM 9.6045550.662200. Therefore, fish present in reach 3 are not steelhead trout.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is an important area for resident rainbow trout production in an unimpacted state in the context of overall watershed productivity and diversity of fish. This reach provides a rare stretch of suitable gradient and slightly larger substrate than upstream areas for spawning, and complex habitat for rearing. Trout from this reach will

likely migrate to one of several headwater lakes as adults. Channel and riparian function in this reach is also important in maintaining downstream habitat conditions.
This reach exhibits similar habitat to benchmark conditions. Habitat complexity falls within 1 standard deviation of the benchmark with a complexity index of 3.39, and is above the average of all reaches surveyed (see figure 40 and table 1 (page 9)). None of the major habitat unit components (pools, riffles, glides) dominates. Off-channel units were usually well-wetted but infrequent due to the narrow floodplain and dominant channel morphology. Compaction was moderate in glide and “other” units and high in pools and riffles. Spawning gravels were often too large for resident spawners with the exception of pool tailouts, where gravels suitable for resident spawners were abundant. Several possible redds were noted at 1230 metres upstream from the reach break in an area of small gravels with moderate depth of flow in a glide. Spawning gravels were not concentrated in any one area of the reach. LWD function is good in all size classes, and high levels of LWD were present in the active channel. Functional LWD frequency was 0.83 pieces/bankfull width (see figure 39 and table 15). The latter value is higher than the benchmark value, and as such is considered in line with benchmark conditions. On average, functional LWD (affecting cover, morphology) was found in all units sampled, most often in the small or extra-large size classes. Eight pieces were measured on average in pools. Pool frequency is 4.42 bankfull widths between pools, less than 1 standard deviation from the benchmark of 3.67, and is well above the survey average. Functional LWD levels account for excellent pool frequency in this reach. Cover elements were complex, with frequent in-stream cover. Cover consisted most often of LWD and overhead vegetation. Pool depth added a significant element of cover in these units. A somewhat low modal canopy closure value of 20-40% can be attributed to some channel widening in aggraded sections, despite the generally intact riparian canopy. The average temperature differential of 5^{o} C indicated the generally good level of stream shading. Maximum water temperatures did not exceed any critical thermal maxima for rainbow trout at the time of survey (extreme summer temperatures/lowest water levels).

Use of habitat by rainbow trout can be characterized as follows (see figures 35 to 38):

- Pools showed the greatest diversity of age-classes, with all age-classes present. Pool habitat was the only unit category where adult were captured, and as such are considered critical habitat for this age class. Moderate to average densities of other age-classes were present relative to riffles/glides/off-channel units.
- Riffles were inhabited by three age classes (0+/1+/2+) at the time of survey. Highest densities of 0+ fish were sampled, indicating the importance of riffles to this age class. Substrate was the dominant micro-habitat within riffle units.
- Four age classes (0+ to 3+) of fish were present in glides. Highest densities of the 2+ age-class were sampled in these units, indicating their importance to overall rainbow trout rearing habitat quality.
- Other (off-channel).habitat provided important habitat for 0+ to 2+ fish, and yielded the highest densities of 1+ fish. Off-channel habitat was generally had good water levels and cover at the time of survey.

Impact Synopsis

Land-use in this reach has moderately damaged fish habitat quantity and quality. Of particular concern are the level of channel disturbance, the undersized culvert at the FSR crossing, and the level of substrate compaction. Impact sources are dominantly isolated to this particular reach, and are both cumulative and isolated in nature. The dominant source of channel disturbance, as outlined above, is the FSR crossing, as both a sediment source and a vector to channel disturbance downstream. Chronic sediment delivery, aggradation, and bed compaction are also related to the FSR as it parallels the creek. Cross ditches were noted delivering sediment downslope onto the floodplain, and directly into off-channel habitat in one case.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Bank and fill slope erosion, water velocity increases, loss of riparian canopy and associated downstream effects due to improperly sized/installed FSR culvert as outlined above.
2) Cross-ditch sediment inputs from the road at 588 metres and 1130 metres upstream.
3) Loss of riparian vegetation and associated bank stability at 1010 metres upstream.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) Chronic fine sediment delivered to the channel in road runoff and as dust.

Prescriptions

All prescription sites are on crown land in reach 1, and therefore full prescriptions are presented.

Riparian prescriptions for reach 3 are summarized in appendix F. They relate to slope stabilization, stream shading, and sediment filtering. The prescription for polygon MCQ 19 is integrated with impact prescription #1.

One impact prescription site has been identified based on impacts outlined above, and physical and biological goals for mid-elevation reaches presented in section 3 of this report. It relates to reestablishing upstream access and stabilize riparian sources of sediment and channel disturbance (impact prescription #1) (see appendix G).

Priority and sequence of prescriptions is presented in figure 41. This reach has a very high priority for restoration as indicated by the reach prioritization table in appendix H

McQuarrie Creek Sub-Basin Restoration Plan

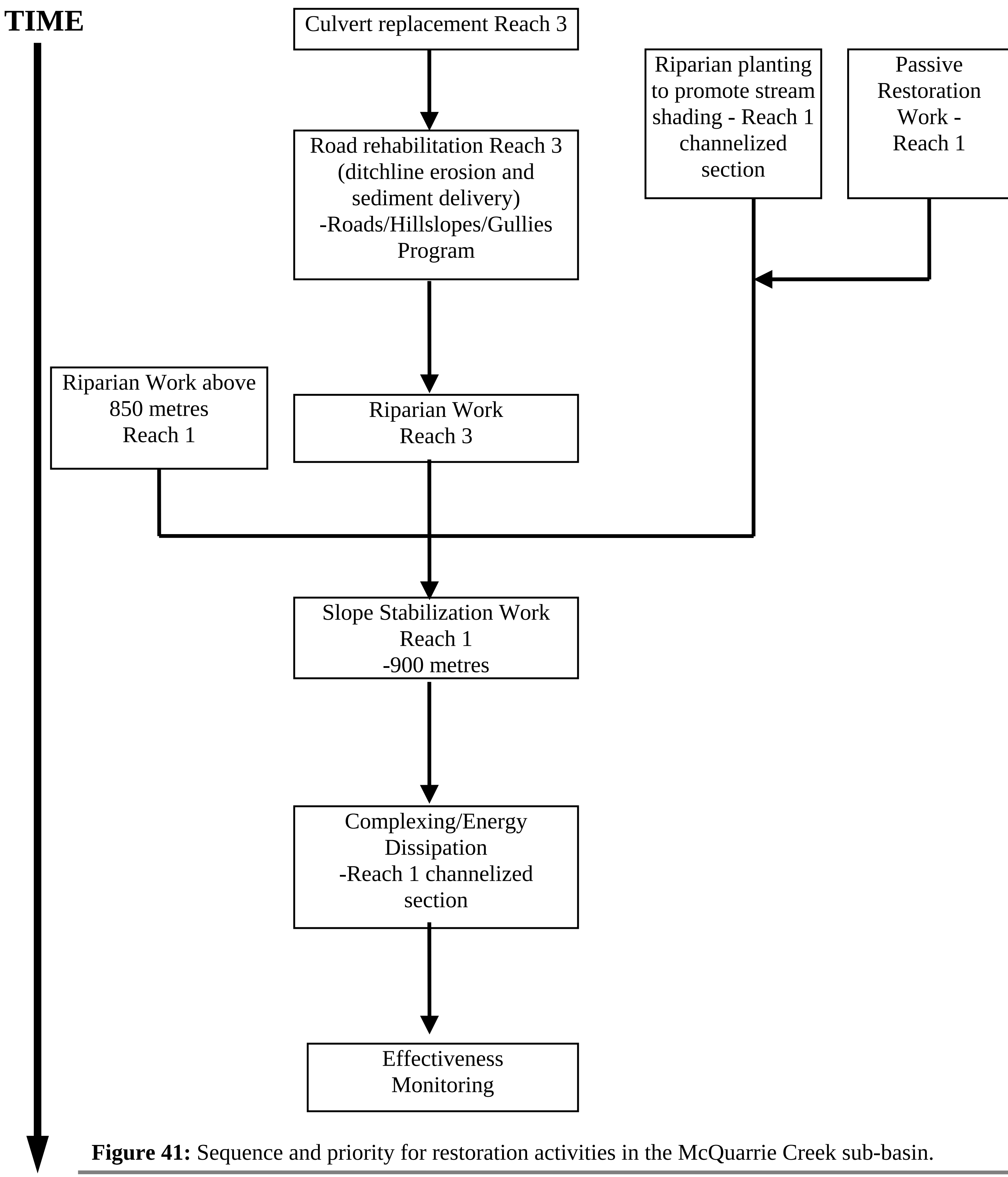

Figure 41: Sequence and priority for restoration activities in the McQuarrie Creek sub-basin.

4.6 Barren Creek Reach 1

Land Uses

Land use in this short reach includes a railway crossing at 28 metres (2 small culverts), cattle grazing (40-270 and 290-425 metres), and a highway crossing (270-290 metres) (pipe-arch culvert). Upstream land uses include access roads, forest access roads, grazing (private land and a grazing license), hay cultivation, a gravel quarry, two powerline corridors, and minor levels of forest harvesting in the headwaters and on small intermittent tributaries. The Equivalent Clearcut Area of the Barren sub-basin is 15% (BCCF, 1997). Land-use in the headwaters is not expected to have altered the runoff regime, but may be of future concern if all proposed cutblocks are approved.

Riparian Assessment

The riparian area of this reach was divided into 5 polygons occupying a total area of 1.70 hectares with a riparian zone width of 20 metres (see Richfield Creek entry, appendix D). Land-use has modified 100%, or 1.70 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool, with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

In the vicinity of the oxbow pond, in the first 200 metres below the highway, a floodplain (08) site series is assumed, with initial and shrub plant communities typical of a low-bench site. Species presence indicated pacific willow-mountain alder-lady fern (TEM code=ML) sites. Above this, species presence and composition indicates the black cottonwood-black twinberry ($58) seral association.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- Loss of the shrub/herb layer and associated root system and soil compaction from cattle grazing carried out in areas where the overstory still exists
- Removal of riparian forest at transportation corridors
- Past harvesting of spruce and cottonwood by the private landowner preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (white clover, Canada thistle), the possible modification of floodplain and channel features (diversions, landfilling), and the possible removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.

Typical riparian polygon photos are found in plates 21-22.

Reach Impact and Restoration Diagnostics

Table 17: Summary of habitat quality indicators by habitat unit category for Barren Creek, reach 1.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	S	None	L	AR	N	0
Pool	G	S	M	R	L	0

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	0	0	0	C, SWD	1
Pool	0	0	0	OV, SWD	5

Table 18: Reach summary of other indicators of impacts to watershed function and fish habitat for Barren Creek, reach 1.

Functional pieces of LWD/bankfull width	**0.16**
Pool frequency	**5.20**
Bankfull : wetted width ratio	**4.24**
Bankfull : wetted depth ratio	**1.33**
Average temperature differential at summer low flows (^{o}C)	**1.75**
Area of disturbed riparian forest (ha)	**7.34**
Length of disturbed channel (m)	**131**

Table 19: Mean values for selected parameters which may assist in designing instream restoration works, Barren Creek, Reach 1.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m
Glide	0.75	0.14	2.60	12.00	1.07	1.05
Pool	0.50	0.43	5.80	0.00	22.18	2.15
				Reach Mean Estimated Bankfull Discharge	11.63	

Channel Assessment

Reach 1 is a 426 metre long RPgw channel flowing between the elevations of 609 and 617 metres a.s.l., with an average gradient of 0.62 %, bankfull width of 4.20 metres, and bankfull depth of 0.29 metres. It is a depositional reach whose dominant channel-forming mechanism is LWD. Streambanks are composed of fine-textured sand. The channel is straight with a very low degree of lateral stability. Upslope areas are disconnected from the active channel. The floodplains of Barren Creek and the Bulkley River play a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement in this reach.

Channel assessment in reach 1 indicated that 100% (426 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2) (see appendix C). Dominant indicators of disturbance include sediment wedges, extensive bars, elevated mid-channel bars, multiple wetted channels (braiding), abandoned channels, and eroding banks. Much of the water in this reach was flowing subsurface. The bankfull:wetted width ratio (4.24) indicates an extreme departure from benchmark conditions related to extensive aggradation, braiding, and subsurface flows. The bankfull:wetted depth ratio (1.33) is also a departure from benchmark conditions, again indicating aggradation, and lack of a definite channel thread. The ratio value still falls within 1 standard deviation of the benchmark, however, and does not indicate severe impacts. Sources of aggradation are related largely to sediment sources and channel impacts upstream, but a loss of bank stability within reach 1 due to cattle grazing of understory and soil compaction is also thought to be a source of sediment and bedload.

Fish and Fish Habitat Assessment

Reach 1 can be characterized as high value fish habitat. Rainbow/steelhead (0+) were the only fish present at the time of survey. Historically, chinook salmon and coho salmon also have a documented presence in this reach up to the highway culvert (BCCF, 1997).

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is a critical and productive area for spawning and rearing, particularly for coho salmon and steelhead trout, in an unimpacted state. Although normally a mainstem spawning and rearing species, this reach may also be an important area for chinook salmon considering the extreme low-gradient nature of the Bulkley River in reaches 2 and 4. The alluvial fans of tributaries to the upper Bulkley River, as discussed in part 3 of this report, ideally provide areas of swifter current and larger substrate, diverse invertebrate communities, complex channel morphology and cooler water temperatures relative to the mainstem. As such they are important for summer rearing and summer and fall spawning habitat. Their proximity to the Bulkley provides access to overwintering habitat, mainstem rearing areas for older juvenile salmonids, and a choice of habitat refugia in either the mainstem or tributary during high water events.

This would be greatly enhanced by restored access to the oxbow pond near the mouth. The use of this reach by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.
This reach exhibits highly degraded habitat relative to benchmark conditions. Habitat complexity falls 2.7 standard deviations away from the benchmark with a complexity index of 2.84, and is almost two standard deviations lower than the average of all reaches surveyed (see table 1, page 9). Riffles and glides dominate the spectrum of habitat units, and there are very few pool and "other" units present. Compaction was low in glides and moderate in pool units. Spawning gravels were usually absent in glides and low in pool tailouts, which had resident gravels only. Fines was the dominant substrate size class in glides, and the subdominant size class in pools. LWD function was low in the small and extra-large size classes, and moderate in the large size class. Functional LWD frequency is 0.16 pieces/bankfull width (see table 18). The latter value is 2.3 standard deviations below the benchmark value, and as such is considered a significant departure from benchmark conditions. On average, functional LWD (affecting cover, morphology) was not measured in sampled units. Pool frequency is 5.20 bankfull widths between pools, which is within 1 standard deviation from the benchmark of 3.67, and is lower (more frequent pools) than the survey average. Cover elements showed good complexity, with frequent in-stream cover. Cover usually consisted of small woody debris. Canopy closure was 30-50% on average due to abundant shrub and pole sapling cover. The average temperature differential of 1.75 ^{o}C indicated poor stream shading and/or low water levels upstream, with maximum water temperatures (19.5 ^{o}C) exceeding thermal maxima for successful growth and reproduction (metabolic stress) of coho and chinook at the time of survey (extreme summer temperatures/lowest water levels).

Use of habitat by different fish species can be characterized as follows (see figures 43 to 44):

- Moderate densities of 0+ rainbow/steelhead (0.25 fish/m^3) were present in pools in reach 1. No other species were present in sampled units at the time of survey.
- Extremely high densities (72 fish/m^3) of 0+ rainbow/steelhead were present in glides in reach 1.

Impact Synopsis

Land-use in this reach has severely fish habitat quantity and quality. Of particular concern are high water temperatures, the absence of species historically present in the reach, and extreme aggradation. The latter is responsible for upstream access problems due to extremely low water levels, the lack of a distinct channel thread, the simplification of habitat, poor LWD function, and burial of spawning gravels and certain invertebrate habitats by fine sediment. Impact sources are dominantly not isolated to this particular reach, and are cumulative in nature. However, bank instability due to riparian impacts may play a role in the aggradation, and the extent to which braiding and channel widening has occurred. Combined with extremes in water levels, undersized and poorly installed culverts will exaggerate access problems to this reach and upstream.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Loss of riparian vegetation as well as undersized and poorly designed culverts for proper fish passage at transportation corridors.
2) Loss of riparian shrub/herb layer and bank stability due to intensive ungulate grazing between the railway and the highway.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) Extreme aggradation and associated channel and fish habitat impacts as discussed above including loss of access to off-channel (oxbow) habitat for overwintering and summer rearing, burial of functional LWD, simplification of critical fish habitat, subsurface water flow and braiding causing upstream access problems and high temperatures during summer low flow period, as well as freezing over during winter low-flows, and burial of spawning substrate and invertebrate habitat.
2) High summer water temperatures due to upstream land-clearing and floodplain development.

Prescriptions

All prescription sites are on private land in reach 1, and therefore only conceptual prescriptions are presented.

The one riparian prescription for reach 1 is summarized in appendix F. It (polygon BAR003) relates to bank stabilization and stream shading and is integrated with impact prescription #1.

One impact prescription site has been identified based on impacts outlined above, and physical and biological goals for alluvial fan reaches presented in section 3 of this report. It relates to reestablishing upstream access, spatial habitat diversity, passive restoration of riparian areas, and stabilizing areas of channel widening and braiding (impact prescription #1) (see appendix G).

Priority and sequence of prescriptions is presented in figure 45. This reach has a high priority for restoration as indicated by the reach prioritization table in appendix H

Barren Creek Sub-Basin Restoration Plan

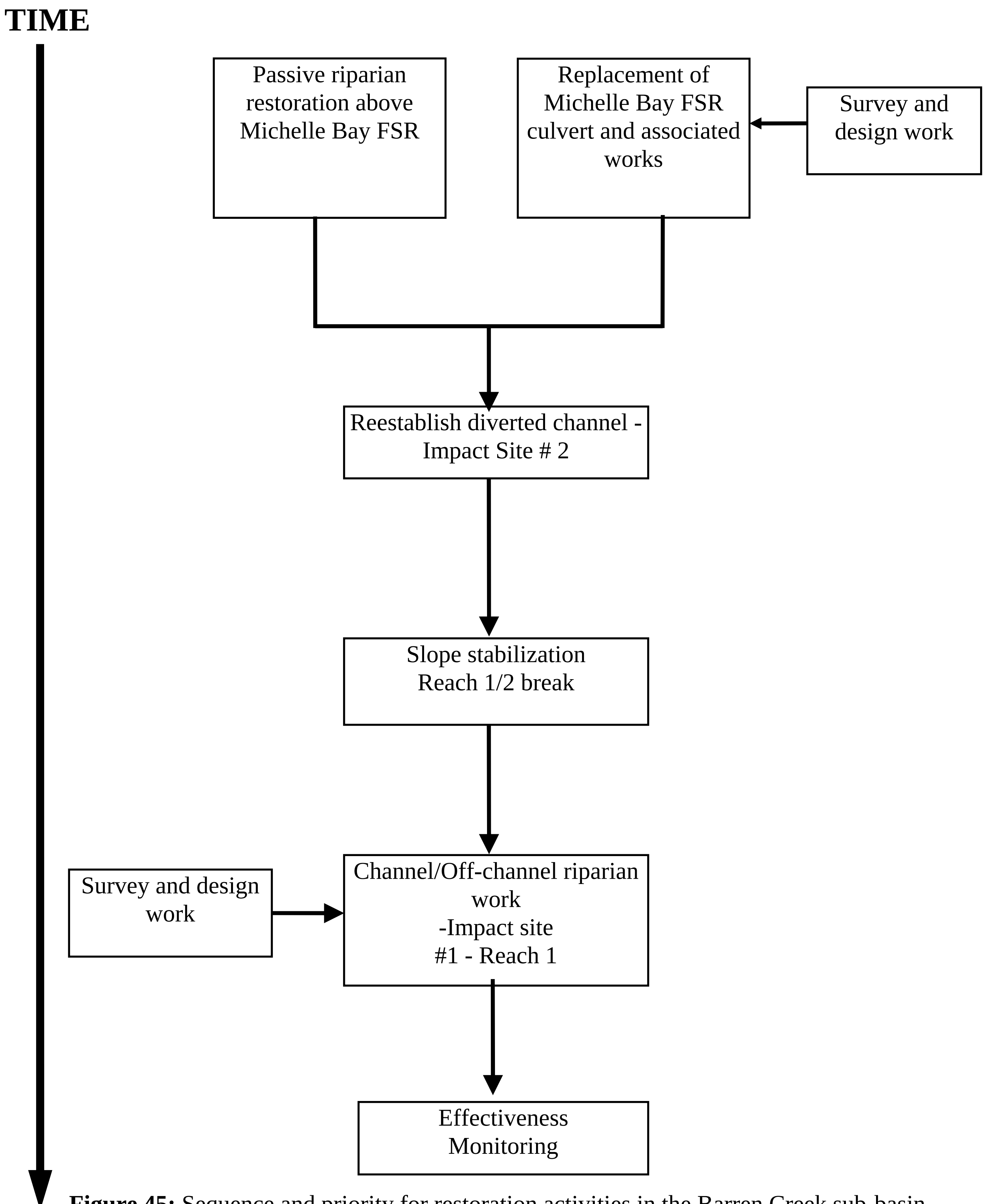

Figure 45: Sequence and priority for restoration activities in the Barren Creek sub-basin.

4.7 Barren Creek Reach 2

Land Uses

Reach 2 of Barren Creek has been heavily grazed by ungulates for its entire length. Many sections of the stream and banks were disturbed where cattle had crossed or had used the creek for watering. Moving upstream from the reach 1 and 2 break, other uses include a small section of dyking along the Highway 16 right-of-way, dyking to protect a powerline right-of-way at 1050 metres and to protect a private residence at 1450 metres. A gravel pit is located at 1700 metres on the downstream right bank. A small area of bank failure and a point source of sediment input were associated with this gravel pit. At 1790 metres, further dyking to protect a fence line was also observed. All dykes were on the downstream right bank. At 1845 metres a hayfield or pasture was present on the downstream left bank. A small dam used for irrigation or drinking water may have been located at 2015 metres. A very rusty piece of grating was found embedded in the substrate and some small earthworks were located on the streambanks which suggest this. The Michelle Bay Forest Service road and a high tension powerline bisect this reach at approximately the half-way point at 2300 metres. The culvert at the North Road is a barrier to upstream fish migration and was used as a section break. Immediately upstream of the North Road culvert, the floodplain of Barren Creek has been heavily used by cattle for approximately 100 metres. A rough access road or ATV trail parallels the creek on the downstream left bank from 2780 metres to 2937 metres where it fords the creek. The road continues to parallel the stream on the right bank, however, the floodplain is wider on this side and the road is farther away from the creek. The road is unsurfaced and is covered in grass with a few muddy rutted sections. At 3772 metres two large cottonwood stems have been cut into the channel to deflect the stream away from pasture land. Based on the amount of decomposition, they have been in place for at least 10 years. Nutrient loading due to cattle waste is likely highly deleterious to water quality as observed in the field by odour and an increased amount of fines covering substrate in all types of habitat except the most active riffles. The entire stream bed was covered by algae with large mats of filamentous green algae were present in many pools. Water quality measurements were unfortunately beyond the scope of this study. Upstream land uses include forestry and the attendant road building and cattle ranching. The Equivalent Clearcut Area of the Barren Creek sub-basin is 14% (BCCF, 1997). Land-use in the headwaters is not expected to have altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 23 polygons occupying a total area of 23.2 hectares with a riparian zone width of 30 metres (see Richfield Creek entry, appendix D). Land-use has modified 79.5%, or 18.5 hectares of this. The BEC

Reach Impact and Restoration Diagnostics

Table 20: Summary of habitat quality indicators by habitat unit category for Barren Creek, reach 2.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	G	H	AR	L	3
Other	G	G	H	R	L	1
Pool	S	G	H	AR	L	6
Riffle	C	G	H	AR	L	2

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	2	1	0	OV, B	2
Other	0	0	1	LWD, OV	1
Pool	3	2	1	LWD, OV	3
Riffle	1	1	0	B,OV	1

Table 21: Reach summary of other indicators of impacts to watershed function and fish habitat for Barren Creek, reach 2.

Functional pieces of LWD/bankfull width	**0.17**
Pool frequency	**7.71**
Bankfull : wetted width ratio	**1.93**
Bankfull : wetted depth ratio	**2.70**
Average temperature differential at summer low flows (^{O}C)	**1.60**
Area of disturbed riparian forest (ha)	**18.60**
Length of disturbed channel (m)	**49**

Table 22: Mean values for selected parameters which may assist in designing instream restoration works, Barren Creek, Reach 2.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.33	0.37	3.73	15.30	9.82	4.84
Riffle	1.32	0.33	4.58	18.58	8.46	4.31
Pool	1.29	0.51	5.13	11.86	40.60	6.50
				Reach Mean Estimated Bankfull Discharge	19.63	

classification for this reach is sub-boreal spruce, dry-cool (SBSdk) , with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

On the alluvial fan of Barren Creek, the dominant plant community is predicted to be the cottonwood-twinberry ($58) seral association with areas of black cottonwood-dogwood ($59) on mid-bench areas with more frequent overbank flooding. These are 08 floodplain site series seral associations.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest and soil compaction in areas used for grazing/ hay production/ powerline corridor.
- Loss of the shrub/ herb layer and associated root system and soil compaction from cattle grazing carried out in areas where the overstory still exists.
- Removal of riparian forest and disconnection of the channel from the riparian zone due to channelizing in transportation corridors and at the housing development on the floodplain.
- Past harvesting of spruce and cottonwood by landowners preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (Canada thistle, white clover), the possible modification of floodplain and channel features (diversions and landfilling) and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.

Typical riparian polygon photos are found in plates 24-25.

Channel Assessment

Reach 2 is a 3837 metre long RPgw and RPcw channel flowing between the elevations of 617 and 740 metres a.s.l., with an average gradient of 1.32%, bankfull width of 4.3 metres, and bankfull depth of 0.4 metres. It is an aggraded alluvial floodplain reach whose dominant channel-forming mechanism is LWD. Streambanks are composed of erodible sands and gravels. The channel is irregularly wandering with a moderate degree of lateral stability. Upslope areas are occasionally connected to the active channel except at the upstream end of the reach where the stream flows out of a canyon and the channel is confined. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, moderating temperatures, acting as a sink and source for sediment/bedload and creating diverse habitat through lateral movement.

Channel assessment in reach 2 indicated that 2.3% (89 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2) (see appendix C). Dominant indicators of disturbance include the presence of extensive bars, extensive riffles and minimal pool area. Sediment wedges, bars and eroding banks are distributed throughout the reach. Avulsions were observed from 89 metres to 680 metres and from 880 metres to 1887 meters. The bankfull:wetted width ratio (1.93) indicates stability relative to benchmark conditions while the bankfull:wetted depth ratio (2.70) indicates a departure. Compacted floodplain soils, channelization and riparian modification causing eroding banks and channel incision are largely responsible for this departure. See plates 25 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 2 can be characterized as high value fish habitat. Coho salmon (0+) were present at the time of survey. Coho were not captured past 1306 metres upstream from the reach break (1726 metres upstream from the Bulkey River). Rainbow/ steelhead trout (0+, 1+, 2+, 3+, adult) were also present in large numbers during the survey. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout (Tredger, 1984) up to the impassable culvert at the North Road crossing. Above this barrier, all rainbow trout captured are assumed to be resident. Chinook juveniles also have a documented presence in reach 1 to the Highway 16 culvert (SKR Consultants Ltd., 1997). With no permanent barriers up to the North Road crossing, it may be assumed that without any other limiting factors, juvenile chinook could use reach 2A as rearing habitat. Several adult chinook spawners were observed in the mainstem Bulkley River at the confluence with Barren Creek. These fish were likely holding or resting here while they migrated further up the Bulkey.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is a critical and productive area for spawning and rearing, particularly for coho salmon and steelhead trout, in an unimpacted state. Although normally a mainstem spawning and rearing species, this reach may also be an important area for chinook salmon considering the extreme low-gradient nature of the Bulkley River in reaches 2 and 4. The alluvial fans of tributaries to the upper Bulkley River, as discussed in part 3 of this report, ideally provide areas of swifter current and larger substrate, diverse invertebrate communities, complex channel morphology and cooler water temperatures relative to the mainstem. As such they are important for summer rearing and summer and fall spawning habitat. Their proximity to the Bulkley provides access to overwintering habitat, mainstem rearing areas for older juvenile salmonids, and a choice of habitat refugia in either the mainstem or tributary during high water events. Their use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits degraded habitat relative to benchmark conditions. Habitat complexity falls within 2.3 standard deviations of the benchmark with a complexity index of 2.96, and is less than the average of all reaches surveyed (see figure 52 and table 1 (page 9)). Riffles dominate the spectrum of habitat units, and there are very few off-channel units present. Compaction was moderate to high in most units. Spawning gravels were usually low to absent in all units. Of the spawning habitat present, most were suitable for anadromous salmon species. Excellent resident spawning gravels were observed in a glide at 1886 metres. Resident spawning gravels were slightly more abundant upstream of the North Road crossing in section B. LWD function is 37% or less in all size classes, and functional LWD frequency is 0.17 pieces/bankfull width (see figure 51 and table 21). The latter value is 2.2 standard deviations below the benchmark value, and as such is considered a significant departure from benchmark conditions. On average, functional LWD (affecting cover, morphology) is found in all units except other (off-channel) units. No functional LWD was present in any off-channel units sampled. Pool frequency is 7.71 bankfull widths between pools, 1.1 standard deviations from the benchmark of 3.67, and is above the survey average. Cover elements showed moderate complexity, with good in-stream cover. Cover usually consisted of LWD or overstream vegetation. Canopy closure was 20-40% on average, however, most of the overstory consisted of and dense alder growth. Many of the mature conifers and cottonwoods have been harvested over the years. The average temperature differential of 1.6 reflected this, with maximum water temperatures (18.75 ^{o}C) exceeding thermal maxima for salmonid spawning at the time of survey, and were within the range of metabolic stress for coho and chinook salmon (extreme summer temperatures/lowest water levels).

Use of habitat by different fish species can be characterized as follows (see figures 47 to 50):

- Pools yielded the lowest densities of fish of all types of units sampled. The dominant species/age-classes were 1+ rainbow/steelhead (2.51 fish/m^3). The least dominant were 0+ coho salmon at 0.09 fish/m^3. Coho and rainbow/steelhead are expected to compete for similar habitats and food, and coho may be preyed upon by larger rainbow/steelhead (Scott and Crossman, 1973). The high diversity of age-classes suggests the importance of pools in the context of the reach and watershed.
- Riffles were used dominantly by 0+ rainbow/steelhead trout (11.6 fish/m^3). No coho were captured, and 3+ rainbow/steelhead accounted for the smallest proportion of the catch. Riffles exhibited the greatest age-class diversity and were the only units in which adult resident rainbow trout were captured.
- Rainbow trout/steelhead and coho salmon were present in glides and they provided good diversity of age-structure. Four age-classes of rainbow trout/ steelhead were present as well as 0+ coho. Rainbow trout/ steelhead showed highest densities in the 1+ age-class. Densities and age-class representation of both these species were similar to those in pool habitats.
- The limited amount of other (off-channel) habitat available to fish provided rearing habitat for both 0+ (primarily) and 1+ rainbow trout/ steelhead. Densities of fish in these units were quite high (9.1 and 3.5 fish/m^3 respectively). Habitat quality in these units was poor at the time of survey, indicating the condition of the floodplain in general.

Impact Synopsis

Land-use in this reach has reduced fish habitat quantity and quality. Of particular concern is the extensive eroding banks and associated bedload, poor LWD function, lack of channel complexity and loss of riparian vegetation. Impact sources are dominantly isolated to this particular reach, and are cumulative in nature. The bank erosion is related to a loss of soil cohesion as the root system of riparian vegetation is lost (overstory and/or shrub layer), bank calving from repeated cattle trampling, migration of the thalweg as sediment load and bar size increases, and increases in water velocities due to channelizing and culverts. Poor LWD function is likely due to a combination of poor bank stability (anchoring), high sediment load (increased sheer forces and/or burial) and contributes to the lack of channel complexity. Cattle grazing limits the recruitment of further LWD by eliminating juvenile trees.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Channel diversion along residential access road and various dykes causing increased bank erosion and lateral channel movement.
2) Small bank failure and sediment input at the gravel pit near the North Road and at a hayfield or pasture at 1845 metres.
3) A 20 metre long section of eroding bank at 2044 metres.
4) The 1.75 metre diameter culvert at the North Road crossing. This culvert is perched 1.3 metres above the streambed. There is no plunge pool below the culvert as the flow spills directly onto a pile of rip-rap 1.5 metres long. This 40 metre long, 1.5% gradient culvert is a barrier to upstream fish migration. This culvert is poorly placed and too small to accommodate the volume of water in this stream at freshet. Extensive eddy action and bank erosion are occurring upstream of this culvert causing an increase in sedimentation and bedload.
5) A road or trail paralleling stream in section B causing some bank erosion and failure.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) The frequent removal and/or alteration of riparian forest canopy and subsequent loss of stream shading and functional riparian microclimate. This in turn causes stressful to potentially lethal summer rearing temperatures, poor water quality, and exacerbates the nutrient loading/eutrophication problem through accelerated primary productivity.
2) The frequent removal and/or alteration of riparian forest canopy and subsequent loss of root system, soil cohesion and streambank stability. The positive feedback nature of this impact leads to an increased sediment load which further perpetuates bank erosion. Channel widening and sediment load in turn are related to higher water temperatures, loss of habitat complexity through in-filling of pools, poor LWD function and loss of channel sinuosity and off-channel habitat, and penetration of spawning gravel matrices by fine sediments causing compaction and smothering of redds.
3) The alteration of floodplain function by removal of LWD and riparian forest, as well as compaction of floodplain soils leading to a decreased groundwater recharge and

water storage capacity, and a disconnection of the floodplain from the channel. The latter includes the formation of off-channel features, the buffering of overbank flood flows by riparian LWD, and an increase in surface erosion during overbank flood events as surface roughness is minimized. Spinoff effects include decreased rearing and overwintering habitat quality and quantity for salmonids (particularly juvenile coho) in off-channel areas, lower summer and winter baseflows and subsequently greater extremes in temperature, and channel impacts (loss of sinuosity, increased sediment load and associated effects on fish habitat).

Prescriptions

Prescription sites are on crown land in reach 2, and therefore full prescriptions are presented in some cases and in others only conceptual prescriptions.

Riparian prescriptions for reach 2 are summarized in appendix F. They relate to slope stabilization, bank stabilization, and sediment filtering. The prescription for polygon BAR008 is integrated with impact prescription #2, and BAR011 with impact prescription #3. Much of the riparian work in this reach pertains to passive restoration of the shrub layer and associated bank stability by excluding cattle access.

Three impact prescription sites have been identified based on impacts outlined above, and physical and biological goals for alluvial fan reaches presented in section 3 of this report. They relate to reestablishing upstream access (impact prescription #4) and stabilizing riparian and upslope sources of sediment and channel disturbance (impact prescriptions #2 and 3) (see appendix G).

Priority and sequence of prescriptions is presented in figure 53. This reach has a very high priority for restoration as indicated by the reach prioritization table in appendix H

Barren Creek Sub-Basin Restoration Plan

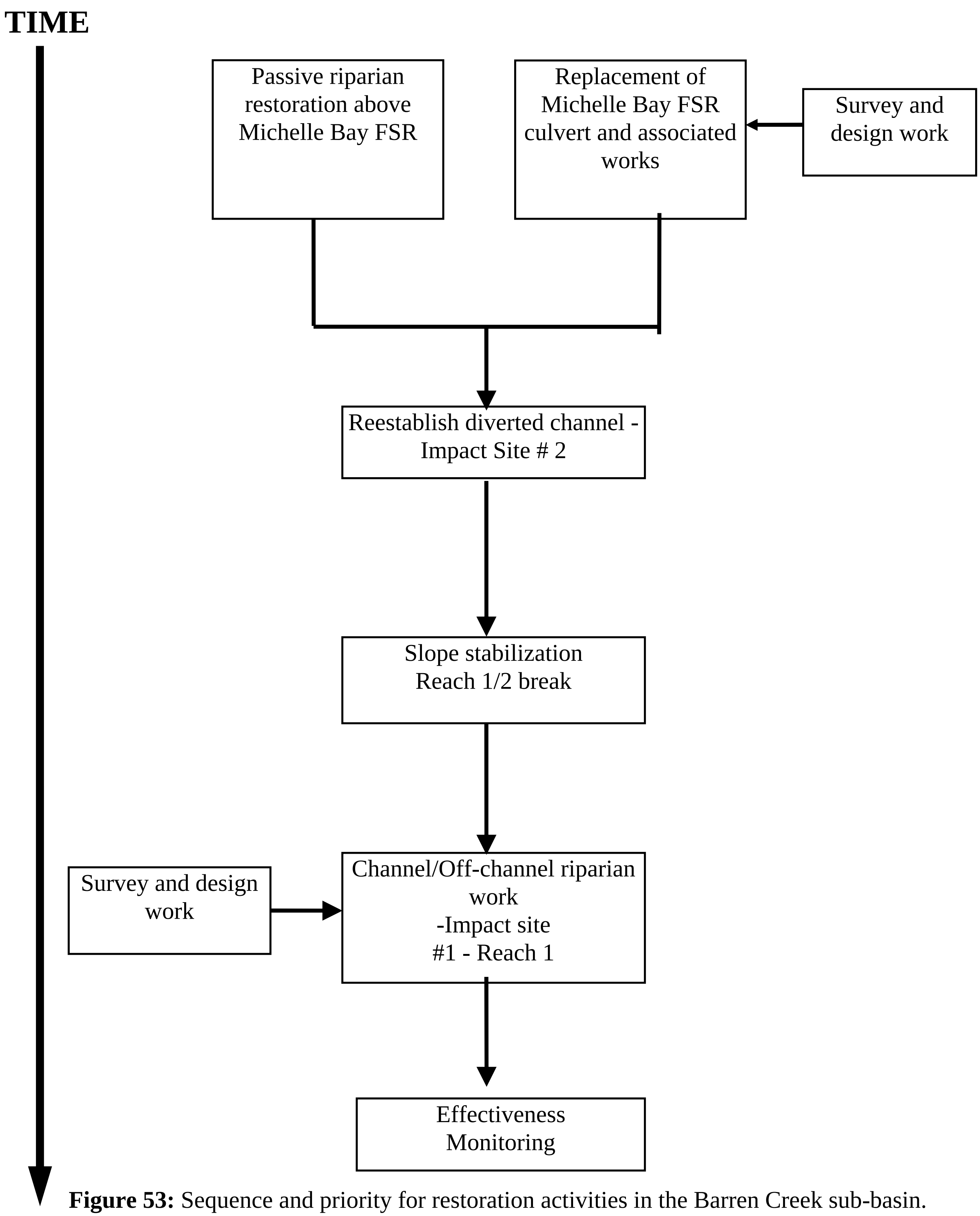

Figure 53: Sequence and priority for restoration activities in the Barren Creek sub-basin.

4.8 Aitken Creek Reach 1

Land Uses

Land use in this reach is fairly minimal, consisting of one secondary road crossing (a ford at 530 m upstream), and old passively restoring hay fields, and sparse cattle grazing throughout. Upstream land uses include roads and stream crossings, water withdrawals, two small dams, a natural gas line and powerline corridor, and extensive forest harvesting activity. The Equivalent Clearcut Area of the Aitken sub-basin is 30% (BCCF, 1997). Land-use in the headwaters is expected to have altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 14 polygons occupying a total area of 8.8 hectares with a riparian zone width of 30 metres (see Richfield Creek entry, appendix D). Land-use has modified 74%, or 6.5 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

On the alluvial fan of Aitken Creek, the dominant plant community is predicted to be the black cottonwood-dogwood ($59) seral association with areas of cottonwood-twinberry ($58) seral association on lower-bench areas with more frequent overbank flooding. These are 08 floodplain site series seral associations. It may be possible that prior to agricultural land development that pacific willow-mountain alder-lady fern (TEM code=ML) communities often existed in low-bench regularly flooded sidechannels of the Bulkley or McQuarrie Creek but these seem to be mostly absent due to either decreased overbank disturbance, or being filled in for hayland, or both. Above 600 metres, the reach is confined on the left bank by valley walls of morainal materials with both easterly and westerly aspects. The presence of abundant *Populus tremuloides* (trembling aspen) and 0-40% slopes indicates spruce-horsetail (07a) and/or spruce-twinberry-coltsfoot (06) sites. These sites are deciduous seral associations, and are predicted as aspen-twinberry ($57) and aspen-cow parsnip ($56) based on species presence and aspect.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- Loss of the shrub/herb layer and associated root system and soil compaction from cattle grazing carried out in areas where the overstory still exists
- Past harvesting of spruce and cottonwood for land clearing and possibly railway ties preceded many of these impacts. The modified floodplain plant communities are still in varying states of recovery, and abundant lateral movement has exacerbated this.
- Insidious impacts on riparian plant communities from land-use include the

Reach Impact and Restoration Diagnostics

Table 23: Summary of habitat quality indicators by habitat unit category for Aitken Creek, reach 1.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Cascade	C	B	M	A	L	0
Glide	G	C	H	AR	H	1
Other	G	C	H	AR	H	0
Pool	S	G	M	AR	L	4
Riffle	C	G	H	AR	L	3

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Cascade	0	0	0	B, OV	1
Glide	0	0	0	OV, C	1
Other	0	0	0	OV, IV	1
Pool	2	2	0	LWD, OV	1
Riffle	0	1	1	OV	1

Table 24: Reach summary of other indicators of impacts to watershed function and fish habitat for Aitken Creek, reach 1.

Functional pieces of LWD/bankfull width	**0.25**
Pool frequency	**15.54**
Bankfull : wetted width ratio	**1.68**
Bankfull : wetted depth ratio	**3.01**
Average temperature differential at summer low flows (^{O}C)	**3.30**
Area of disturbed riparian forest (ha)	**6.50**
Length of disturbed channel (m)	**784**

Table 25: Mean values for selected parameters which may assist in designing instream restoration works, Aitken Creek, Reach 1.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.08	0.72	5.53	17.00	39.76	7.76
Riffle	1.0625	0.5325	6	16.25	22.09	5.66
Pool	1.25	0.715	5.125	10.5	69.52	8.94
				Reach Mean Estimated Bankfull Discharge	30.93	

introduction of invader species (white clover, Canada thistle).

Channel Assessment

Reach 1 is a 1592 metre long RPcw and CPcw channel flowing between the elevations of 609 and 645 metres a.s.l., with an average gradient of 1.11%, bankfull width of 5.68 metres, and bankfull depth of 0.58 metres. It is an alluvial fan reach whose dominant channel-forming mechanism is LWD. Streambanks are composed of a mix of unconsolidated clay/silt to boulder alluvium with a highly variable dominant size class of materials. The channel is sinuous t6 regularly meandering with a very low degree of lateral stability. Upslope areas are disconnected from the active channel except in the upper third of the reach where bedrock outcrops and natural mass movements persist. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 1 indicated that 49% (784 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2-A3) (see appendix C). Dominant indicators of disturbance include extensive bars, abandoned channels, eroding banks, avulsions, abundant SWD, and poor LWD function. More aggraded areas had elevated mid-channel bars present as well. Bankfull:wetted width and bankfull:wetted depth ratios (1.68 and 3.01 respectively) indicate a departure relative to benchmark conditions. In the case of the width ratio, it falls within 1 standard deviation from the benchmark value, and is not considered a significant departure. The depth ratio indicates significant channel incising and disconnection from the floodplain, with a 1.6 standard deviation difference from the benchmark value. Sources of channel disturbance are both natural and anthropogenic. The bedrock and surficial geology of the Aitken sub-basin showed significantly more weathering of mafic bedrock materials and possibly sedimentary mudstone or claystone and subsequently many of the bedrock outcrops and natural mass movements were composed of fine-textured clay materials. Combined with morainal materials, a great deal of fine sediment is incorporated into alluvium in this reach. Thus, this creek probably naturally carries a high sediment load. It is likely that fish populations and plant communities have naturally adapted to this state. However, an increase in the rate of spring runoff from cleared land at higher elevations is likely forcing the channel pattern to equalize with higher volumes of water and greater stream power. This is probably resulting in a downcutting of the stream channel, greater erosion and transport of streambank materials downstream, and an increase in toe erosion of naturally active slides and bedrock outcrops. Thus, the level of aggradation is increased due to greater erosion upstream and deposition downstream. In any case, it is upstream land use that delivers the bulk of impact downstream. See plates 32 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 1 can be characterized as very high value fish habitat. Coho (0+/1+) and chinook (0+) salmon, and resident mountain whitefish (2+) and long-nose dace (0+/1+/2+/3+) were present at the time of survey. Rainbow/steelhead trout (0+/1+/2+/3+) were also caught in this reach. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout due to a lack of downstream barriers (Tredger, 1984). All species were present throughout the reach. No previous sampling was carried out in the reach for fish presence, distribution, and/or abundance. No redds or sign of spawning was noted. Lower densities of 0+ rainbow/steelhead in all units compared to other similar systems (where rainbow/steelhead have been the dominant species) suggests that juveniles move into this creek from elsewhere, or that mortalities are high in this age class or in incubating eggs.
This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is an important area for all life-stages, possibly with the exception of spawning (as discussed above), in an unimpacted state in the context of overall watershed productivity and diversity of fish. Habitat condition for rearing and overwintering was better than in many similar reaches in the valley bottom of the mid-Bulkley River (see below), and flows and temperatures seemed adequate despite the level of aggradation. Its use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits degraded habitat relative to benchmark conditions. Habitat complexity falls within 1 standard deviation of the benchmark with a complexity index of 3.76 (this reach is more complex than benchmark conditions), and is significantly higher than the average of all reaches surveyed (see figure 60 and table 1 (see page 9)). Riffles dominate the spectrum of habitat units, but pools appear in higher proportions, and glides in lower proportions relative to similar reaches in the watershed. Higher gradient channel features such as cascades add to habitat complexity. Despite frequent lateral movement, functioning off-channel ("other") habitat did not frequently occur. Compaction was generally high in all unit types except pools and cascades, where it was moderate. Fine sediment was the dominant substrate in pools, indicating high concentrations of suspended sediment and bedload that are not flushed during the spring freshet. Spawning gravels were present in most cases in low amounts, but were abundant in glides. Gravel sizes were suitable for both resident and anadromous species in riffles, pools and glides. LWD function was low in the small size class, average in the large size class, and excellent in the extra-large size class. Extra large LWD was only available in very low volumes in the reach, indicating poor LWD recruitment from the floodplain. Functional LWD frequency is 0.25 pieces/bankfull width (see figure 61 and table 24). The latter value is 2 standard deviations from the benchmark value, and as such is considered a significant deviation from benchmark conditions. On average, functional LWD (affecting cover, morphology) is only found in pools and riffles, and no small functional LWD was present except at pools. Pool frequency is 15.54 bankfull widths between pools, which is 3 standard deviations from the benchmark of 3.67, and is almost double the survey average. Note the positive (direct) relationship between pool frequency and LWD function. Cover elements showed excellent complexity, with frequent in-stream cover. Cover commonly consisted of overhead vegetation, and boulders in cascades, cutbanks in glides, instream vegetation in off-channel units, and LWD in pools. Riffles showed poor in-stream cover. Canopy closure was 0-20% on average due to the extent of aggradation and dominantly early to mid-successional forest canopy. The average temperature differential was 3.3 ^{o}C, with maximum water temperatures (20 ^{o}C) exceeding thermal maxima for successful growth and reproduction in salmon species (metabolic stress) at the time of survey (extreme summer temperatures/lowest water levels). These water temperatures were slightly lower than similar reaches surveyed. despite similar weather conditions (hot and sunny) and air temperatures.

Use of habitat by different fish species can be characterized as follows (see figures 55 to 59):

- Pools showed excellent species and age-class diversity (5 species and 9 age-classes). Pools were infrequent (as discussed above), but were often quite deep and had good cover. They were the only units where mountain whitefish and 3+ long-nose dace were captured, and the only habitat/reach in the survey area where 1+ coho were sampled (they were also sampled in the Bulkley mainstem). This indicates the importance of pools for these species, and for the overall productivity of these species in the watershed. Chinook were the dominant species in pools, and the full range of age-classes for rainbow/steelhead were present. 2+ rainbow/steelhead were found in highest densities within pools, indicating their importance to this age-class. Low densities of 0+ rainbow/steelhead may be due to the abundance of larger predatory species and competition with these individuals for resources. Dominantly fine substrate would preclude the use of cobble/gravel as a refuge microhabitat to avoid being preyed upon.
- Riffles were utilized by rainbow/steelhead and long-nose dace. Highest densities of 1+ rainbow/steelhead were present in riffles, as well as 1+ dace. Lower densities of 0+ rainbow/steelhead and dace may be related to embedded and compact substrate, which is inhibiting the use of this preferential microhabitat. Higher levels of compaction and in-filling of the substrate matrix were noted in Aitken riffles relative to other systems. Clay mineralogy of sediment source areas is likely the cause.
- Four species and 9 age-classes were present in glides. Chinook and coho salmon were present in highest densities, as were 3+ rainbow trout and 0+ long-nose dace. The frequent presence of stable, near bank cutbank cover might account for the diversity and density of fish in these units, as might the average wetted depth of 0.2 metres (indicating good water depth).
- Other (off-channel) habitat provided excellent habitat for the youngest age classes, yielding highest densities of 0+ rainbow/steelhead and long-nose dace. The gravel/cobble substrate and lower compaction of the units sampled further indicated habitat suitability for small juveniles of these species.

Impact Synopsis

Land-use in this reach has not significantly damaged fish habitat quantity and quality. Impacts of upstream land-use are, however, propagating downstream and the effects of past land-use in this reach may be exacerbating these problems. Of particular concern is the level and nature of channel disturbance given the exceptionally high fish values, and high summer water temperatures. Extreme spring meltwater runoff combined with higher sediment load due to land-clearing and forestry upstream is leading to habitat simplification and loss of LWD function. Associated impacts on habitat include loss of complexity and therefore habitat density for multiple life-stages of rearing fish, increased surface and embedded fine sediments, increased bank erosion and lateral channel movement leading to greater sediment inputs. Although water levels appeared higher and water temperatures lower than similarly aggraded reaches in the survey area during the summer critical period, the level of aggradation suggests that they would be similarly improved with a more stable channel. It is difficult to separate the effects of what would appear to be many natural sources of fine sediment, but the extensive study of basin response to similar levels and types of land-use elsewhere suggests that channel disturbance has been heightened by human activities upstream. Impact sources are dominantly not isolated to this particular reach, and are more cumulative in nature.

Category 1 Impacts

There are no isolated, point-source impacts in this reach except for the following:

1) Two short areas of extensively eroding banks due to cattle trampling, shrub layer removal and past land clearing and exacerbated by upstream problems.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are related to land-use in the headwaters. They have manifested themselves here as follows:

1) Extensive channel disturbance (aggradation) due to rapid changes in upstream sediment and water budgets. Channel incision has resulted as increasing deposition is leading to bank erosion in this reach. Simplification of habitat is occurring due to in-filling of pools and poor anchoring conditions for LWD. Clay and sand sediment fractions are infiltrating the substrate matrix and smothering gravels and important microhabitat for juvenile (0+) rainbow/steelhead. Areas of good spawning gravels in glides and riffles are compacted.

Prescriptions

Prescription sites are on private land in reach 1, and therefore only conceptual prescriptions are ;presented.

Riparian prescriptions for reach 1 are summarized in appendix F. They relate to slope bank stabilization. This reach is recovering from a long period of land use which at this point has dominantly been removed. However, it continues to respond to upstream disturbance. No impact prescriptions have been established at this point.

Priority and sequence of prescriptions is presented in figure 62. This reach has a high priority for restoration as indicated by the reach prioritization table in appendix H

Aitken Creek Sub-Basin Restoration Plan

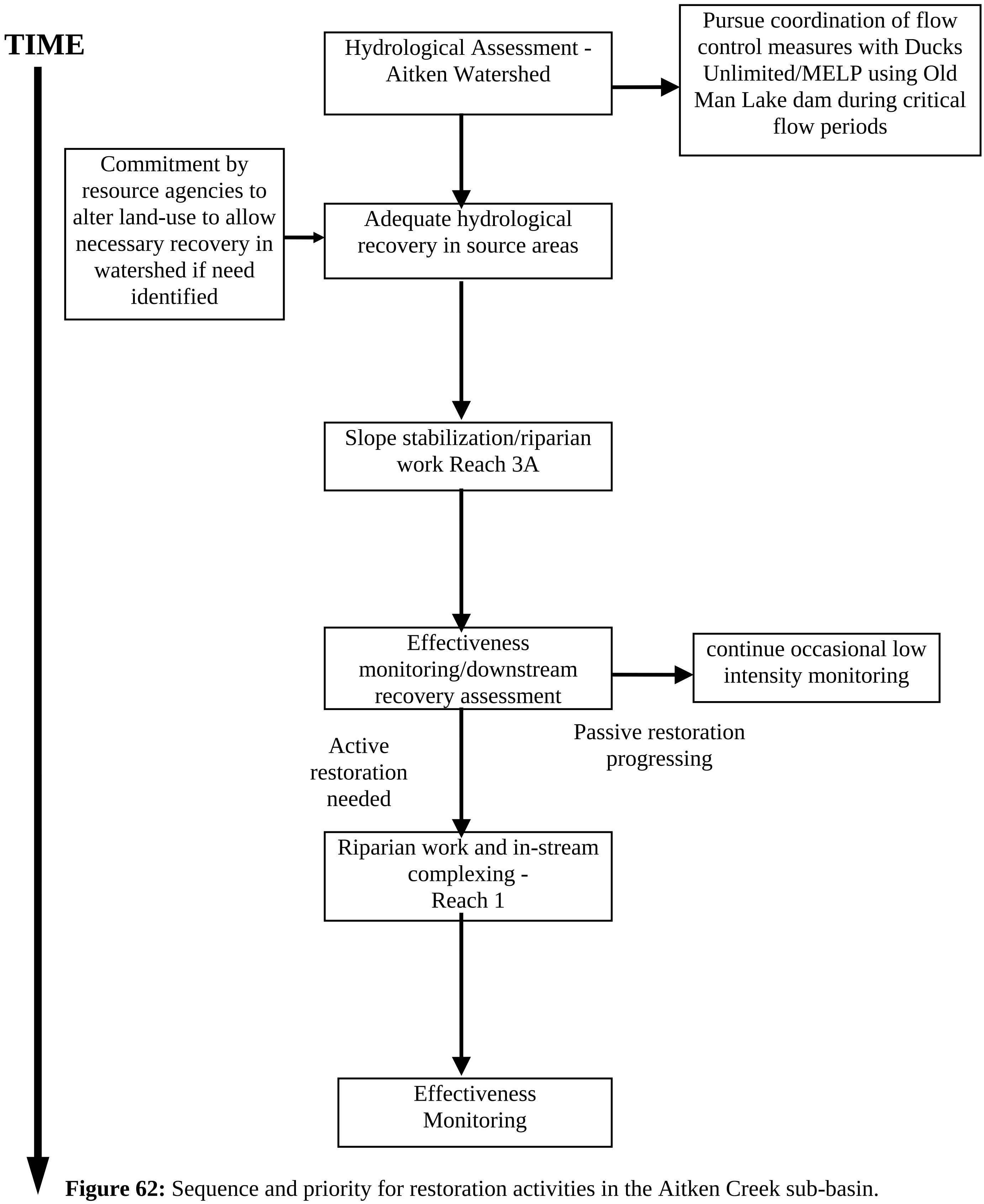

Figure 62: Sequence and priority for restoration activities in the Aitken Creek sub-basin.

4.9 Aitken Creek Reach 3A

Land Uses

Land use in this reach is extensive, and includes large areas of clearcut harvesting on private land, road crossings (bridges), a powerline and natural gas line, grazing land for cattle, two small dams, and water withdrawals. The majority of land-use occurs above 1200 metres upstream. Upstream and upslope land uses include forestry, roads and ranch land, powerline and gas line corridors, and a small dam installed by Ducks Unlimited at the outlet of Old Man Lake. Forest harvesting is evenly distributed around the slopes above Old Man Lake, and in the Heading Creek basin and the basin of an unnamed tributary to Reach 3B. Logging in the floodplain and directly adjacent to it on Aitken Creek is isolated to a complex of clearcuts between 1550 and 4000 metres upstream from the reach break (forest cover map 93L.048, opening #'s 19 (A-07499), 20 (A-08416), and 26 (X-78442)). Opening #19 was logged across the stream and on both sides from 1550 to 2550 metres. An area of forest harvesting directly upslope of the creek was noted at 1226 metres upstream (forest cover map 93L.048, opening #32, A-08444). All of this logging has been done on private land. The Equivalent Clearcut Area of the Aitken sub-basin is 30% (BCCF, 1997). Land-use here and in the headwaters is expected to have altered the runoff regime. The dam at the outlet of Old Man Lake is thought to improve flow conditions significantly in the creek during summer low flow periods.

Riparian Assessment

The riparian area of this reach was divided into 37 polygons occupying a total area of 26.3 hectares with a riparian zone width of 30 metres (see Richfield Creek D). Land-use has modified 51%, or 13.3 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool (SBSdk) with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

The dominant riparian plant community in this reach is predicted as the cottonwood-twinberry ($58) seral association. This is an 08 floodplain site series seral association. Hillside sites are generally spruce-horsetail (07a) or spruce-twinberry-coltsfoot (06). Some of these polygons are seral associations, with species presence and aspect indicating aspen-black twinberry ($57) sites on easterly/northeasterly-facing slopes, and aspen-rose-peavine ($55) sites on westerly-facing slopes. Low-bench floodplain sites occur occasionally with willow and sedges dominant, particularly in beaver modified areas between 1800 and 2800 metres.

- Land-use impacts affecting watershed function, channel morphology, and fish habitat in

Reach Impact and Restoration Diagnostics

Table 26: Summary of habitat quality indicators by habitat unit category for Aitken Creek, reach 3.

Unit Category	Modal Dominant Substrate Size-Class	Modal Sub-dom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean total LWD Tally (Funct./Non-Funct)
Cascade	C	B	H	AR	N	3
Glide	C	G	H	AR	L	5
Other	S	C	H	AR	H	2
Pool	C	G	H	AR	L	6
Riffle	C	C	H	AR	L	2

Unit Category	Mean Small Funct. LWD Tally (10-20cm)	Mean LargeFunct. LWD Tally (20-50cm)	Mean Extra Large Funct. LWD Tally (50+cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Cascade	1	0	0	B,C	1
Glide	1	0	1	L.OV	1
Other	0	1	2	OV,IV	1
Pool	2	3	1	LWD,C	1
Riffle	1	1	0	OV,B	1

Table 27: Reach summary of other indicators of impacts to watershed function and fish habitat for Aitken Creek, reach 3.

Functional pieces of LWD/bankfull width	**0.58**
Pool frequency	**3.32**
Bankfull : wetted width ratio	**1.29**
Bankfull : wetted depth ratio	**1.60**
Area of disturbed riparian forest (ha)	**7.30**
Length of disturbed channel (m)	**886**

Table 28: Mean values for selected parameters which may assist in designing instream restoration works, Aitken Creek, Reach 3.

Unit	Gradient	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est Q (m^3/s)	Trac. Force (kg/m^2)
Glide	1.25	0.59	6.22	16.2	29.04	7.33
riffle	1.31	0.43	7.63	15.33	22.63	5.67
Pool	1.38	0.67	5.52	13.8	33.32	9.23
		Reach Mean Estimated Bankfull Discharge			28.33	

the riparian zone include:

- A complete loss of riparian forest and associated floodplain/riparian functions in areas which have been clearcut across the streambank. Most of these areas are not regenerating significantly due to intense shrub layer competition. There is a significant loss of future LWD recruitment, as most upstream sections of creek are dominantly wetland.
- A complete loss of riparian forest and soil compaction in areas used for ungulate grazing.
- Loss of the shrub/herb layer and associated root system and soil compaction from cattle grazing carried out in areas where the overstory has not been removed or has regenerated to some extent.

Typical riparian polygon photos are found in plates 35-37.

Channel Assessment

Reach 3A is a 4000 metre long RPgw and RPcw channel flowing between the elevations of 740 and 801 metres a.s.l., with an average gradient of 1.4%, bankfull width of 6.18 metres, and bankfull depth of 0.52 metres. It is a low-gradient, depositional, mid-elevation reach whose dominant channel-forming mechanism is LWD. Streambanks are composed of consolidated basal tills (clays within a matrix of gravel/cobble) in many areas (25 of length), interspersed with sections of stratified clay or sand (55% of length), and sections of unconsolidated sand/gravel/cobble alluvium (20% of length). The channel is irregularly meandering with a moderate to low degree of lateral stability (increases with increasing distance downstream from the section break). Upslope areas show variable connectivity to the active channel and confinement is sporadic. The floodplain plays an important role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement. In some areas, hillslope processes act to influence channel morphology through inputs of colluvium and LWD. Some areas of channel are bedrock controlled..

Channel assessment in reach 3 indicated that 22% (886 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2) (see appendix C). Dominant indicators of disturbance include sediment fingers, sediment wedges, extensive bars, and eroding banks. Bankfull:wetted width and bankfull:wetted depth ratios (1.29 and 1.60 respectively) indicate a relatively stable channel relative to benchmark conditions. At this point in the basin, stream energies and erosive power have not increased significantly, although clearly there are indications of a sediment load which is not in equilibrium with forces of sediment transport (i.e.-there is surplus sediment). This is the main vector of downstream disturbance. See plates 33,34 and 36 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 3 can be characterized as moderate value fish habitat with excellent species diversity. Healthy fish habitat, channel and riparian function in this reach acts to maintain high fish value in downstream reaches. Resident rainbow trout (0+/1+/2+/3+), white suckers (0+/1+/2+/adult), longnose suckers (0+/1+/2+/adult), and lake chub (1+) were present at the time of survey. Lake chub were only captured near the end of the section in more sluggish wetland habitat. Other species were present throughout the section.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is an important area for resident fish in an unimpacted state in the context of overall watershed productivity and biodiversity. The reach is particularly important for rearing and spawning of all species present, prior to their migration to Old Man Lake, and lakes upstream of it for adult life.

This reach exhibits only moderately degraded habitat relative to benchmark conditions despite fairly intensive land use. Habitat complexity is in line with benchmark values with a complexity index of 3.88 (see figure 70 and table 1 (page 9)). Pools make up the greatest fraction of habitat units, and there is no significant paucity of any unit type. Compaction was high in all units except “other” (off-channel) units. Spawning gravels were usually low to negligible in abundance, except for off-channel units which had poor flow conditions for spawning. Gravels were suitably sized for resident spawners in all cases. LWD function was somewhat low compared to available (total) LWD in all size classes. Functional LWD frequency over the reach was 0.58 pieces/bankfull width (see figure 69 and table 26). The latter value is 0.8 standard deviations below the benchmark value, and as such is considered a moderate departure from benchmark conditions. Most LWD was found within or in the vicinity of log jams. On average, functional LWD (affecting cover, morphology) was found in all units categories, with the greatest proportion in pool habitat (mostly in the large size class). Pool frequency is 3.32 bankfull widths between pools, less than 1 standard deviation lower (more frequent pools) than the benchmark value of 3.67, indicating excellent pool habitat and LWD function in the reach. Cover elements showed good complexity, with at least one element usually relating to in-stream or cutbank cover. Cover commonly consisted of overhead vegetation combined with boulders in riffles and cascades, cutbanks in glides and cascades, instream vegetation in off-channel areas, and LWD in pools. Canopy closure was 0-20% on average.

Use of habitat by different fish species can be characterized as follows (see figures 64 to 68):

- Glides were used by all four species of fish and showed excellent age-class diversity (12 age-classes). Typically, juvenile to adult fish were captured for all species, with the exception of lake chub and rainbow trout (only 0+/1+/2+). Longnose suckers used glides preferentially, and were found in no other units with the exception of off-

channel areas. Relatively low densities of salmonids were sampled in glides relative to other habitat types.
- Riffles were occupied by rainbow trout and white suckers at the time of survey. Relatively low densities of both species were encountered.
- Rainbow trout, lake chub, and white suckers were present in pools, with a wide range of age classes. Highest densities of 1+, 2+ and 3+ rainbow trout and 0+ white suckers were sampled in pool habitat.
- Other (off-channel) habitat yielded juvenile rainbow trout and longnose suckers in their highest densities of all unit categories. Competition with adult fish was minimal in these units due to shallow water and poorer water quality.

Impact Synopsis

Land-use in this reach has damaged fish habitat quantity and quality. Of particular concern are high compaction/embeddedness of the substrate indicating a significant sediment load, generally low canopy closure, and relatively poor LWD function. Impact sources are dominantly isolated to this particular reach, but are also related to extensive logging in the headwaters and possibly the alteration of streamflow regime by the dam at Old Man Lake. Impacts are both point source and cumulative in nature. High sediment load is expected to be especially related to a very high equivalent clearcut area and a myriad of upslope sediment sources, extensive lateral movement which occurred and is occurring at an unnatural rate due to large-scale removal of riparian forest, and point source inputs from land-use related mass movements. Similarly, poor LWD function is thought to be related to both a diminishing LWD supply and poor lateral channel stability in clearcut areas. The low to negligible canopy closure in this reach, along with poor floodplain function, high ECA, and high sediment load is expected to be having a detrimental effect on downstream fish habitat and channel condition in reach 1. Addressing impacts in this reach is expected to have a much more positive effect on passive restoration in reach 1 than active restoration work there.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Two road crossings where riparian forest has been removed and creek channelized for short distance.
2) Small boulder/cobble dam installed by a landowner at 1650 metres upstream to power a small hydroelectric power generation setup. This dam restricts fish passage at low flows.
3) Two slope failures related to logging/land-clearing at 1220 and 3270 metres upstream (see figure 181, appendix G).

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) Extensive land-clearing and logging in the riparian area leading to unnatural rates and levels of lateral channel movement and sedimentation downstream, and damage to floodplain water and sediment storage functions, as well as future supply of LWD.
2) Extensive land clearing. logging and roads in upslope/upstream areas affecting flow regimes and contributing sediment from a myriad of point sources downstream as cumulative impacts.

Prescriptions

All prescription sites are on private land in reach 3A, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 3 are summarized in appendix F. They relate to slope stabilization, stream shading, future sources of LWD and sediment filtering. The prescription for polygon AIT25 is integrated with impact prescription #1, for AIT25, AIT31-33, and AIT35 with impact prescription #2, andAIT37 is integrated with impact prescription #3.

Three impact prescription site have been identified based on impacts outlined above, and physical and biological goals for mid-elevation reaches presented in section 3 of this report. They relate mitigating upslope sources of sediment (impact prescriptions 1 and 3), and restoring floodplain and riparian functions (impact prescription #2)(see appendix G).

Priority and sequence of prescriptions is presented in figure 71. This reach has a high priority for restoration as indicated by the reach prioritization table in appendix H

Aitken Creek Sub-Basin Restoration Plan

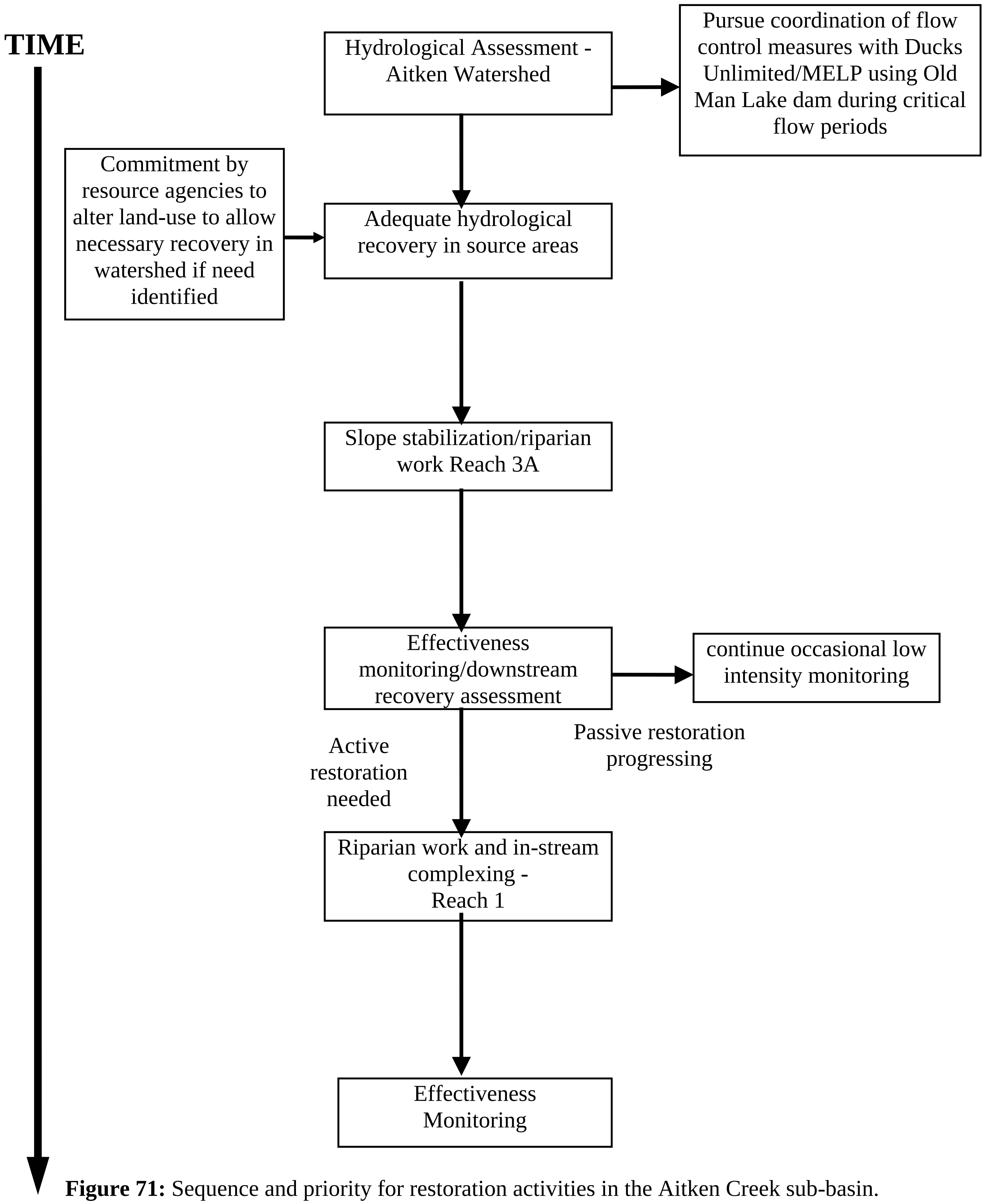

Figure 71: Sequence and priority for restoration activities in the Aitken Creek sub-basin.

4.10 Klo Creek Reach 1

Land Uses

There are no land uses within this reach. Upstream land uses include forest harvesting and forest access roads, the Equity Mine road, and an extensive but now deactivated gravel quarry. A large fire (the Paul Fire) swept through the headwaters in 1961, and large areas of related salvage logging and burn still remain not sufficiently restocked. The Equivalent Clearcut Area of the Klo sub-basin is 38% (BCCF, 1997). Land-use in the headwaters is expected to have altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 14 polygons occupying a total area of 14.7 hectares with a riparian zone width of 30 metres (see Richfield Creek entry, appendix D). Land-use has modified 0%, or 0 hectares of this. The BEC classification for this reach is sub-boreal spruce/moist-cold (Babine variant) (SBSmc2), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

Sites on middle to low bench areas with frequent flooding and erosion and abundant black cottonwood and alder, and an absence of horsetails are predicted as spruce-twinberry-coltsfoot (05) site series. Sites on less well-drained soils with a subsurface layer restrictive to groundwater flow with black cottonwood absent and horsetails and three-leaved foamflower present are predicted as spruce-oak fern (06) sites.

There are no land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone..

Typical riparian polygon photos are found in plates 38-41.

Channel Assessment

Reach 1 is a 2450 metre long RPcw and RPgw channel flowing between the elevations of 903 and 933 metres a.s.l., with an average gradient of 1.15%, bankfull width of 8.5 metres, and bankfull depth of 0.298 metres. It is an alluvial fan reach whose dominant channel-forming mechanism is LWD, although several short confined sections are bedrock controlled. Streambanks are composed of a mix of unconsolidated clay, sand, gravel, and cobble alluvium with some areas of purely clay or purely sand at the top of the reach. Slide faces (which were abundant) showed extensively stratified fine-textured deposits which appeared to be lacustrine in origin. They are thought to have been

Reach Impact and Restoration Diagnostics

Table 29: Summary of habitat quality indicators by habitat unit category for Klo Creek, reach 1.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	G	C	H	AR	L	10
Other	S	Varies	L	AR	N	0
Pool	S	G	H	AR	L	3
Riffle	G	C	H	A	L	11

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	9	1	0	OV	1
Other	0	0	0	C , DP	2
Pool	0	3	0	C, LWD	1
Riffle	8	3	0	None	1

Table 30: Reach summary of other indicators of impacts to watershed function and fish habitat for Klo Creek, reach 1.

Functional pieces of LWD/bankfull width	**0.49**
Pool frequency	**6.91**
Bankfull : wetted width ratio	**2.33**
Bankfull : wetted depth ratio	**2.51**
Average temperature differential at summer low flows (^{O}C)	**1.83**
Area of disturbed riparian forest (ha)	**0.00**
Length of disturbed channel (m)	**2450**

Table 31: Mean values for selected parameters which may assist in designing instream restoration works, Klo Creek, Reach 1.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.17	0.70	9.57	18.33	70.98	8.17
Riffle	1.17	0.55	13.17	14.33	55.75	6.46
Pool	1.17	1.01	5.20	5.00	116.83	11.74
				Reach Mean Estimated Bankfull Discharge	81.19	

deposited at the bottom of Goosly Lake prior to the extent of isostatic rebound present today, or when the water balance of the lake catchment was different than it presently is. The channel is irregularly wandering with a very low degree of lateral stability. The lacustrine soils on the floodplain are highly erodible. Upslope areas are disconnected from the active channel except in short, confined sections. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 1 indicated that 100% (2450 metres) of channel is severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A3) (see appendix C). Dominant indicators of disturbance include sediment wedges, extensive bars, elevated mid-channel bars, abandoned channels, and avulsions. Bankfull:wetted width and bankfull:wetted depth ratios (2.33 and 2.51 respectively) indicate a significant departure of more than 1 standard deviation from benchmark conditions. Sources of channel disturbance are thought to be related to high equivalent clearcut area causing increase in the rate of spring meltwater runoff, and subsequently higher stream energies are causing extensive lateral movement and erosion of lacustrine deposits. The materials entrained in erosive activity are being deposited in the active channel. Some areas of the channel had bankfull widths of more than 30 metres above geomorphic control points (points of sediment storage). Many of these points where large log jams would have been expected are not jammed up, also indicating the increased stream power of spring freshets. Such losses of sediment and bedload storage function are also thought to be increasing levels of downstream aggradation. See plates 38-39 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 1 can be characterized as moderate value fish habitat. Resident rainbow trout (0+/1+/2+/adult), prickly sculpins (1+), coarsescale suckers (0+) and longnose dace (1+) were present at the time of survey. All species were captured throughout the reach. No other survey or sampling was carried out in the reach prior to this project.

This reach, due to its position in the watershed, its gradient, and dominant channel morphology is an important area for resident salmonids in an unimpacted state in the context of overall watershed productivity and diversity of fish. It is one of two ideal areas of higher year-round discharges and suitable substrate for rearing and spawning which are tributary to Goosly Lake.

This reach exhibits degraded habitat relative to benchmark conditions. Habitat complexity is 1.3 standard deviations lower than the benchmark with a complexity index of 3.22, and is less than the average of all reaches surveyed (see figure 76 and table 1 (page 9)). Riffles and glides dominate the spectrum of habitat units, and there are very few “other” (off/channel, beaver dammed) units present which had adequate water levels for sampling or which would function as fish habitat. Compaction was high in all units except “other” units sampled, and surface fine sediments were noted in field observations. As an indication of a high fine sediment load, the dominant substrate size class in pools was fines (sand, clay). Spawning gravels were usually not abundant in typical spawning habitat (pool tailouts, glides, riffles), and in the case of riffles, gravel sizes were unsuitable for resident spawners. LWD function is low in all size classes except large, and functional LWD frequency is 0.49 pieces/bankfull width (see figure 77 and table 30). The latter value is 1.1 standard deviations below the benchmark value, and as such is considered a moderate departure from benchmark conditions. On average, functional LWD (affecting cover, morphology) was found in all units sampled except “other” units, and it was dominantly from the small size class. Pool frequency is 6.91 bankfull widths between pools, which falls within 1 standard deviation of the benchmark value of 3.67. Cover elements showed good complexity except in riffle units (no cover), with moderate in-stream cover. Cover usually consisted of cutbanks, along with deep pool cover in off-channel units, and LWD cover in pools. The only cover in glides was from overhead vegetation. Canopy closure was 0-20% on average due to channel widening. The average temperature differential of 1.83 ^{o}C did not reflect summer low flow temperature problems. Maximum water temperatures (15.5 ^{o}C) did not exceed thermal maxima for any species present at the time of survey (extreme summer temperatures/lowest water levels).

Use of habitat by different fish species can be characterized as follows (see figures 73 to 75):

- Pools were used by all species except coarsescale suckers, and age-class diversity was high (six age classes). This was the only unit category where prickly sculpins and rainbow trout 2+ and adult age classes were encountered, indicating the importance of larger habitat volumes to accommodate the increasing resource requirements of larger salmonids, and areas of lower water velocities preferred by sculpins. Pools also yielded the highest densities of 1+ rainbows.
- Riffles were occupied only by small juvenile fish, although they were present in their highest densities. The lack of cover elements in riffles is thought to be responsible for this distribution, and these fish were noted using substrate as a microhabitat for cover.
- Suckers, dace, and rainbow trout were present in glides, with younger age-classes dominant. Glides were the only unit category where suckers were present in the reach, indicating a critical habitat for these fish.
- Other (off-channel/beaver dam) units that were sampled yielded no fish

Impact Synopsis

Upstream land-use has damaged fish habitat quantity and quality in this reach. Of particular concern are extreme channel disturbance, abundant surface sediments and embedded substrate affecting spawning habitat, loss of log jams at geomorphic control points and their sediment storage function, and a low habitat complexity relative to benchmark conditions indicating habitat simplification by sediment/bedload. These impacts are related to changes in the flow regime and subsequent levels of erosion of lacustrine sediment materials in streambanks and hillslopes in the reach. Impact sources are dominantly secondary in this reach, and passive recovery should ensue if spring flood levels and upstream sediment loads were generally of a lesser magnitude.

Prescriptions

No restoration work is prescribed to this reach at this time, due to the need for further study of the Klo Creek basin and land-use impacts in reach 2. The priority and sequence for restoration in Klo Creek is presented in the restoration plan for the Buck Creek sub-basin (figure 138, page 201).

4.11 Klo Creek Reach 2

Land Uses

Land use in this reach consists of five clearcuts (two in Houston Forest Products tenure on right bank, and three in Northwood's tenure on left bank) which have been harvested to the lip of the valley wall between 400 and 2750 metres upstream. Two roads linking these blocks, one on either side of the valley, are also located close to the edge of the canyon/valley. Upstream land uses include extensive clearcuts and roads on tributaries to Klo Creek in reach 3 (not surveyed), as well as the Equity Mine road, and a large but deactivated quarry in the headwaters. The Equivalent Clearcut Area of the Klo sub-basin is 38% (BCCF, 1997). Land-use in the headwaters and in this reach is expected to have altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 9 polygons occupying a total area of 22.1 hectares with a riparian zone width of 30 metres (see Klo Creek entry, appendix D). Land-use has modified 15%, or 3.4 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

Sites on middle to low bench areas with frequent flooding and erosion and abundant black cottonwood and alder, and an absence of horsetails are predicted as spruce-twinberry-coltsfoot (05) site series. Sites on less well-drained soils with a subsurface layer restrictive to groundwater flow with black cottonwood absent and horsetails and three-leaved foamflower present are predicted as spruce-oak fern (06) sites.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- two instances of unstable slopes caused by abundant windthrow and associated loss of rooting strength in soils due to harvesting of an upslope cutblock (opening#10, 93L.028, FLA 16827-CP314-02) to the lip of the valley wall, and the top of a gully. Several other partial gully failures may be occurring for the same reasons just downstream of these sites.

Typical riparian polygon photos are found in plates 42-44.

Channel Assessment

Reach 2 is a 3780 metre long RPcw channel flowing between the elevations of 933 and

Reach Impact and Restoration Diagnostics

Table 32: Summary of habitat quality indicators by habitat unit category for Klo Creek, reach 2.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	G	H	AR	L	0
Other	G	S	M	R	L	0
Pool	C	B	H	AR	H	4
Riffle	C	G	H	AR	H	1

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	0	0	0	B, OV	1
Other	0	0	0	SWD, B	1
Pool	2	2	0	LWD, B	1
Riffle	1	0	0	B	1

Table 33: Reach summary of other indicators of impacts to watershed function and fish habitat for Klo Creek, reach 2.

Functional pieces of LWD/bankfull width	**0.20**
Pool frequency	**9.27**
Bankfull : wetted width ratio	**2.24**
Bankfull : wetted depth ratio	**2.41**
Average temperature differential at summer low flows (°C)	**4.38**
Area of disturbed riparian forest (ha)	**5.46**
Length of disturbed channel (m)	**2083**

Table 34: Mean values for selected parameters which may assist in designing instream restoration works, Klo Creek, Reach 2.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.50	0.63	12.13	17.33	87.54	9.50
Riffle	1.50	0.55	14.18	27.60	66.74	8.19
Pool	1.00	1.45	16.40	8.00	666.24	14.50
				Reach Mean Estimated Bankfull Discharge	273.51	

984 metres a.s.l., with an average gradient of 1.4%, bankfull width of 13.60 metres, and bankfull depth of 0.65 metres. It is a semi-confined canyon reach with a narrow but active floodplain whose dominant channel-forming mechanisms are both bedrock control and hillslope processes of LWD and colluvium recruitment, and LWD and lateral movement in the floodplain. Streambanks are composed of unconsolidated alluvium (generally gravel/cobble) in floodplain stretches, and colluvial boulders at the toe of bedrock controlled areas. The channel is irregularly wandering with a moderate degree of lateral stability, depending on the degree of confinement. Upslope areas are irregularly connected to the active channel. The floodplain plays an important role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 2 indicated that 55% (2083 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2 to A3) (see appendix C). Dominant indicators of disturbance include extensive bars, extensive riffles, minimal pools, and poor LWD function. Bankfull:wetted width and bankfull:wetted depth ratios (2.24 and 2.21 respectively) indicate an increased bankfull width (1.6 standard deviations) relative to benchmark conditions. Sources of aggradation include erosion of sediment wedges in increased stream power as log jams at key points have been blown out, gully and slope failures due to windthrow at the boundary of the aforementioned cutblock, internal sediment sources as floodplains adjust to changes in channel-forming (bankfull) flood events, and a large natural slide at 3220 metres. The channel was dominantly stable above 3220 metres. See plates 43-45 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 1 can be characterized as moderate value fish habitat. Resident rainbow trout (0+/1+/2+/3+/adult), prickly sculpins (1+/2+), and longnose dace (1+) were present at the time of survey. All species were sampled throughout the reach. No sampling or survey of the reach was done prior to this project, and therefore no historic presence or distribution information was available.

This reach, due to its position in the watershed, its gradient, and dominant channel morphology is an important area for resident salmonids in an unimpacted state in the context of overall watershed productivity and diversity of fish. It is one of two ideal areas of higher year-round discharges and suitable substrate for rearing and spawning which are tributary to Goosly Lake. This lake is known to support a significant population of adult rainbow trout.

This reach exhibits degraded habitat relative to benchmark conditions. Habitat complexity is 1.3 standard deviations of the benchmark with a complexity index of 3.06, and is more than 1 standard deviation below the average of all reaches surveyed (see figure 84 and table 1 (page 9)). Riffles dominate the spectrum of habitat units, and there were very few cascade and other units present. Compaction was high in all units except off-channel units. Spawning gravels were abundant in riffles and pool tailouts, which had suitably sized gravels for resident spawners. LWD function is low to moderate in all size classes, and functional LWD frequency is 0.20 pieces/bankfull width (see figure 83 and table 33). The latter value is within 1 standard deviation of the benchmark value, and as such is considered within the range of natural variability for benchmark conditions. On average, functional LWD (affecting cover, morphology) is only found in pools (small and large wood) and riffles (small wood), and no functional LWD was present in glide and "other" units sampled. Pool frequency is 9.27 bankfull widths between pools, which is 2.2 standard deviations from the benchmark of 6.36, and is 1.18 bankfull widths greater than the survey average for these reach types. Cover elements showed good complexity, with good in-stream cover. Cover usually consisted of boulders, as well as overhead vegetation in glides, small woody debris in off-channel areas, and large woody debris in pools. Canopy closure was 0-20% on average due to aggradation and channel widening. The average temperature differential of 4.38 ^{o}C indicated that topographic shading played a significant role in maintaining lower stream temperatures. Maximum water temperatures (13.5 ^{o}C) did not exceed thermal maxima for any species present at the time of survey (extreme summer temperatures/lowest water levels).

Use of habitat by different fish species can be characterized as follows (see figures 79 to 82):

- Pools were used preferentially by prickly sculpins. Rainbow trout were captured in very low densities relative to other units..
- Riffles exhibited good diversity of age-classes, with highest densities of 2+ and 3+ rainbow trout and 1+ longnose dace relative to other habitat units types.
- Longnose dace and rainbow trout of all age classes used glide habitat in this reach. 0+ and 1+ rainbow trout were sampled in higher relative densities in glide units.
- Other (off-channel) habitat provided rearing habitat for 0+ rainbow trout which exhibited average relative densities.

Impact Synopsis

Land-use in this reach has damaged fish habitat quantity and quality. Of particular concern are the impacts of clearcutting on groundwater flow and valley wall drainage patterns, and the initiation of gully failures from at least one clearcut due to large amounts of windthrow on the gully headwall. Impact sources related to basin runoff regime and upstream sediment inputs warrant a more specific hydrologic and sediment source mapping study to determine the effects of multiple land uses and high ECA on the Klo Creek and Buck Creek watersheds.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Two unstable gullies as indicated in the riparian assessment results. There is the

possibility of more being initiated as valley walls are steep and gullied, and there are several clearcuts which have been harvested to the lip of the valley wall. More windthrow and root decomposition may lead to more instances of this problem.

Category 2 Impacts

Cumulative and non-point source impacts in this reach due to land-use are difficult to separate from possible natural impacts. A bain-wide hydrologic and sediment source mapping study are warranted to determine whether more severe measures should be imposed on land-use development to allow hydrologic recovery and forest regeneration in the Klo Creek watershed prior to restoration being carried out in this reach. This creek is an important headwaters tributary to the high-value and severely impacted Buck Creek. Impacts here have most certainly propagated and will continue to propagate downstream, and interacting with an already poor floodplain and channel condition and the Swiss Fire land-base. Management and restoration here will have more beneficial effects in the short term on the health of the watershed than downstream efforts will.

Prescriptions

All prescription sites are on crown land in reach 2, and therefore full prescriptions are presented.

Riparian prescriptions for reach 3 are summarized in appendix F. They relate to slope stabilization. The prescription for polygons KLO21 and 22 are integrated with impact prescription #1.

One impact prescription site has been identified based on impacts outlined above, and physical and biological goals for headwaters reaches presented in section 3 of this report. It relates to mitigating upslope sources of sediment (impact prescription #1)(see appendix G). The extremely high sediment load, lack of large log jams in the canyon of reach 2, and high percentage of cleared land in the basin indicates the possibility of cumulative impacts on basin hydrology. An important step prior to restoration is to determine the effects of land clearing on basin hydrology, and channel stability upstream of the study area.

Priority and sequence of prescriptions in the Buck Creek sub-basin is presented in figure 138, page 201. This reach has a very high priority for restoration as indicated by the reach prioritization table in appendix H

4.12 Dungate Creek Reach 1

Land Uses

Land use in Dungate Creek, proceeding from the mouth, includes cattle and horse grazing on extensively cleared land (0-350 metres on both banks, to 600 metres on the right bank), a homestead at 300 metres, a road crossing and bridge at 360 metres, and continued grazing in the floodplain and upland forest from 600 metres to the reach break on the right side of the creek. Water withdrawals were being made from the creek at approximately 300 metres. Upstream land uses include forestry and forest access roads including a bridge over the creek at the Dungate FSR, the Equity Mine Road, cattle grazing and land clearing. The Equivalent Clearcut Area of the Dungate sub-basin is 16% (BCCF, 1997). Land-use in the headwaters is not expected to have altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 9 polygons occupying a total area of 8.55 hectares with a riparian zone width of 20 metres (see Dungate Creek entry, appendix D). Land-use has modified 43%, or 3.6 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

On the alluvial fan of Dungate Creek, the dominant plant community is predicted to be the black cottonwood-dogwood ($59) seral association with areas of cottonwood-twinberry ($58) on higher-bench areas with less frequent overbank flooding. These are 08 floodplain site series seral associations. Low-bench sites in the first 250 metres are likely pacific willow-mountain alder-lady fern (TEM code=ML) in regularly flooded sidechannels of Buck Creek, and other initial vegetation and shrub communities.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest, and soil compaction in areas used for grazing. Various seral stages are present in different areas with such impacts.
- Loss of the shrub/herb layer and associated root system and soil compaction from grazing carried out in areas where the overstory still exists
- Past harvesting of spruce and cottonwood by the private landowner preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (white clover, Canada thistle), and the removal of LWD from the floodplain and channel, which controls lateral channel movement and plant community distribution on the floodplain.

Reach Impact and Restoration Diagnostics

Table 35: Summary of habitat quality indicators by habitat unit category for Dungate Creek, reach 1.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Cascade	C	G	H	A	L	0
Glide	C	G	H	AR	L	1
Other	S	Varies	M	AR	L	2
Pool	G	S	M	AR	L	2
Riffle	C	G	M	AR	L	0

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Cascade	0	0	0	C, OV	3
Glide	1	0	0	OV	2
Other	2	0	0	OV	1
Pool	2	0	0	SWD	1
Riffle	0	0	0	OV, B	1

Table 36: Reach summary of other indicators of impacts to watershed function and fish habitat for Dungate Creek, reach 1.

Functional pieces of LWD/bankfull width	**0.22**
Pool frequency	**9.26**
Bankfull : wetted width ratio	**1.69**
Bankfull : wetted depth ratio	**2.42**
Average temperature differential at summer low flows (^{O}C)	**2.5**
Area of disturbed riparian forest (ha)	**2.42**
Length of disturbed channel (m)	**250**

Table 37: Mean values for selected parameters which may assist in designing instream restoration works, Dungate Creek, Reach 1.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.33	0.51	4.83	21.67	18.17	6.76
Riffle	1.38	0.41	5.40	19.50	14.60	5.60
Pool	1.25	0.60	4.75	11.00	27.32	7.50
				Reach Mean Estimated Bankfull Discharge	20.03	

Typical riparian polygon photos are found in plates 46-52.

Channel Assessment

Reach 1 is a 900 metre long RPgw and RPcw channel flowing between the elevations of 638 and 664 metres a.s.l., with an average gradient of 1.3%, bankfull width of 4.63 metres, and bankfull depth of 0.49 metres. It is an alluvial fan reach whose dominant channel-forming mechanism is LWD. Streambanks are composed of an unconsolidated mix of clay, sand, gravel, and cobble alluvium. The channel is regularly meandering with a moderate degree of lateral stability. Upslope areas are disconnected from the active channel except at the end of the reach where steep valley walls begin to confine the creek. The floodplain plays an important role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 1 indicated that 28% (250 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2-A3) (see appendix C). Dominant indicators of disturbance include sediment wedges, extensive bars, elevated mid-channel bars, multiple channels, and eroding banks. Bankfull:wetted width and bankfull:wetted depth ratios (1.69 and 2.42 respectively) indicate a similarity to benchmark conditions. Sources of aggradation in the first 250 metres are related to the channel moving through an area which it did not previously run. The bottom 250 metres is a new channel which was likely formed due an avulsion across the floodplain between the creek's original channel (which was noted at 220 metres upstream, and previously flowed south before it entered Buck Creek) and Buck Creek.. In other words, the channel now flows west in a straighter path to reach its confluence. The 250 metres of moderately to severely disturbed channel pertains to this section. Within it, the creek is highly braided without a distinct channel thread. This may be due to weakened banks in the floodplain due to ungulate grazing, possible channel diversion at the top of the reach, or an increased sediment load due to upstream land-use, or a combination of the above. See plates 46-49 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 1 can be characterized as high value fish habitat. Chinook and coho salmon, and resident bull trout were present at the time of survey. Rainbow/steelhead trout were also present. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout due to a lack of barriers upstream from the mainstem (Tredger, 1984). Coho were only captured at the bottom of the reach in a large off-channel pond. All other species were caught throughout, although an impassable falls exists at 1440 metres upstream at the end of Reach 2A. Juvenile Dolly Varden also have a documented presence in the reach (Tredger, 1984). It may be quite possible that these were juvenile bull trout since they were sampled prior to their classification as a separate char species, and also due to an absence of Dolly Varden in surveyed reaches of the Mid-Bulkley watershed.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is an important area for spawning and rearing in an unimpacted state in the context of overall watershed productivity and diversity of fish. It represents a smaller, cooler, and swifter creek which is immediately accessible to Buck Creek and the Bulkley River, with a greater degree of channel stability. The alluvial fans of tributaries to the upper Bulkley River, as discussed in part 3 of this report, ideally provide areas of swifter current and larger substrate, diverse invertebrate communities, complex channel morphology and cooler water temperatures relative to the mainstem. As a tributary to Buck Creek, it is important for summer rearing and summer and fall spawning habitat. Its proximity to the Bulkley provides access to overwintering habitat, mainstem rearing areas for older juvenile salmonids, and a choice of habitat refugia in either the mainstem or tributary during high water events. Its use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits degraded habitat relative to benchmark conditions. Habitat complexity is 1 standard deviation of the benchmark with a complexity index of 3.84 (higher complexity), and is 0.5 greater than the average of all reaches surveyed (see figures91 and table 1 (page 9)). Riffles dominate the spectrum of habitat units, and there are much fewer pools units present. The appearance of regular cascades higher in the reach adds an element of habitat complexity. Compaction was high in cascade and glide units and moderate in riffles, pools and “others”. Spawning gravels were low in abundance in all unit categories, although gravels which were present were suitable for both resident and anadromous species. LWD function is low in the large size class, with the exception of small wood which shows excellent function in Reach 1 (likely due to section of multiple channels and little mature forest), and extra large, which shows average function and moderate presence. Functional LWD frequency is 0.22 pieces/bankfull width (see figure 92 and table 36). The latter value is 2.1 standard deviations below the benchmark value, and as such LWD frequency is considered to be responding to land-use impacts. On average, functional LWD (affecting cover, morphology) is found in glides, pools, and off-channel units in low quantities. In these cases, small wood was the only size class functioning. On average, no functional LWD was present in cascades and riffles. Pool frequency is 9.26 bankfull widths between pools, which is 1.5 standard deviations from the benchmark of 3.67, and is 1.08 bankfull widths greater than the survey average. Cover elements showed low complexity, expect in cascades and riffles, with some in-stream cover elements. Cover usually consisted of overhead vegetation. with cutbanks in cascades, small woody debris (only) in pools, and boulder cover in riffles. Canopy closure was 20-40% on average, although the quality of forest cover and associated microclimate was much lower in the bottom 250 metres of creek. The average temperature differential was 2.5 ^{o}C, with maximum water temperatures (14 ^{o}C) not exceeding thermal maxima for any species present at the time of survey (extreme summer temperatures/lowest water levels).

Use of habitat by different fish species can be characterized as follows (see figures 86 to 90):

- Pools were used by three age classes of rainbow/steelhead trout (0+ to 2+) and by adult bull trout (only present in one pool sampled). This was the only habitat category where bull trout were captured. As such, pools are considered highly important for this rare blue-listed species. Highest relative densities of 1+ rainbow/steelhead were sampled in pools, indicating their importance for rearing to this age class.
- Riffles were occupied only by rainbow/steelhead trout in the riffle units sampled. Fairly high densities of 0+ fish were caught from within substrate microhabitat.
- Glides yielded the highest densities of 0+ rainbow/steelhead, and the only instances of 3+ (likely resident) fish (although only in low (0.2 fish/m^3) densities). Again, secretive juveniles were captured from within the substrate matrix, and compaction/embedding of this microhabitat could be detrimental to 0+ rainbow/steelhead.
- Cascades yielded very high densities (5.6 fish/m^3) of 2+ rainbow/steelhead. The use of such swiftwater habitats by older juveniles underlines the importance of habitat/hydraulic complexity in short alluvial reaches such as this an easily accessible range of habitats.
- Other (off-channel) habitat yielded low densities of coho and chinook salmon, and highest densities of 0+ rainbow/steelhead. This was the only unit category where salmon species were captured in reach 1.

Impact Synopsis

Land-use in this reach has damaged fish habitat quantity and quality, but not severely. Of particular concern is the bottom 250 metres section of multiple channels and low vegetative cover which has been occupied by the creek after avulsing across the Buck Creek floodplain area. Although naturally an area of frequent lateral movement (typical of alluvial fans), the loss of sinuosity and bank stability, and upstream channel widening is probably related to land-use impacts. Also, low pool frequency and LWD function above this area indicate possible cumulative channel impacts related to upstream land-use. Sources of upstream impact are likely exposed soils at the Dungate FSR crossing, surface runoff and erosion of the Equity Mine Road fill slope where it falls within the riparian zone, and/or slope instability at cutblock boundaries at the top of the downstream left valley wall in Reach 2B (see Mackay, 1997). Impact sources are dominantly isolated to this particular reach, but may be cumulative in nature considering potential upstream sediment impacts.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) An avulsion across the Buck Creek floodplain, as outlined above.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) Sedimentation from upstream sediment sources related to the Equity Mine Road, possible mass movements in logged areas on the north and south slopes (as indicated in BCCF, 1997), and surface erosion of exposed mineral soils at the Dungate FSR crossing.

Prescriptions

Prescription sites are on private land in reach 1, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 1 are summarized in appendix F. They relate to bank stabilization, and will have collateral effects of stream shading, and future sources of LWD.

The impact prescription for reach 1 integrates a series of restoration prescriptions in riparian polygons in the first 250 metres of Dungate Creek. It is assumed, due to the low level of channel disturbance and land-use impacts upstream, that riparian prescriptions will do much more to restore the function of the Dungate Creek alluvial fan than to actively manipulate the channel. This area of the creek, where it's floodplain intersect the Buck Creek floodplain is and has been, highly active. It is thought that any actions to alter the channel will either be met with failure, or will do more damage than good. Riparian prescriptions will allow the channel-floodplain interaction to heal itself over time by mitigating land-use and actively restoring healthy riparian forest plant communities.

Priority and sequence of prescriptions in the Buck Creek sub-basin are presented in figure 138, page 201. This reach has a high priority for restoration as indicated by the reach prioritization table in appendix H

4.13 Dungate Creek Reach 2A

Land Uses

Land use in this reach consists of cattle grazing in upslope and floodplain areas, and upslope forest harvesting (1 cutblock, forest cover map 93L.037, opening #13, A-08417). Upstream land uses include forestry and forest access roads including a bridge over the creek at the Dungate FSR, the Equity Mine Road, cattle grazing and land clearing. The Equivalent Clearcut Area of the Dungate sub-basin is 16% (BCCF, 1997). Land-use in the headwaters is not expected to have altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 2 polygons occupying a total area of 3.24 hectares with a riparian zone width of 20 metres (see Richfield Creek entry, appendix D). Land-use has modified 100%, or 3.24 hectares of this. Modification is minimal, however, with low intensity grazing of the understory shrub/herb layer by cattle. The BEC classification for this reach is sub-boreal spruce/dry-cool, with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

Due to a long history of ranching and homesteading in the watershed, most of the riparian forest in this confined reach is altered 06 (spruce-twinberry-coltsfoot) or 07a (spruce-horsetail) site series in polygons without, or with minimal floodplain. Much of the hillslope area (northerly or southerly aspects) in this reach has either been logged, and/or cleared to improve cattle forage in the understory. These sites are dominantly deciduous seral associations, with aspen-rose-peavine ($55) and aspen-twinberry ($57) sites. Floodplain (08) sites are subject to regular disturbance in unconfined sections, and are predicted as $58 (black cottonwood-dogwood) seral associations.

Riparian land-use present in reach 2A has not impacted affecting watershed function, channel morphology, or fish habitat:

Channel Assessment

Reach 2A is a 540 metre long RPcw channel flowing between the elevations of 664 and 680 metres a.s.l., with an average gradient of 2%, bankfull width of 4.6 metres, and bankfull depth of 0.57 metres. It is a confined, intermediate canyon reach whose dominant channel-forming mechanism is bedrock. Streambanks are composed of mixed, consolidated alluvium (clay/gravel/cobble). The channel is straight to sinuous with a high degree of lateral stability. Upslope areas are highly connected the active channel. The floodplain plays a minor role in an unmodified state in channel morphology, and

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Table 38: Summary of habitat quality indicators by habitat unit category for Dungate Creek, reach 2.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	B	H	AR	N	2
Cascade	B	C	H	AR	N	0
Pool	G	C	H	AR	L	1

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	1	1	0	B, LWD	3
Cascade	0	0	0	B, OV	3
Pool	1	0	0	LWD, OV	2

Table 39: Reach summary of other indicators of impacts to watershed function and fish habitat for Dungate Creek, reach 2.

Functional pieces of LWD/bankfull width	**0.22**
Pool frequency	**9.10**
Bankfull : wetted width ratio	**1.96**
Bankfull : wetted depth ratio	**2.54**
Average temperature differential at summer low flows (^{O}C)	**2.50**
Area of disturbed riparian forest (ha)	**3.20**
Length of disturbed channel (m)	**0**

Table 40: Mean values for selected parameters which may assist in designing instream restoration works, Dungate Creek, Reach 2.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.50	0.66	3.40	28.00	20.00	9.90
Pool	1.50	0.43	4.50	26.00	16.58	6.45
				Reach Mean Estimated Bankfull Discharge	18.29	

maintaining fish habitat, and riparian plant communities. This function is provided by upslope LWD recruitment (mass movements, blowdown), colluvium, and bedrock controlled areas.

Channel assessment in reach 2A indicated that 0% (0 metres) of channel is moderately to severely disturbed. The dominant indicator of disturbance is sediment wedges. Bankfull:wetted width and bankfull:wetted depth ratios (1.96 and 2.54 respectively) indicate a symmetry with benchmark conditions. The appearance of frequent sediment wedges in a higher-energy reach such as this one, particularly during the spring freshet, points to sediment sources upstream. Sediment inputs should approximate sediment outputs in this type of transportational intermediate channel.

Fish and Fish Habitat Assessment

Reach 2A can be characterized as high value fish habitat. Chinook salmon, and rainbow/steelhead trout were present at the time of survey. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout due to a lack of barriers upstream from the mainstem (Tredger, 1984). Both species were found throughout the reach up to the impassable falls at 1450 metres upstream from the mouth (UTM 9.6026460.655640). It is also expected that bull trout are present in the reach, as they were captured in reach 1 and habitat indicators (water velocities, substrate size) show good potential for this species.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is an important area for juvenile anadromous and adfluvial species summer rearing and adult residence in an unimpacted state in the context of overall watershed productivity and diversity of fish. Spawning may take place in isolated areas of good gravels and flow. The reach provides dominantly larger substrate and higher water velocities and a more stable channel, as well as an area of less intense land use, than many alluvial fan reaches in the watershed. Its use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits minimally impacted habitat relative to benchmark conditions (see figure 97 and table 1 (page 9)). Habitat complexity is greater than the benchmark with a complexity index of 3.97, and shows the most greatest richness and diversity of habitats of any reach surveyed in the watershed. Riffles dominate the spectrum of habitat units, and there are relatively fewer pool units present than lower gradient reaches. Cascades and small off-channel units are relatively more frequent, contributing to habitat complexity. Compaction was high in all unit categories. Spawning gravels were usually absent except in pool tailouts, which had suitable gravels for both resident and anadromous salmonid spawners. LWD function is low in the large size class and frequent in other size classes. This is considered typical for more confined, stable, higher energy reaches. Functional LWD frequency is 0.17 pieces/bankfull width (see figure 95 and table 39). The latter value is equal to the benchmark value, and as such is considered in line with benchmark conditions. On average, functional LWD (affecting cover, morphology) is only found in pools and glides, and no functional LWD was present in any of the cascade units sampled. Pool frequency is 9.10 bankfull widths between pools, 2 standard deviations from the benchmark of 6.36. Cover elements showed good complexity, with abundant in-stream cover. Cover usually consisted of boulders and overhead vegetation, with LWD cover in pools and glides. Canopy closure was 40-60% on average due to good forest cover, a narrow channel and steep valley walls. The average temperature differential of 2.5 ^oC reflected this, with maximum water temperatures (14 ^oC) not exceeding thermal maxima for any species present at the time of survey (extreme summer temperatures/lowest water levels).

Use of habitat by different fish species can be characterized as follows (see figures 93 to 96):

- Pools were occupied by rearing chinook salmon (0+) and rainbow/steelhead trout (0+/1+). This was the only unit category where chinook were captured and thus represent a critical rearing habitat in this reach. Only moderate densities of rainbow/steelhead were captured, likely due to competition with larger and more territorial chinook juveniles for space/resources.
- Riffles were not sampled in this reach
- Three age classes (0+ to 2+) of rainbow/steelhead were present in glides. This was the only unit category where 2+ fish were caught, indicating their importance to this age class. Highest densities 0+ fish were also caught from within substrate microhabitat on the margins of glides.
- Cascades were occupied by only 1+ rainbow/steelhead, but in high densities. As such, cascades represent an important habitat to this life-stage/age-class.

Impact Synopsis

Land-use in this reach has not damaged fish habitat quantity and quality. Upstream land use may be causing chronic downstream transport of fine sediments which are manifesting themselves as sediment wedges, bed compaction and pool in-filling. Such sources are likely related to exposed soils at the Dungate FSR crossing, surface runoff and erosion of the Equity Mine Road fill slope where it falls within the riparian zone, and/or slope instability at cutblock boundaries at the top of the downstream left valley wall in Reach 2B (see BCCF, 1997). There are no direct or cumulative impacts in this reach, aside from natural mass movement and erosion of valley walls and exposed bedrock.

There is no restoration prescribed at this time for reach 2.

4.14 Buck Creek Reach 1

Land Uses

Land use in Reach 1 has modified the entire reach in one way or another. This reach runs directly through the center of Houston, British Columbia. Proceeding upstream from the mouth, there is no land-use up to 226 metres, at which point a park occupies the right bank riparian zone. All vegetation has been removed to the streambank. This extends to 629 metres. At 434 metres on this bank, the streambank has been rip-rapped for bank protection and it continues up to the reach break (2833 metres). On the left bank, a dirt access road is eroding quite severely into the creek at 650 metres on the left bank. Above this area, the riparian forest has mostly been removed for the town proper, and any vegetation present is growing directly out of, or on top of rip-rap. At 700 metres upstream, rip-rap to greater than bankfull height is at its downstream extent on the left bank. Here the creek is channelized on both sides and becomes very confined up to 1668 metres. A railway bridge and highway bridge cross the creek at 920 and 980 metres, respectively. At 1668 metres, land-use ceases on the left bank. On the right bank between 1900 and 2700 metres, a large number of private residences occur in the riparian zone. Land use upstream of this reach includes cattle ranching, forestry and forest access roads, powerline corridors, mining (placer mining on Bob Creek, open pit mining at the Equity Silver Mine -both operations are at least temporarily defunct), Buck Flats road and various bridges at which it and its secondary roads cross the creek, and residences in the Buck Flats area. Historic land-use includes a concrete factory at the mouth of Dungate Creek. The Equivalent Clearcut Area of the Buck sub-basin is 22% (BCCF, 1997). Land-use in the headwaters is expected to have altered the runoff regime both due to extensive land clearing, and large areas of compacted and altered floodplain.

Riparian Assessment

The riparian area of this reach was divided into 18 polygons occupying a total area of 23.2 hectares with a riparian zone width of 30 metres (see Buck Creek entry, appendix D). Land-use has modified 100%, or 23.2 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool, with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

On the alluvial fan of Buck Creek, the dominant plant community is predicted to be the cottonwood-twinberry ($58) seral association with areas of black cottonwood-dogwood ($59) on mid-bench areas with less frequent overbank flooding. These are 08 floodplain site series seral associations. It may be possible that prior to agricultural land development that pacific willow-mountain alder-lady fern (TEM code=ML) communities often existed in low-bench regularly flooded sidechannels of the Bulkley or Buck Creek but these seem to be mostly absent due to either decreased overbank disturbance, or

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Table 41: Summary of habitat quality indicators by habitat unit category for Buck Creek, reach 1.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount
Glide	C	G	H	AR	H
Pool	S	G	L	AR	H
Riffle	C	B	M	AR	L

Unit Category	Mean Total LWD Tally (Funct./Non-Funct.)	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	1	1	0	0	1, 7	1
Pool	7	1	1	0	3, 4	1
Riffle	3	2	0	0	4, 7	1

Table 42: Reach summary of other indicators of impacts to watershed function and fish habitat for Buck Creek, reach 1.

Functional pieces of LWD/bankfull width	**0.39**
Pool frequency	**9.57**
Bankfull : wetted width ratio	**2.50**
Bankfull : wetted depth ratio	**2.74**
Average temperature differential at summer low flows (^{O}C)	**3.57**
Area of disturbed riparian forest (ha)	**23.2**
Length of disturbed channel (m)	**2833**

Table 43: Mean values for selected parameters which may assist in designing instream restoration works, Buck Creek, Reach 1.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.13	0.61	19.10	23.50	92.77	6.81
Riffle	1.13	0.75	11.75	20.50	79.12	8.38
Pool	1.00	1.39	25.40	12.00	982.06	13.90
				Reach Mean Estimated Bankfull Discharge	384.65	

being filled in for hayland, or both. Above 1650 metres, the reach is confined on the right bank by valley walls of morainal materials with an easterly aspect. The presence of *Populus tremuloides* (trembling aspen) and cottonwood on 0-20% slopes indicates a spruce-horsetail (07a) site. This area is a seral association, and is predicted as aspen-twinberry ($57) based on species presence and aspect.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest and soil compaction in areas used for homes, parkland, buildings, and streets
- Removal of riparian forest and disconnection of the channel from the riparian zone due to channelizing in transportation corridors and at housing developments on the floodplain.
- Insidious impacts on riparian plant communities such as the introduction of invader species (white clover, Canada thistle), the modification of floodplain and channel features (diversions, landfilling), and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.
- The simplification of surface drainage patterns and compaction of floodplain soils due to extensive paved areas and storm drain system.
- Drawdown of the floodplain water table for the town water supply during drought periods.

Typical riparian polygon photos are found in plates 56,57 nd 59.

Channel Assessment

Reach 1 is a 2833 metre long RPgw and RPcw channel flowing between the elevations of 580 and 592 metres a.s.l., with an average gradient of 1.1%, bankfull width of 17.4 metres, and bankfull depth of 0.82 metres. It is an alluvial fan reach whose dominant channel-forming mechanism is LWD in a properly functioning state. Streambanks are composed of rip-rap over most of the channel's length, with areas above and below the channelized section composed of unconsolidated alluvial materials (sand/gravel at the mouth and sand/cobble upstream). The channel has a modified unnatural stream geometry which is dominantly straight, with irregular meanders above and below the channelized section. It has a very low degree of lateral stability outside of this section. Upslope areas are disconnected from the active channel except for a short stretch between 1670 and 1850 metres where it is confined by a valley wall on the left bank. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 1 indicated that 100% (2833 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2-A3) (see appendix C). Dominant indicators of disturbance include extensive bars, long riffles, minimal pool frequency and extent, elevated mid-channel bars, and poor LWD function. Bankfull:wetted width and bankfull:wetted depth ratios (2.5 and 2.74, respectively) indicate a significant departure from benchmark conditions. The spatial distribution of aggraded areas is dominantly controlled by the channelized section, which does not allow the channel to equalize in width with an increased sediment load, thus the most aggraded areas lie at the upstream and downstream ends. Sediment sources within the reach would also include areas of extensively eroding banks below the channelized section where the channel is responding to extensive deposition and higher water velocities. The latter is due to a lack of vertical and lateral energy dissipation in this section due to channel straightening and excavation of channel materials. Channel straightening continues downstream of the channelized section, as a large avulsion at the most downstream meander neck has breached the floodplain to the Bulkley River. Although the main channel continues to carry the bulk of the flow, the avulsion channel will likely become the main channel during the next major flood event. See plates 56-59 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 1 can be characterized as high value fish habitat. Coho (0+) and chinook salmon (0+, spawners), and resident bull trout (adult), coarsescale suckers (0+/2+), and longnose dace (0+) were present at the time of survey. Rainbow/steelhead trout (0+/1+/3+) were also caught in this reach. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout (Tredger, 1984). Pink salmon (spawners) also have a documented presence in the reach (BCCF, 1997). Several chinook salmon redds were documented at 310, 340, 373 and 650 metres upstream from the mouth at the time of survey. This section of creek is a depositional area for gravels, and is clearly an important spawning area in the creek, particularly due to poorer upstream spawning habitat condition.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is a critical and productive area for spawning and rearing, particularly for coho salmon, chinook salmon, pink salmon, and steelhead trout in an unimpacted state. Although normally a mainstem spawning and rearing species, this reach may also be an important area for chinook salmon considering the extreme low-gradient nature of the Bulkley River in reaches 2 and 4. The alluvial fans of tributaries to the upper Bulkley River, as discussed in part 3 of this report, ideally provide areas of swifter current and larger substrate, diverse invertebrate communities, complex channel morphology and cooler water temperatures relative to the mainstem. As such they are important for summer rearing and summer and fall spawning habitat. Their proximity to the Bulkley provides access to overwintering habitat, mainstem rearing areas for older juvenile salmonids, and a choice of habitat refugia in either the mainstem or tributary during high water events. Their use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits severely degraded habitat condition relative to benchmark conditions. Habitat complexity is 2.1 standard deviations from the benchmark with a complexity index of 3.02, and is considered responding to land-use impacts (see figure 102 and table 1 (page 9)). Glides dominate the spectrum of habitat units, and there are very few pools and off-channel ("other") units present. Compaction was high in all units except pools, where fines were the dominant substrate. Spawning gravels were usually high with the exception of riffles. All units sampled had suitable spawning substrate for both resident and anadromous spawners. LWD function is very low in all size classes, and functional LWD frequency is 0.39 pieces/bankfull width (see figure 103 and table 42). The latter value is 1.5 standard deviations from the benchmark value, and as such is considered a significant departure from benchmark conditions. On average, functional LWD (affecting cover, morphology) was found in all units sampled, was dominantly small LWD, and no extra large functional LWD was present in any of the units sampled. Pool frequency is 9.57 bankfull widths between pools, 1.6 standard deviations from the benchmark of 3.67. Cover elements showed good complexity, with some in-stream cover. Cover usually consisted of boulders (rip-rap) and LWD (log jams). Canopy closure was 0-20% on average due to loss of riparian forest, and aggradation and channel widening. The average temperature differential of 3.5 ^{o}C was remarkably high considering riparian losses in Buck Creek. Maximum water temperatures (17 ^{o}C) exceeded preferred spawning temperatures for chinook and coho salmon at the time of survey (extreme summer temperatures/lowest water levels), but did not exceed more critical thermal maxima for metabolic stress, migration and lethality.

Use of habitat by different fish species can be characterized as follows (see figures 99 to 101):

- Pools were poorly and atypically utilized in reach 1 compared to all other reaches surveyed in the watershed. Only rainbow/steelhead trout and coarsescale suckers were present, and densities were the lowest of all unit categories sampled for all age classes of both species.. Pools had very poor habitat quality, with smothered substrate and low volume which may be responsible for such poor use.
- Riffles were occupied by the most diverse range of species/age classes of any unit categories in the reach. Chinook and coho salmon and bull trout were only captured in riffles, as were 2+ and 3+ rainbow/steelhead, 1+ longnose dace, and 2+ coarsescale suckers. Highest densities of 0+ and 1+ rainbow/steelhead were sampled in highest densities in this unit type. The poor quality of other habitat, combined with large cobble and boulders added as cover and microhabitat by rip-rap is thought to have increased the utility and use of riffles in this reach.
- Rainbow/steelhead (0+/1+), longnose dace, and coarsescale suckers were present in glides. The fish were dominantly small juveniles due to the use of minimal areas of uncompacted/unembedded substrate for cover and microhabitat at the margins of these units. Glides were the only units sampled in which longnose dace were present.

Impact Synopsis

Land-use in this reach has significantly damaged fish habitat quantity and quality. Of particular concern are the extreme channel disturbance, paucity of LWD except at the bottom of the reach, habitat homogenization due to pool in-filling and excavation of bed paving material from the channelized section of the reach, sedimentation and substrate compaction/embedding, and poor riparian function. Impact sources are both within the reach and related to upstream disturbance.

Category 1 Impacts

There are no isolated point source impacts in this reach which are not integrated with and related to other impacts in the channel and riparian zone.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) Channelizing of the creek on both sides for a 900 metre section through Houston which has lead to extreme channel disturbance (aggradation, bank erosion, avulsions and loss of sinuosity) both up and downstream. The creek has been disconnected from its floodplain, and lateral channel movement and associated off-channel habitat creation has been minimized. Associated fish habitat impacts include homogenization of habitat and pool infilling, loss of LWD function for cover and pool creation/scouring of fine sediments, loss of spawning gravels from a high-value spawning area to downstream areas due to bed degradation, and extremes in water levels leading to poor habitat conditions for larger juvenile and adult salmonids in low flow periods and smaller fish during high flow periods. A loss of off-channel habitat has lead to a potential loss of overwintering habitat, and a definite loss of habitat refugia during high water and high turbidity events. Riparian impacts include a loss of more frequent overbank flooding which interrupts forest succession, and perpetuates the diverse floodplain forest community, loss of stream shading, loss of LWD recruitment to the active channel, and the myriad of other well-documented riparian and floodplain-related functions.
2) Channelizing of the creek on one side (right bank) for nearly the entire reach has perpetuated channel widening and erosion both above and below the double-bank channelizing through downtown Houston. Impacts are similar and related to those above.
3) Many other cumulative impacts on floodplain hydrology related to drainage simplification, floodplain alterations, and water withdrawal which are beyond the scope of this study, but which effect water levels and the rate of delivery of runoff to the channel during rain event and snowmelt periods and thus also effect fish.

Prescriptions

All prescription sites are on private land in reach 1, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 3 are summarized in appendix F. They relate to stream shading, and future sources of LWD. The prescription for polygon BUC4 is integrated with impact prescription #2, and for BUC10-12 with impact prescription #1.

Two impact prescription site have been identified based on impacts outlined above, and physical and biological goals for alluvial reaches presented in section 3 of this report. They relate to increasing bank stabilizing and maintaining channel morphology (impact prescription #2), and increasing the spatial diversity of habitat and energy dissipation in channelized areas (impact prescription #1)(see appendix G).

Priority and sequence of prescriptions for Buck Creek are presented in figure 138, page 201. This reach has moderate priority for restoration as indicated by the reach prioritization table in appendix H

4.15 Buck Creek Reach 2

Land Uses

As in reach 1, land-use is abundant in this reach, mostly due to its proximity to Houston. Moving upstream from the reach break, cottonwood harvesting on private land occupies the left bank from 213 to 300 metres, on the right bank, flood dyking continues from reach 1, from 0 to 193 metres. At 550 to 600 metres, a powerline corridor dissects the creek, and includes a ford. A steep hill on the right is used by recreational vehicles, and surface runoff from this hill is delivering fines to the creek. This is adjacent to a gravel quarry, which runs along the lip of the valley wall on the right up to 1060 metres, where a revegetated gully failure from the quarry margin is present. Land use is minimal between here and 3200 metres with the exception of historic selective spruce logging by landowners in the area. Beyond this, range land extends on the left bank to 4500 metres, and the right bank to 4100 metres. Three cutblocks and associated access roads are located on the bench at the lip of steep valley walls on the right side from 4500 metres to the reach break at 5819 metres. An eroding firebreak has caused a slope failure off the edge of the most downstream cutblock (no history opening number, forest cover map 93L.037) at 4742 metres. Historic land-use includes a concrete factory at the mouth of Dungate Creek. Land use upstream of this reach includes cattle ranching, forestry and forest access roads, powerline corridors, mining (placer mining on Bob Creek, open pit mining at the Equity Silver Mine -both operations are at least temporarily defunct), Buck Flats road and various bridges at which it and its secondary roads cross the creek, and residences in the Buck Flats area. The Equivalent Clearcut Area of the Buck sub-basin is 22% (BCCF, 1997). Land-use in the headwaters is expected to have altered the runoff regime both due to extensive land clearing, and large areas of compacted and altered floodplain.

Riparian Assessment

The riparian area of this reach was divided into 29 polygons occupying a total area of 34.9 hectares with a riparian zone width of 30 metres (see Richfield Creek entry, appendix D). Land-use has modified 43%, or 15.1 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

On the alluvial fan of Buck Creek, the dominant plant community is predicted to be the cottonwood-twinberry ($58) seral association with areas of black cottonwood-dogwood ($59) on mid-bench areas with more frequent overbank flooding. These are 08 floodplain site series seral associations. Low-bench sites above 1700 metres are likely pacific willow-mountain alder-lady fern (TEM code=ML) in regularly flooded sidechannels. Between 865 and 1700 metres, the reach is confined on the both banks by

Reach Impact and Restoration Diagnostics

Table 44: Summary of habitat quality indicators by habitat unit category for Buck Creek, reach 2.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	S	H	R	H	0
Other	S	G	L	AR	L	3
Pool	C	S	M	R	L	1
Riffle	C	G	H	R	L	0

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	0	0	0	OV, SWD	1
Other	3	0	0	C, SWD	4
Pool	0	1	0	DP, SWD	1
Riffle	0	0	0	B, OV	1

Table 45: Reach summary of other indicators of impacts to watershed function and fish habitat for Buck Creek, reach 2.

Functional pieces of LWD/bankfull width	**0.14**
Pool frequency	**7.68**
Bankfull : wetted width ratio	**1.71**
Bankfull : wetted depth ratio	**2.83**
Average temperature differential at summer low flows (^{O}C)	**1.13**
Area of disturbed riparian forest (ha)	**15.1**
Length of disturbed channel (m)	**3113**

Table 46: Mean values for selected parameters which may assist in designing instream restoration works, Buck Creek, Reach 2.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Trac. Force (kg/m2)
Glide	0.83	0.84	18.50	24.00	6.97
Riffle	0.92	0.65	18.83	30.83	5.96
Pool	0.83	1.18	12.15	34.33	9.86
				Reach Mean Estimated Bankfull Discharge	124.50

steep valley walls of morainal materials and bedrock with all aspects and extensive topographic shading. The presence of abundant *Populus tremuloides* (trembling aspen) and 0-40% slopes indicates spruce-horsetail (07a) and/or spruce-twinberry-coltsfoot (06) sites. Some of these sites are deciduous seral associations, and are predicted as aspen-twinberry ($57) and aspen-rose-peavine ($55) based on species presence and aspect.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest and soil compaction in areas used for ungulate grazing/powerline corridor.
- Loss of the shrub/herb layer and associated root system and soil compaction from cattle grazing carried out in areas where the overstory has not been removed or has regenerated to some extent.
- Past harvesting of spruce and cottonwood by landowners preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (white clover, Canada thistle), the possible modification of floodplain and channel features (diversions, landfilling), and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.

Typical riparian polygon photos are found in plates 61-62.

Channel Assessment

Reach 2 is a 5819 metre long RPcw and CPcw channel flowing between the elevations of 592 and 659 metres a.s.l., with an average gradient of 0.85%, bankfull width of 16.13 metres, and bankfull depth of 0.83 metres. It is an alluvial fan reach whose dominant channel-forming mechanism is LWD. Streambanks are composed of unconsolidated alluvium (dominantly sand/gravel/cobble with occurrences of boulders in more confined areas) and short stretches of sporadic bedrock control between 870 and 1700 metres and above 5000 metres. The channel is irregularly wandering with a very low degree of lateral stability except when confined by steep valley walls and bedrock. Upslope areas are disconnected from the active channel except in confined areas outlined above, where hillslope processes dominate. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 2 indicated that 55% (3173 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2-A3) (see appendix C). Dominant indicators of disturbance include extensive bars, extensive riffles, minimal pool frequency and extent, elevated mid-channel bars, eroding banks, and poor LWD function. Bankfull:wetted width and bankfull:wetted depth ratios (1.71 and 2.83 respectively) indicate a greater rate of channel incision but not channel widening. Field observations and disturbance indicators show that channel widening is significant in certain areas of the reach, although degrading and confined sections have smoothed the effect out over the reach. This reach is one of several extremely important and sensitive (to channel disturbance) depositional reaches in the watershed which occur directly above bedrock constrictions and canyons (geomorphic control points). Sediment movement downstream from these reaches is normally inhibited by large log jams at the mouths of and within downstream constrictions. They normally have multiple channels as the creek meanders through easily erodible alluvium and extensive floodplain riparian forests which thrive on the disturbances of lateral movement and erosion. These areas are highly valuable as fish habitat with extensive rearing, overwintering, and spawning habitat within a short distance from each other, similar to valley-bottom alluvial fans. Both internal and upstream sediment sources are propagating downstream in a cumulative fashion, as these alluvial reaches are downcutting and erosion is increasing. This is occurring as spring freshets increase in magnitude in response to basin-wide land clearing and floodplain disturbance. Sediment storage mechanisms such as frequent debris and log jams are lost due to increased water velocities. Therefore, channel disturbance in this reach is likely linked to changes in the runoff regime of the basin combined with increased upstream sediment load.

See plates 60-63 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 2 can be characterized as high value fish habitat. Coho (0+) and chinook (0+) salmon, and resident mountain whitefish (1+), white suckers (2+/adult), and longnose dace (1+) were present at the time of survey. Coho salmon were only caught as far upstream as the first confined canyon section at 820 metres upstream from the reach break. Rainbow/steelhead trout (0+/1+/3+) were also caught in this reach. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout (Tredger, 1984). Pink salmon (spawners) also have a documented presence in the reach (BCCF, 1997). Several chinook salmon redds were documented at 1073, 1808, 2116, 2140, 2490, and 5815 meters upstream from the reach 1/2 break at the time of survey. No chinook spawners were actually observed on the redds.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is a critical and productive area for spawning and rearing, particularly for coho salmon, chinook salmon, pink salmon, and steelhead trout in an unimpacted state. Although normally a mainstem spawning and rearing species, this reach may also be an important area for chinook salmon considering the extreme low-gradient nature of the Bulkley River in reaches 2 and 4. The alluvial fans of tributaries to the upper Bulkley River, as discussed in part 3 of this report, ideally provide areas of swifter current and larger substrate, diverse invertebrate communities, complex channel morphology and cooler water temperatures relative to the mainstem. As such they are important for summer rearing and summer and fall spawning habitat. Their proximity to the Bulkley provides access to overwintering habitat, mainstem rearing areas for older juvenile salmonids, and a choice of habitat refugia in either the mainstem or tributary during high water events. Their use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits degraded habitat relative to benchmark conditions (see figures108 and table 1 (page 9)) . Habitat complexity falls within 1 standard deviation of the benchmark with a complexity index of 3.31. Riffles dominate the spectrum of habitat units, and there are very few pool and wetted off-channel units present. Cascades in confined areas increase the complexity of rearing habitat overall for species which prefer swiftwater rearing. Compaction was high in riffle and glide units, moderate in pools and low in off-channel ("other") units. Spawning gravels were usually low in abundance, with the exception of glides. Riffles, pool tailouts, and glides had suitable gravels for resident spawners. LWD function is extremely low in all size classes, and functional LWD frequency is 0.14 pieces/bankfull width (see figure 109 and table 45). The latter value is 2.4 standard deviations lower (less frequent LWD) than the benchmark value, and as such is considered a significant departure from benchmark conditions. On average, functional LWD (affecting cover, morphology) is only found in off-channel units and in very low amounts in pools, and no extra large functional LWD was present in any of the units sampled. In a degrading canyon section of the reach, non-functional LWD with a >65 cm diameter at breast height (dbh) was noted. Pool frequency is 7.68 bankfull widths between pools, which is 1.1 standard deviations from the benchmark of 3.67. Cover elements showed good complexity, with abundant in-stream cover. Cover usually consisted of small woody debris, combined with overhead vegetation in glides and riffles, cutbanks in off-channel areas, and depth in pools. Canopy closure was 0-20% on average due to channel widening, and riparian forest disturbance. Temperatures at the time of survey do not warrant comparison to the summer low flow period, as air temperatures were significantly lower.

Use of habitat by different fish species can be characterized as follows (see figures 105 to 107):

- Pools were used by five species and seven age classes in total. These included chinook salmon, rainbow/steelhead trout, coarsescale suckers, longnose dace, and white suckers. Units sampled in reach 2 yielded the highest densities of 0+ and 1+ chinook, and was the only habitat used by 2+ white suckers and 3+ coarsescale suckers. Among salmonids, 1+ chinook salmon are somewhat of an anomaly in the watershed, with only 4 individuals sampled throughout all reaches surveyed. Three of these fish were caught in the Bulkley mainstem. The absence of coho salmon in sampled pools probably indicates a competitive exclusion and a paucity of pool habitat in the reach for rearing salmon.
- Riffles yielded high densities of coho salmon, longnose dace, and rainbow/steelhead trout. 0+ and 1+ rainbow/steelhead, 0+ coho, and 2+ longnose dace were found in highest densities of any unit categories sampled. The occurrence of coho in higher densities in riffles than other more commonly occurring habitat is likely due to competitive exclusion by larger rearing salmonid and coarse fish species, rather than a

habitat preference.

- Chinook and coho salmon, longnose dace, rainbow/steelhead, white suckers, and mountain whitefish were present in glides, with a wide spectrum of age classes. Glides had the only occurrences of whitefish, adult white suckers, and 2+ rainbow/steelhead in the units sampled in this reach, indicating their importance as a critical habitat to these species.

Impact Synopsis

Land-use in this reach has damaged fish habitat quantity and quality. Of particular concern are low pool frequency and poor LWD function, a lack of spawning gravels in degrading sections, a loss of log jams in the downstream canyon area, upslope sediment sources, and extensive channel and riparian disturbance. Impact sources are dominantly not isolate to this particular reach, and are cumulative in nature. Several point source impacts do exist, however.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Slope failures from the edge of the quarry at 1060 metres, and from an upslope cutblock at 4740 metres. These are delivering fine sediments and bedload to the active channel.
2) Surface erosion from the powerline crossing on the steep right hand slope at 580 metres is delivering fine sand/silt sediments in runoff.
3) Riparian impacts related to land-clearing, old selective forest harvesting of conifers and cattle grazing. Associated impacts include poor canopy closure, decreased stream shading and a lack of overstory microclimate causing temperature and primary productivity increases in the creek.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) Bank erosion and lateral channel movement at cleared and grazed land is an internal sediment source to the active channel, but is exacerbated by upstream sediment sources propagating downstream, and changes to the runoff regime. Associated effects include habitat homogenization (loss of complexity and pool infilling), poor LWD function due to a loss of bank strength in unconfined sections, and substrate compaction/embedding..

Loss of LWD function, habitat homogenization, substrate compaction/embedding, and degradation of spawning gravels related to increases in the magnitude of spring freshets in confined canyon sections of the reach. Of particular concern is the loss of large log jams at the mouth of and within the lower canyon which acted to store sediment upstream.

Prescriptions

All prescription sites are on private land in reach 1, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 3 are summarized in appendix F. They relate to slope stabilization, bank stabilization, stream shading, future sources of LWD and sediment filtering. The prescription for polygon BUC55 is integrated with impact prescription #2. Two impact prescription site have been identified based on impacts outlined above, and physical and biological goals for alluvial fan reaches presented in section 3 of this report. They relate mitigating upslope sources of sediment (impact prescription 2), and restoring sediment storage functions (impact prescription #1)(see appendix G).

Priority and sequence of prescriptions for the Buck Creek sub-basin is presented in figure 138, page 201. This reach has a moderate priority for restoration as indicated by the reach prioritization table in appendix H.

4.16 Buck Creek Reach 4

Land Uses

There is relatively little human activity in this reach. Land use is confined to low-intensity grazing intermittently on both banks up to the confluence of Bob Creek at 3025 metres upstream from the reach break. It appears that much of the hillside riparian forest has been cleared or burned at some point in the past to encourage understory growth for cattle forage. At the Bob Creek confluence, there is a placer mining claim which appears to presently lie dormant, and an area of cleared land or natural grassland. on the right bank. Beyond this, the Buck Flats road parallels the creek in close proximity on the upper valley wall to the left, dissecting the riparian zone at 3570 metres. An access road to the Bob Creek mining claim and homestead is directly adjacent to the creek on the right bank between 3900 and 4100 metres. The Buck Flats bridge #1 crosses the creek at 4100 metres, and channelizes the creek. The Buck Flats road continues in the riparian zone in the upslope on the right bank between 4600 and 4870 metres upstream. Upstream land uses include cattle ranching, forestry and forest access roads, mining (open pit mining at the Equity Silver Mine -not presently operational), Buck Flats road and various bridges at which it and its secondary roads cross the creek, and residences in the Buck Flats area. The Equivalent Clearcut Area of the Buck sub-basin is 22% (BCCF, 1997). Land-use in the headwaters is expected to have altered the runoff regime both due to extensive land clearing, and large areas of compacted and altered floodplain.

Riparian Assessment

The riparian area of this reach was divided into 29 polygons occupying a total area of 33.4 hectares with a riparian zone width of 30 metres (see Buck Creek entry, appendix D). Land-use has modified 44.6%, or 14.9 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

The dominant riparian plant community in this reach is predicted as the cottonwood-twinberry ($58) seral association with areas of black cottonwood-dogwood ($59) on mid-bench areas with less frequent overbank flooding. These are 08 floodplain site series seral associations. Hillside sites are generally spruce-horsetail (07a) or spruce-twinberry-coltsfoot (06). Some of these polygons are seral associations, with species presence and aspect indicating aspen-black twinberry ($57) sites on easterly/northeasterly-facing slopes, and aspen-rose-peavine ($55) sites on westerly-facing slopes. Low-bench floodplain sites occur occasionally with willow and sedges dominant.

Reach Impact and Restoration Diagnostics

Table 47: Summary of habitat quality indicators by habitat unit category for Buck Creek, reach 4.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	G	H	A	L	1
Other	S	C	L	AR	N	3
Pool	C	G	M	A	L	2
Riffle	C	G	H	A	L	3

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	0	1	0	IV	1
Other	1	2	0	LWD	2
Pool	0	2	0	LWD, SWD	2
Riffle	2	1	0	LWD	2

Table 48: Reach summary of other indicators of impacts to watershed function and fish habitat for Buck Creek, reach 4.

Functional pieces of LWD/bankfull width	**0.59**
Pool frequency	**6.04**
Bankfull : wetted width ratio	**1.84**
Bankfull : wetted depth ratio	**2.48**
Average temperature differential at summer low flows (^{O}C)	**1.94**
Area of disturbed riparian forest (ha)	**14.9**
Length of disturbed channel (m)	**2883**

Table 49: Mean values for selected parameters which may assist in designing instream restoration works, Buck Creek, Reach 4.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.42	0.74	15.93	19.00	120.33	10.48
Riffle	1.45	0.51	16.16	23.00	66.61	7.37
Pool	1.50	1.10	10.90	19.33	158.50	16.50
				Reach Mean Estimated Bankfull Discharge	115.15	

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- some areas of lateral channel movement and bank erosion where riparian forest has been modified and banks compacted by cattle grazing
- loss of riparian vegetation and connection to the active channel at the Buck Flats bridge and in areas upstream and downstream where roads fall directly adjacent to the creek.
- past harvesting of spruce and cottonwood by the private landowners preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (white clover, Canada thistle), the modification of floodplain and channel features (diversions) and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.

Typical riparian polygon photos are found in plates 66,67 and 69.

Channel Assessment

Reach 4 is a 5561 metre long RPcw (with short sections of CPcw and RPgw) channel flowing between the elevations of 740 and 759 metres a.s.l., with an average gradient of 1.42 %, bankfull width of 14.6 metres, and bankfull depth of 0.72 metres. It is a semi-confined depositional reach (similar to reach 2) whose dominant channel-forming mechanisms are LWD and hillslope processes. Streambanks are composed of a mix of consolidated alluvial materials (clay/gravel/cobble) with some areas of alluvial fine materials (clay/sand). The channel is irregularly wandering with a low degree of lateral stability. Upslope areas are sporadically connected to the active channel where it is confined by steep valley walls. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 4 indicated that 52% (2883 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2-A3) (see appendix C). Dominant indicators of disturbance include sediment wedges, extensive bars, extensive riffles, minimal pool frequency/extent, eroding banks and poor LWD function. Bankfull:wetted width and bankfull:wetted depth ratios (1.84 and 2.48 respectively) indicate a similarity with benchmark conditions. Field observations and disturbance indicators show that channel widening is significant in certain areas of the reach, although degrading and confined sections have smoothed the data out over the length of the reach. This reach is one of several extremely important and sensitive (to channel disturbance) depositional reaches in the watershed which occur directly above bedrock constrictions and canyons (geomorphic control points). Sediment movement downstream from these reaches is normally inhibited by large log jams at the mouths of and within downstream constrictions. They often have multiple channels and extensive off-channel areas as the creek meanders through easily erodible alluvium and extensive floodplain riparian forests which thrive on the disturbances of lateral movement and erosion. These areas are highly valuable as fish habitat with extensive rearing, overwintering, and spawning habitat within a short distance from each other, similar to valley-bottom alluvial fans. Both internal and upstream sediment sources are propagating downstream in a cumulative fashion, as these alluvial reaches are downcutting and erosion is increasing. This is occurring as spring freshets increase in magnitude in response to bain-wide land clearing and floodplain disturbance. Sediment storage mechanisms such as frequent debris and log jams are lost due to increased water velocities. Aerial photography from (BCCF, 1997) shows several past log jams sites at the upper end of reach 3 which have been blown out by high spring discharge. Therefore, channel disturbance in this reach is likely linked to changes in the runoff regime of the basin combined with increased upstream sediment load.

See plates 68-70 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 4 can be characterized as high value fish habitat. Chinook salmon (spawners), and resident mountain whitefish (1+/2+), white suckers (0+/1+/2+), and longnose dace (0+/1+/2+) were present at the time of survey. Rainbow/steelhead trout (0+/1+/2+/3+) were also caught in this reach. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout due to a lack of barriers upstream from the mainstem (Tredger, 1984). All species were present throughout the reach. Juvenile and spawning coho salmon also have a documented presence in the reach (BCCF, 1997). Chinook redds were observed at 600, 1580, 2509, 2520, and 3079 metres upstream from the reach break. Holding spawners, spawning pairs, and spent carcasses (a total of 8 individuals) were noted, indicating that the time of survey (August 31st to September 2nd) coincided with peak spawning in the reach.

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is an important area for anadromous spawning and possibly rearing (references are conflicting), and all resident life-stages (with the exception of adult lake rearing) in an unimpacted state in the context of overall watershed productivity and diversity of fish. It has characteristics similar to reach 2 with the exception of proximity to the mainstem Bulkley River. It ideally provides areas of swifter current and larger substrate, diverse invertebrate communities, complex channel morphology and cooler water temperatures relative to the mainstem. As such it is important for summer rearing and summer and fall spawning habitat. Its proximity to the Bulkley provides access to overwintering habitat, mainstem rearing areas for older juvenile salmonids, and a choice of habitat refugia in either the mainstem or tributary during high water events. Its use by salmon species likely depends heavily on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries and reaches, as well as habitat condition.

This reach exhibits marginally degraded habitat relative to benchmark conditions (see figures 116 and table 1 (page 9)). Habitat complexity falls within 1 standard deviation of the benchmark with a complexity index of 3.32. Riffles are proportionately the dominant unit type, but riffles, pools and glides are approximately equal. Compaction was high in glide and riffle units, moderate in pools and low in off-channel units. Spawning gravels were usually low in abundance, and gravels were suitably sized for anadromous species. LWD function is low in the small and extra large size classes, and moderate in the large size class. Functional LWD frequency is 0.59 pieces/bankfull width (see figure 115 and table 48). This value is within 1 standard deviation of the benchmark value, and as such is considered in line with benchmark conditions. On average, functional LWD (affecting cover, morphology) is found in all units, although no extra large functional LWD was present in any of the units sampled. Pool frequency is 6.04 bankfull widths between pools, which is within 1 standard deviation from the benchmark of 3.67. Cover elements showed low complexity, with frequent in-stream cover. Cover usually consisted of LWD except in glides which had instream vegetation for cover, and in pools which also had a cover element of SWD. Canopy closure was 20-40% on average due to the presence of a riparian overstory layer in most riparian polygons. Temperatures at the time of survey do not warrant comparison to the summer low flow period, as maximum daytime air temperatures were significantly lower.

Use of habitat by different fish species can be characterized as follows (see figures 111 to 114):

- Pools were occupied by a diverse range of species/age-classes. Highest densities of 2+ mountain whitefish were present, and the only occurrence of 2+ white suckers was in pools. The most dominant species was mountain whitefish, and the least dominant was juvenile longnose dace. The latter is probably due to predation by larger juveniles of other species present in pools.
- Riffles also showed a wide array of species/age classes. The most dominant species in these units was rainbow/steelhead trout, and the least dominant was mountain whitefish. These were the only units 2+ longnose dace were sampled. Highest densities of 1+ longnose dace and adult rainbow trout were present in riffles.
- Longnose dace and rainbow/steelhead were present in glides, with a breakdown into 5 age classes. Rainbow/steelhead showed higher densities than dace, but densities were moderate for these age classes in comparison to other unit categories.
- Other (off-channel/beaver dammed pool) habitat was occupied by a similar range of age-classes and species to pool habitat with the exception of mountain whitefish. Similar to other reaches surveyed, highest densities of 0+ rainbow trout and 0+ white suckers were present in these units.

Impact Synopsis

Land-use in this reach has not significantly altered fish habitat quantity and quality. Of particular concern is the level and cumulative nature of channel disturbance which may lead to habitat damage with subsequent extreme flood events. Impact sources are dominantly found upstream of this particular reach, and are cumulative in nature.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Several isolated areas of bank erosion throughout the reach.
2) Chronic fine sediment from the Buck Flats road entering the creek via dust, surface runoff, and in the course of road maintenance and snow removal in the area.
3) Placer mining of stream substrate at the mouth of Bob Creek is causing sedimentation and possibly deleterious effects to water quality downstream in spawning habitat.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) Channel aggradation, sedimentation, bank erosion, habitat homogenization and poor LWD function in some disturbed channel polygons which are responding differently than the mean/modal reach characteristics to upstream sediment delivery and higher peak flows.
2) Loss of LWD function, habitat homogenization, substrate compaction/embedding, and degradation of spawning gravels related to increases in the magnitude of spring freshets in confined canyon sections of the reach. These areas occur at the reach 2/3 break, at the confluence of Bob Creek, and just downstream of the reach 4/5 break. Of particular concern is the loss of large log jams at the mouth of and within these sections which acted to store sediment upstream in this reach.

Prescriptions

All prescription sites are on private land in reach 4, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 4 are summarized in appendix F. They relate to bank stabilization, stream shading, and sediment filtering.

One impact prescription site has been identified based on impacts outlined above, and physical and biological goals for mid-elevation reaches presented in section 3 of this report. Impact prescription #1 relates to restoring sediment storage function in the geomorphic notch point at the reach 4/5 break.(impact prescriptions 1 and 3)(see appendix G).

Priority and sequence of prescriptions for the Buck Creek sub-basin is presented in figure 138, page 201. This reach has a high priority for restoration as indicated by the reach prioritization table in appendix H

4.17 Buck Creek Reach 5

Land Uses

Reach 5 of Buck Creek has been used extensively for grazing, forest harvest and homesteading for several decades. Moving upstream from the reach break (situated approximately 1600 metres from Buck Bridge #1), clearcuts or land clearing for agriculture occur immediately and at 250 metres, 800 metres, 2000 metres, 5200 metres and 5600 metres. All of these openings are adjacent to the stream. Over 2 km of both banks are designated open range land. Private properties and residences begin at 300 metres. A skid trail fords Buck Creek at 3290 metres and would be a source of sediment during freshet. This skid trail is now mostly revegetated. The Buck Flats Road runs parallel to the creek throughout the reach in the upslope area and bridges it at approximately 4500m upstream. From the bridge to the reach break there is an increase of land clearing on private property in addition to the road's close proximity to the creek. In some cases the road is only a few metres away from the channel. Upstream land uses include forestry and forest service roads, cattle ranching, Buck Flats road and various bridges at which it and its secondary roads cross the creek, and the residences in the Buck Flats area. The Equivalent Clearcut Area of the Buck sub-basin is 22% (BCCF, 1997). Land-use in the headwaters is expected to have altered the runoff regime both due to extensive land clearing, and large areas of compacted and altered floodplain.

Riparian Assessment

The riparian area of this reach was divided into 76 polygons occupying a total area of 39.3 hectares with a riparian zone width of 30 metres (see Buck Creek entry, appendix D). Land-use has modified 83% or 25 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

The dominant riparian plant community in this reach is predicted as the cottonwood-twinberry ($58) seral association with areas of black cottonwood-dogwood ($59) on mid-bench areas with less frequent overbank flooding. These are 08 floodplain site series seral associations. Hillside sites are generally spruce-horsetail (07a) or spruce-twinberry-coltsfoot (06). Some of these polygons are seral associations, with species presence and aspect indicating aspen-black twinberry ($57) sites on easterly/northeasterly-facing slopes, and aspen-rose-peavine ($55) sites on westerly-facing slopes. Low-bench floodplain sites occur occasionally with willow and sedges dominant.

Reach Impact and Restoration Diagnostics

Table 50: Summary of habitat quality indicators by habitat unit category for Buck Creek, reach 5.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	G	H	AR	L	0
Other	S	G	H	AR	N	2
Pool	S	G	L	AR	L	5
Riffle	C	G	H	A	H	2

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	0	0	0	B	1
Other	2	0	0	OV	1
Pool	2	3	0	LWD, B	1
Riffle	1	1	0	B	1

Table 51: Reach summary of other indicators of impacts to watershed function and fish habitat for Buck Creek, reach 5.

Functional pieces of LWD/bankfull width	**0.39**
Pool frequency	**8.82**
Bankfull : wetted width ratio	**1.72**
Bankfull : wetted depth ratio	**2.83**
Average temperature differential at summer low flows (°C)	**5.13**
Area of disturbed riparian forest (ha)	**25.60**
Length of disturbed channel (m)	**1510**

Table 52: Mean values for selected parameters which may assist in designing instream restoration works, Buck Creek, Reach 5.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.00	0.72	15.03	15.00	90.99	7.20
Riffle	1.13	0.61	14.83	13.83	73.52	6.95
Pool	1.00	0.98	11.70	5.33	249.54	9.83
		Reach Mean Estimated Bankfull Discharge			138.02	

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest and soil compaction in areas used for ungulate grazing.
- Loss of the shrub/herb layer and associated root system and soil compaction from cattle grazing carried out in areas where the overstory has not been removed or has regenerated to some extent.
- Past harvesting of spruce and cottonwood by landowners preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (white clover, Canada thistle), the possible modification of floodplain and channel features (diversions, landfilling), and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.
- Disconnection from the floodplain and the complete loss of riparian vegetation due to the Buck Flats Road.

Typical riparian polygon photos are found in plates 74-76.

Channel Assessment

Reach 5 is a 5900 metre long RPgw and RPcw channel flowing between the elevations of 759 and 805 metres a.s.l., with an average gradient of 1.2%, bankfull width of 14.54 metres, and bankfull depth of 0.82 metres. It is a heavily aggrading, depositional reach whose dominant channel-forming mechanism is LWD. A small amount of beaver activity was present in this reach. Streambanks are composed of unconsolidated alluvium (dominantly fines/sand/gravel) and short degraded stretches of sporadic bedrock control above 3440 metres. The channel is irregularly wandering with a low degree of lateral stability. Upslope areas are disconnected from the active channel except for a few coupled valley walls within the upper half of the reach. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 5 indicated that 32% (1870 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2) (see appendix C). Dominant indicators of disturbance include extensive bars, minimal pool frequency, sediment wedges, eroding banks and lack of functional LWD. Extensive bars were noted throughout the entire reach, except between 2490 and 3580 metres. Minimal pool area occurs above 2490 metres. Sediment wedges occur between 460 and 1840 metres and 3580 and 5440 metres, eroding banks are prevalent throughout the reach except for the two degrading sections between 3440-3580 metres and 5540-5690 metres. There was a lack of functional LWD from 1840 metres upstream to the reach break. Bankfull:wetted width ratios indicate stability and are within 0.4 standard deviations of benchmark conditions. Bankfull:wetted depth ratios

(2.83) indicate a departure relative to benchmark conditions and are within 1.4 standard deviations. These comparisons to benchmark conditions indicate that the channel is incising while the bankful width is not increasing. Field observations and disturbance indicators show that channel widening is significant in certain areas of the reach, although small degrading and confined sections have smoothed the effect out over the reach. This reach is one of several extremely important and sensitive (to channel disturbance) depositional reaches in the watershed which occur directly above bedrock constrictions and canyons (geomorphic control points). Sediment movement downstream from these reaches is normally inhibited by large log jams at the mouths of and within downstream constrictions. They normally have multiple channels as the creek meanders through easily erodible alluvium and extensive floodplain riparian forests which thrive on the disturbances of lateral movement and erosion. These areas are highly valuable as fish habitat with extensive rearing, overwintering, and spawning habitat within a short distance from one another, similar to valley-bottom alluvial fans. Both internal and upstream sediment sources are propagating downstream in a cumulative fashion, as these alluvial reaches are downcutting and erosion is increasing. This is occurring as spring freshets increase in magnitude in response to bain-wide land clearing and floodplain disturbance. Sediment storage and channel widening mechanisms such as frequent debris and log jams are lost due to increased water velocities. Therefore, channel disturbance in this reach is likely linked to changes in the runoff regime of the basin combined with increased upstream sediment load.. See plates 74-78 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 5 can be characterized as high value fish habitat. Spawning chinook were observed at 1840 and 2148 metres. Resident longnose dace (0+/1+/2+), largescale suckers (1+) and mountain whitefish (1+/2+) were present at the time of survey. Rainbow/steelhead trout (0+/1+/2+/3+)were also present in the creek at the time of survey. The 0+ and 1+ age classes are assumed to be dominantly steelhead trout (Tredger, 1984). Steelhead redds have been observed in reach 6 (BCCF, 1997). There were no coho observed in this reach during time of sampling, although coho have been observed upstream of the cascades in reach 3 (BCCF, 1997).

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is a critical and productive area for chinook and rainbow trout/ steelhead and potentially coho in an unimpacted state in the context of overall watershed productivity and diversity of fish. The channel complexing mechanisms of the small canyon sections and the LWD jams that would be present historically would create an abundance of diverse habitats. Off-channel habitat would form as the channel migrates laterally and pools would form in association with log jams. LWD would be distributed downstream and would continue to diversify the habitat. The proximity of this reach to the lower gradient reach 6 and the presence of beaver dams and off-channel units would provide access to excellent rearing, overwintering and refugia habitat for juvenile salmonids.

This reach exhibits degraded habitat relative to benchmark conditions. Habitat complexity falls within 0.8 standard deviations of the benchmark with a complexity index of 3.35, and is near the mean of all reaches surveyed (see figure123 and table 1 (page 9)). Riffles and glides dominate the spectrum of habitat units, and there are very few cascades and other (off-channel) units present. Compaction was high in all units except pools. Spawning gravels in riffles was abundant, but were limited in pools and glides and absent from other units. Gravels suitable for both anadromous and resident salmonid species were present in glides and pools. Due to substrate sorting, riffles contained only larger particles and were thus suitable for anadromous species only. LWD function is low in all size classes, and functional LWD frequency is 0.39 pieces/bankfull width (see figure 122 and table 51). The latter value is below the benchmark value, and as such is considered a deviation from benchmark conditions. On average, functional LWD (affecting cover, morphology) is only found in pools, and no functional LWD was present in glides. No extra large pieces of LWD were present in this reach and large LWD was only observed in pools and riffles. Pool frequency is 8.82 bankfull widths between pools, 1.4 standard deviations from the benchmark of 3.67, and is less frequent than the survey average. Cover elements showed moderate complexity, with moderate in-stream cover. Cover usually consisted of boulder with the addition of LWD in pools. Cover in other, off-channel units consisted of overhanging vegetation. Canopy closure was 0 to 20% on average due to large channel widths and the loss of mature forest due to land clearing and logging. The average temperature differential of 5.13 reflected this, with maximum water temperatures (15 ^{o}C) exceeding thermal maxima for successful Dolley Varden spawning and the preferred rearing temperature for salmonids at the time of survey (moderate summer temperatures/low water levels). Dead mountain whitefish were observed at 125 and 800 metres.

Use of habitat by different fish species can be characterized as follows (see figures 118 to 121):

- Pools showed a high diversity of age-classes and were the only units in which mountain whitefish were captured. 2+ mountain whitefish were captured in the greatest abundance in these units followed by 3+ rainbow trout and 1+ largescale sucker and mountain whitefish.
- Riffles exhibited the highest densities of rainbow trout/ steelhead in this reach. 0+ rainbow trout/ steelhead were the most abundant age-class. 1+ and 2+ rainbow trout/ steelhead and large numbers of longnose dace (1+ and 0+) were also captured in these units.
- Three age-classes (0+ to 2+) of rainbow trout/ steelhead and a high diversity of age-classes for all fish were present in glides. 0+ to 2+ longnose dace and largescale suckers and 2+ and adult white sucker were also captured.
- Other (off-channel) habitat provided the greatest density of longnose dace in this reach. Longnose dace densities in these units was much higher than that of any other species in all other units. 0+ longnose dace were the only fish caught in these units.

Impact Synopsis

Land-use in this reach has damaged fish habitat quantity and quality. Of particular concern are low pool frequency and poor LWD function, a loss of log jams in the small canyon areas, upslope sediment sources, and extensive channel and riparian disturbance. Impact sources are dominantly not isolated to this particular reach, and are cumulative in nature. Several point source impacts do exist, however.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Slope failures at the edges of clearcuts along this channel. These are delivering fine sediments and bedload to the active channel.
2) Surface erosion from the skid trail crossing at 3290 metres and from the Buck Flats Road ditchlines is delivering fine sand/silt sediments in runoff.
3) Riparian impacts related to land-clearing, old selective and clearcut forest harvesting of conifers and cattle grazing. Associated impacts include poor canopy closure, decreased stream shading and a lack of overstory microclimate causing temperature and primary productivity increases in the creek.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) Bank erosion and lateral channel movement at cleared and grazed land is an internal sediment source to the active channel, but is exacerbated by upstream sediment sources propagating downstream, and changes to the runoff regime. Associated effects include habitat homogenization (loss of complexity and pool infilling), poor LWD function due to a loss of bank strength in unconfined sections, and substrate compaction/embedding.
2) Loss of LWD function, habitat homogenization, substrate compaction/embedding, and degradation of spawning gravels related to increases in the magnitude of spring freshets in confined canyon sections of the reach. Of particular concern is the loss of large log jams at the mouth of and within small canyons which acted to store sediment upstream.
3) The alteration of floodplain function by removal of LWD and riparian forest, as well as compaction of floodplain soils leading to a decreased groundwater recharge and water storage capacity, and a disconnection of the floodplain from the channel. The latter includes the formation of off-channel features, the buffering of overbank flood flows by riparian LWD, and an increase in surface erosion during overbank flood events as surface roughness is minimized. Spinoff effects include decreased rearing and overwintering habitat quality and quantity for salmonids (particularly juvenile coho) in off-channel areas, lower summer and winter baseflows and subsequently greater extremes in temperature, and channel impacts (loss of sinuosity, increased sediment load and associated effects on fish habitat).

Prescriptions

All prescription sites are on private land in reach 5, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 5 are summarized in appendix F. They relate to slope stabilization, bank stabilization, stream shading, future sources of LWD and sediment filtering. There are no impact prescriptions aside from riparian prescriptions in Reach 5. Priority and sequence of prescriptions for the Buck Creek sub-basin is presented in figure 134 (page201). This reach has a very high priority for restoration as indicated by the reach prioritization table in appendix H

4.18 Buck Creek Reach 6

Land Uses

This reach of Buck Creek is contained within the area burned by the Swiss Fire in 1983. Salvage logging, ranching and land clearing for private residences and farms have all taken place adjacent to the creek in this reach. Moving upstream from the reach break, a private bridge at 300 metres has channelized the stream and the banks have been rip-rapped. At 360 metres land has been cleared for a home and lawns. Some bank erosion is present on the downstream left bank. Large clay deposits and bank failure related to another lawn were observed at 500 metres. A second private bridge with associated aggradation is located at 1230 metres. At 1340 metres the downstream left bank has been cleared for the Buck Flats road right-of-way. Valley-bottom clearing and a private residence were observed at 1565 metres. Part of the floodplain has been fenced adjacent to Buck Creek at 1742 metres. The third private bridge in this reach is located at 2272 metres with a residence on the downstream right bank. The Buck Flats road parallels the stream at 2893 metres, and many point sources of sediment were observed along the road right-of-way. A hayfield with no riparian buffer was located at 4080 metres. A road-related slide was observed at 6148 metres. A final private residence was located at 7200 metres near the reach break between reaches 6 and 7. Upstream land uses include ranching (range use), forestry (clearcutting and silviculture), road networks and a limited number of residences.. The Equivalent Clearcut Area of the Buck Creek sub-basin is 22% (BCCF, 1997). Land-use in the headwaters is expected to have altered the runoff regime due to the Swiss fire, extensive salvage and clearcut logging, land clearing for agricultural purposes and large areas of compacted and altered floodplain.

Riparian Assessment

The riparian area of this reach was divided into 77 polygons occupying a total area of 46 hectares with a riparian zone width of 30 metres (see Richfield Creek entry, appendix D). Land-use has modified 88%, or 40.6 hectares of this. The BEC classification for this reach is sub-boreal spruce/ dry-cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

The dominant riparian plant community in this reach is predicted as the cottonwood-twinberry ($58) seral association with areas of black cottonwood-dogwood ($59) on mid-bench areas with less frequent overbank flooding. These are 08 floodplain site series seral associations. Hillside sites are generally spruce-horsetail (07a) or spruce-twinberry-coltsfoot (06). Some of these polygons are seral associations, with species presence and aspect indicating aspen-black twinberry ($57) sites on easterly/northeasterly-facing slopes, and aspen-rose-peavine ($55) sites on westerly-facing slopes. Above 4000 metres upstream from the reach break, cottonwood become scarce, and predicted 06 and 07a and

Reach Impact and Restoration Diagnostics

Table 53: Summary of habitat quality indicators by habitat unit category for Buck Creek, reach 6.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Cascade	C	B	H	A	L	2
Glide	C	B	H	A	L	3
Pool	C	S	H	A	L	0
Riffle	C	B	H	AR	L	0

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Cascade	1	1	0	B, OV	1
Glide	1	2	0	B, SWD	1
Pool	0	0	0	B, OV	1
Riffle	0	0	0	B, OV	1

Table 54: Reach summary of other indicators of impacts to watershed function and fish habitat for Buck Creek, reach 6.

Functional pieces of LWD/bankfull width	**0.10**
Pool frequency	**15.73**
Bankfull : wetted width ratio	**1.36**
Bankfull : wetted depth ratio	**4.23**
Average temperature differential at summer low flows (^{O}C)	**2.43**
Area of disturbed riparian forest (ha)	**40.60**
Length of disturbed channel (m)	**1543**

Table 55: Mean values for selected parameters which may assist in designing instream restoration works, Buck Creek, Reach 6.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	0.88	0.66	12.10	20.75	59.05	5.78
Riffle	0.93	0.75	13.97	26.57	86.41	6.94
Pool	1.00	0.65	6.90	14.00	34.24	6.50
				Reach Mean Estimated Bankfull Discharge	59.90	

07b sites become more common. Low-bench floodplain shrub carr sites occur occasionally with willow and sedges dominant.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest and soil compaction in areas used for ungulate grazing and powerline/ road right-of-ways.
- Loss of riparian forest over much of the reach due to the Swiss Fire.
- Loss of the shrub/herb layer and associated root system and soil compaction from cattle grazing carried out in areas where the overstory has not been removed or has regenerated to some extent.
- Past harvesting of spruce and cottonwood by landowners preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (white clover, Canada thistle), the possible modification of floodplain and channel features (diversions, landfilling), and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.

Typical riparian polygon photos are found in plates 83-85.

Channel Assessment

Reach 6 is a 7838 metre long RPcw and RPgw channel flowing between the elevations of 805 and 825 metres a.s.l., with an average gradient of 0.96%, bankfull width of 12.78 metres, and bankfull depth of 0.79 metres. It is a valley bottom, depositional reach whose dominant channel-forming mechanisms are beaver dams and to a lesser extent, LWD. Streambanks are composed of unconsolidated fines (organic, silt, clay), sand, gravels and cobbles. The soil in the valley bottom is likely of lacustrine origin, as stratified clay and organic soils were noted in the bank texture, as well as glacio-fluvial origin, as indicated by an esker on the right side of the channel between 6300 and 6500 metres. The channel is irregularly meandering with a very low degree of lateral stability. Upslope areas are disconnected from the active channel. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 6 indicated that 10.8% (843 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2) and degrading (D2) (see appendix C). Dominant indicators of disturbance include a lack of functional LWD, eroding banks and the presence of sediment wedges. The bankfull:wetted width ratio (1.36) indicates stability relative to benchmark conditions (difference of 0.1 standard deviations), while the bankfull:wetted depth ratio (4.23, the highest in the study) indicates an large departure (3.4 standard deviations) from the benchmark. These data coupled with field observations illustrate that the channel is becoming more incised while the channel width is not increasing. The lacustrine/ organic nature of the floodplain soils and the frequency of beaver activity allow for deeply incised channels with wetted widths equal to bankful widths. The wetland nature of reach 7 will cause bedload to deposit upstream of reach 6 and would buffer peak flows. The lack of bedload deposition reduces lateral channel movement and aggradation in general which contributes to the stability of channel. See plates 82,84 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 6 can be characterized as high value fish habitat. Chinook salmon spawners were observed at 250, 1150, 4018 and 4568 metres upstream from the reach break. Resident mountain whitefish (2+, 3+, adults), longnose dace (0+, 1+) and white suckers (2+) were present at the time of survey. Rainbow trout/ steelhead (0+, 1+, 2+, 3+, adult) were also captured The 0+ and 1+ age-classes are presumed to be dominantly steelhead trout (Tredger, 1984). The most abundant species captured was longnose dace followed by rainbow trout/ steelhead. No juvenile chinook were captured, however, several spawning pairs were observed in the lower sections of this reach. Coho salmon also have a documented presence in the reach (BCCF, 1997).

This reach, due to its position relative to the mainstem, its gradient, and dominant channel morphology is a critical and productive area for rearing and moderately important area for spawning in an unimpacted state in the context of overall watershed productivity and diversity of fish. The slower moving and deeper water typical of this reach would be suitable rearing habitat for coho (Scott and Crossman, 1973). While this reach is not typical of chinook rearing habitat it would offer excellent refuge during freshet. The majority of the available spawning habitat is located at the downstream end of this reach. This spawning habitat is limited in its extent. Steelhead redds have also been observed in this reach (BCCF, 1997). The use of this reach by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits degraded habitat relative to benchmark conditions. Habitat complexity falls within 1.5 standard deviations of the benchmark with a complexity index of 3.13, and is less complex than the average of all reaches surveyed (see figure 130 and table 1 (page 9)). Riffles and glides dominate the spectrum of habitat units, and there are very few other (off-channel) units present. Compaction was high in all units. Spawning gravels were low in abundance. LWD function is extremely low in all size classes, and functional LWD frequency is 0.1 pieces/bankfull width (see figure 129 and table 54). The latter value is 2.7 standard deviations lower than the benchmark value (the lowest frequency in the study), and as such is considered a significant departure from benchmark conditions. On average, functional LWD (affecting cover, morphology) is only found in glides, and no extra large functional LWD was present in any of the units sampled. Pool frequency is 15.73 bankfull widths between pools, 3.3 standard deviations from the benchmark of 3.67, and is much greater than the survey average. Cover elements showed poor complexity, with a moderate abundance of in-stream cover. Cover usually consisted

of boulders and boulder groups. Canopy closure was 0-20% on average due to the large bankful widths and the lack of mature forest. The average temperature differential of 2.43 reflected this, with maximum water temperatures (14 ^{o}C) being at or below thermal maxima for all salmonids at the time of survey (late summer temperatures/low water levels).
Use of habitat by different fish species can be characterized as follows (see figures 125 to 128):

- Pools were used by two species with one age-class of each being represented. These included 1+ longnose dace and 0+ rainbow trout/ steelhead. Pools also exhibited the lowest densities of fish in this reach (0.048 fish/metre^3).
- Riffles yielded the same species as pools, but with more diverse age-class representation. 0+ and 1+ longnose dace were present as were 0+, 1+ and 2+ rainbow trout/ steelhead. Densities were higher than in pools with longnose dace being the most abundant.
- The greatest diversity of fish species and age-classes was present in glides, with 0+ longnose dace being by far the most abundant. 1+ longnose dace were also present in much lower numbers. Mountain whitefish (2+, 3+, adult)were only captured in glides as well as white suckers. Glides provided habitat for at least five age classes of rainbow trout/ steelhead (0+ to 3+ and adults). Throughout much of this reach glides are providing the same function as pools would. The diversity of species and age-classes present in these units illustrates their importance as critical fish habitat in this reach.
- Cascades provided habitat for 1+ longnose dace and 0+ and 1+ rainbow trout/ steelhead. Fish were encountered in the highest densities in these units.

Impact Synopsis

Land-use in this reach has damaged fish habitat quantity and quality. Of particular concern is the low pool frequency, the lack of functional LWD and extensive riparian disturbances. Impact sources are dominantly isolated to this particular reach, and are cumulative in nature. The low pool frequency is likely a result of infilling due to sediment transport from upslope areas and the lack of functional LWD. The recruitment of LWD to the stream in this reach has been severely limited by the Swiss Fire as well as land clearing for forest harvest and agriculture. Riparian disturbances are also due to the fire and land clearing.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Bank failures associated with residences and lawns at 360 metres and 500 metres are delivering fine sediments (clay) and bedload to the stream.
2) Bank failure and clay slump approximately 20 metres long at 867 metres.
3) Surface and bank erosion and ditch run-off from the Buck Flats road. The road comes to within 30 metres of the stream at several places along this reach. A road-related

slide was located at 6148 metres.

4) Riparian impacts related to the Swiss Fire, land-clearing, old selective forest harvesting of conifers and cattle grazing. Associated impacts include poor canopy closure, decreased stream shading and a lack of overstory microclimate causing temperature and primary productivity increases in the creek.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) Bank erosion and lateral channel movement at cleared and grazed land is an internal sediment source to the active channel, but is exacerbated by upstream sediment sources propagating downstream, and changes to the runoff regime. Associated effects include habitat homogenization (loss of complexity and pool infilling), poor LWD function due to a loss of bank strength in unconfined sections, and substrate compaction/embedding.
2) Loss of LWD function, habitat homogenization, substrate compaction/embedding, and degradation of spawning gravels related to increases in the magnitude of spring freshets. Of particular concern is the loss of large log jams in this reach which acted to store sediment upstream.

Prescriptions

Prescription sites are on both private and crown land in reach 6, and therefore full prescriptions are presented in crown land areas, and conceptual prescriptions are presented on private land.

Riparian prescriptions for reach 6 are summarized in appendix F. They relate to slope stabilization, bank stabilization, stream shading, future sources of LWD and sediment filtering. The prescription for polygon BUC172 is integrated with impact prescription #1, and BUC228 is integrated with prescription #2.

Two impact prescription site have been identified based on impacts outlined above, and physical and biological goals for mid-elevation reaches presented in section 3 of this report. They relate to mitigating upslope sources of sediment within the Swiss Fire area (see appendix G). On is a salvage logging-related disturbance, and the other is a road-related disturbance.

Priority and sequence of prescriptions for the Buck Creek sub-basin is presented in figure 138, page 201. This reach has a high priority for restoration as indicated by the reach prioritization table in appendix H

4.19 Buck Creek Reach 11B

Land Uses

Land use in reach 11B consists of a forest service road (FSR 2417), a quarry, and upslope forest harvesting (forest cover map 93L.019, openings #22 (TSHLA-01474-CP025-01), #23 (FLA-16827-CP310-01), #29 (TSHLA-01474-CP025-03), and #34 (TSHLA-01474-CP070-08)). The 2417 road parallels the creek on the left valley wall for its entire length, and dissects the riparian zone at a number of different locations. The quarry is located at the beginning of the reach adjacent to the road on the left valley wall. Several small intermittent and non-intermittent unnamed tributaries drain the aforementioned cutblocks. Upstream land uses include forest harvesting and roads. The Equivalent Clearcut Area of the Upper Buck sub-basin is 31% (BCCF, 1997). Land-use in the headwaters is expected to have altered the runoff regime.

Riparian Assessment

The riparian area of this reach occupied a total area of 12.27 hectares with a riparian zone width of 30 metres (see Buck Creek entry, appendix D). Land-use has modified 18%, or 2.2 hectares of this. The BEC classification for this reach is sub-boreal spruce/moist-cold (Babine Variant)(SBSmc2), with two different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

Much of the riparian zone on low-bench sites is predicted to be sites series 07b (spruce-scrub birch-feathermoss), combined with areas of willow shrub carr at the water's edge. These sites are present over a dense clay layer with restricted groundwater movement to depth. The water table is less than 10 cm from the surface in most cases. In raised microsites, and where more well-drained morainal materials and/or colluvium predominate, and at the toe of valley walls, conifer-dominated spruce-horsetail (10a) site series are predicted.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- Removal of stream shading, sediment filtering and bank/slope stabilizing function in areas where FSR-2417 dissects the riparian zone. Vegetation directly adjacent to the creek has been taken out, and initial and/or shrub/herb seral stages are present.

Channel Assessment

Reach 11B is a 2405 metre long RPgw and RPcw channel flowing between the elevations of 942 and 980 metres a.s.l., with an average gradient of 1.5, bankfull width of 5.22

Reach Impact and Restoration Diagnostics

Table 56: Summary of habitat quality indicators by habitat unit category for Buck Creek, reach 11.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	G	S	H	A	H	2
Other	S	S	L	AR	N	2
Pool	C	G	L	AR	H	3
Riffle	C	G	H	AR	H	6

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	0	2	0	OV, C	1
Other	1	1	0	OV	3
Pool	1	2	0	OV, C	2
Riffle	3	3	1	OV, C	1

Table 57: Reach summary of other indicators of impacts to watershed function and fish habitat for Buck Creek, reach 11.

Functional pieces of LWD/bankfull width	**0.98**
Pool frequency	**3.26**
Bankfull : wetted width ratio	**1.50**
Bankfull : wetted depth ratio	**2.00**
Area of disturbed riparian forest (ha)	**2.28**
Length of disturbed channel (m)	**804**

Table 58: Mean values for selected parameters which may assist in designing instream restoration works, Buck Creek, Reach 11.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.61	0.61	5.66	12.43	38.21	9.78
Riffle	1.61	0.37	5.71	12.64	14.63	6.04
Pool	1.41	0.68	5.48	9.75	33.91	9.52
			Reach Mean Estimated Bankfull Discharge		28.91	

metres, and bankfull depth of 0.56 metres. It is a depositional, semi-confined headwaters reach whose dominant channel-forming mechanisms are LWD and beaver activity. Streambanks are composed solely of clay in many areas particularly near the bottom of the reach, with stretches of erodible basal tills (mixed sand/gravel or clay/sand/gravel), and unconsolidated alluvial materials (sand/gravel/cobble). The channel is irregularly wandering with a low degree of lateral stability. Upslope areas are sporadically connected to the active channel where it comes in contact with valley walls and (on the left bank) the FSR-2417 right-of-way. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement. Some upslope areas are also important for LWD and bed paving material recruitment.

Channel assessment in reach 11B indicated that 37% (880 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as aggrading (A2-A3) (see appendix C). Dominant indicators of disturbance include sediment wedges, elevated mid-channel bars, eroding banks, avulsions, and recently formed log jams. Bankfull:wetted width and bankfull:wetted depth ratios (1.50 and 2.00 respectively) indicate a close proximity to benchmark conditions. The bulk of disturbed channel occurs at the top of the reach, which is fed by several tributaries which drain clearcut areas. Sediment from several unstable cut slopes above the road are washing into cross-ditches and subsequently the creek. One unnamed tributary at the end of the reach is responding to riparian losses and poor (undersized) culvert installation for an approximately 100 metre stretch between its confluence with Buck Creek and where it is crossed by FSR-2417. Other aggraded areas are associated with isolated, point-source road-related disturbances. See plates 89,91-93 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 11B can be characterized as high-value resident fish habitat. Resident rainbow trout (0+/1+/2+/3+/adult) and longnose suckers (2+) were present at the time of survey. Both species were caught throughout the reach Prickly sculpins and mountain whitefish also have a documented presence in the reach (Bustard, 1989). Minnow trapping at a small, moderate gradient tributary at the end of the reach yielded rainbow trout up to a perched, impassable culvert at the FSR-2417 crossing.

This reach, due to its position in the watershed and proximity to Goosly Lake, its gradient, and dominant channel morphology is a highly important area for spawning and rearing resident fish in an unimpacted state in the context of overall productivity of salmonids (particularly rainbow trout) in the upper Buck Creek area (including reaches 9 to 11 and Klo Creek). It is one of the only free-flowing reaches with stable spawning conditions and abundant resident salmonid spawning substrate in this part of the watershed, as well as complex multi-year rearing habitat. Furthermore, this reach is upstream of water quality and toxicity impacts related to the Equity Mine, whose tailings

ponds drain into Bessemer Creek and then into reach 11A.
This reach exhibits marginally degraded habitat relative to benchmark conditions. Habitat complexity falls within 1 standard deviation of the benchmark with a complexity index of 3.46 (see figure137 and table 1, page 9). The spectrum of habitat units is evenly distributed in abundance between pools, riffles, and glides. Relative to other reaches surveyed, there is frequent off-channel habitat. Compaction was high in riffle and glide units and low in pool and off-channel (“other”) units. Spawning gravels were abundant in riffles. pool tailouts, and glides, with gravels suitable for resident spawners in pool tailouts and riffles. LWD function was good in large and extra large size classes, and moderate in the small sizes. Functional LWD frequency is 0.98 pieces/bankfull width (see figure 136 and table 57). The latter value is within 1 standard deviation of the benchmark value, and as such is considered in-line with benchmark conditions. On average, functional LWD (affecting cover, morphology) was found in all unit categories sampled, with most wood appearing in the large size class. Pool frequency is 3.26 bankfull widths between pools, which is lower (more frequent pools) than the benchmark of 3.67. Cover elements showed good complexity, although was dominantly not in-stream types. Cover usually consisted of overhead vegetation and cutbanks. Canopy closure was 20-40% on average.

Use of habitat by different fish species can be characterized as follows (see figures 132 to 135):

- Pools were inhabited by several age-classes of rainbow trout, from 0+ to 3+. Typical of other resident rainbow trout systems sampled, highest densities of 1+ fish were found in pools. Highest densities of 2+ and 3+ fish were also noted.
- Riffles were used by juvenile (0+/1+) rainbow trout, with the highest densities of 0+ fish encountered in the reach.
- Multiple species and age-classes were sampled in glides. These were the only unit types where long-nose suckers were captured, as well as adult rainbow trout.
- Other (off-channel) habitat supported moderate densities of juvenile rainbow trout at the time of survey. This unit category does not appear to be a critical summer rearing habitat.

Impact Synopsis

Land-use in this reach has not damaged fish habitat quantity and quality. Of particular concern in the long term is the cumulative and continued impact of road-related sediment sources, slope instability below the road cut, and bank instability in an unnamed tributary at the end of the reach. Upslope forest harvesting may be associated with disturbed channel polygons as channel geometry equalizes with higher peak discharges. Impact sources are dominantly isolated to this particular reach, and are both isolated and cumulative in nature.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Cut slope failures and delivery of sediments to ditchlines which drain into Buck Creek at several points along FSR-2417.
2) Extreme bank erosion and delivery of sediment and bedload to Buck Creek from the easternmost unnamed tributary in the reach. Loss of riparian vegetation due to logging, and an undersized, perched culvert at the point where FSR-2417 crosses the creek are causing this problem. Field observations of the creek upstream of the culvert show no such impacts. This perched culvert is also an upstream barrier on this tributary to rainbow trout. No fish were caught above it.
3) Loss of riparian vegetation and delivery of chronic fine sediments from the road where it dissects the riparian zone. Several of these sites also exhibit signs of slope instability.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

1) Possible channel straightening and increases in lateral movement due to changes in the runoff regime from large clearcut areas.

Prescriptions

Prescription sites are on crown land in reach 11B, and therefore full prescriptions are presented.

Riparian prescriptions for reach 6 are summarized in appendix F. They relate to slope stabilization, bank stabilization, and sediment filtering.

One impact prescription site have been identified based on impacts outlined above, and physical and biological goals for headwaters reaches presented in section 3 of this report. It relates to mitigating upstream sources of sediment and reestablishing fish access through an undersized culvert(see appendix G)

Priority and sequence of prescriptions for the Buck Creek sub-basin is presented in figure 138, page 201. This reach has a very high priority for restoration as indicated by the reach prioritization table in appendix H

Buck Creek Sub-Basin Rehabilitation Plan

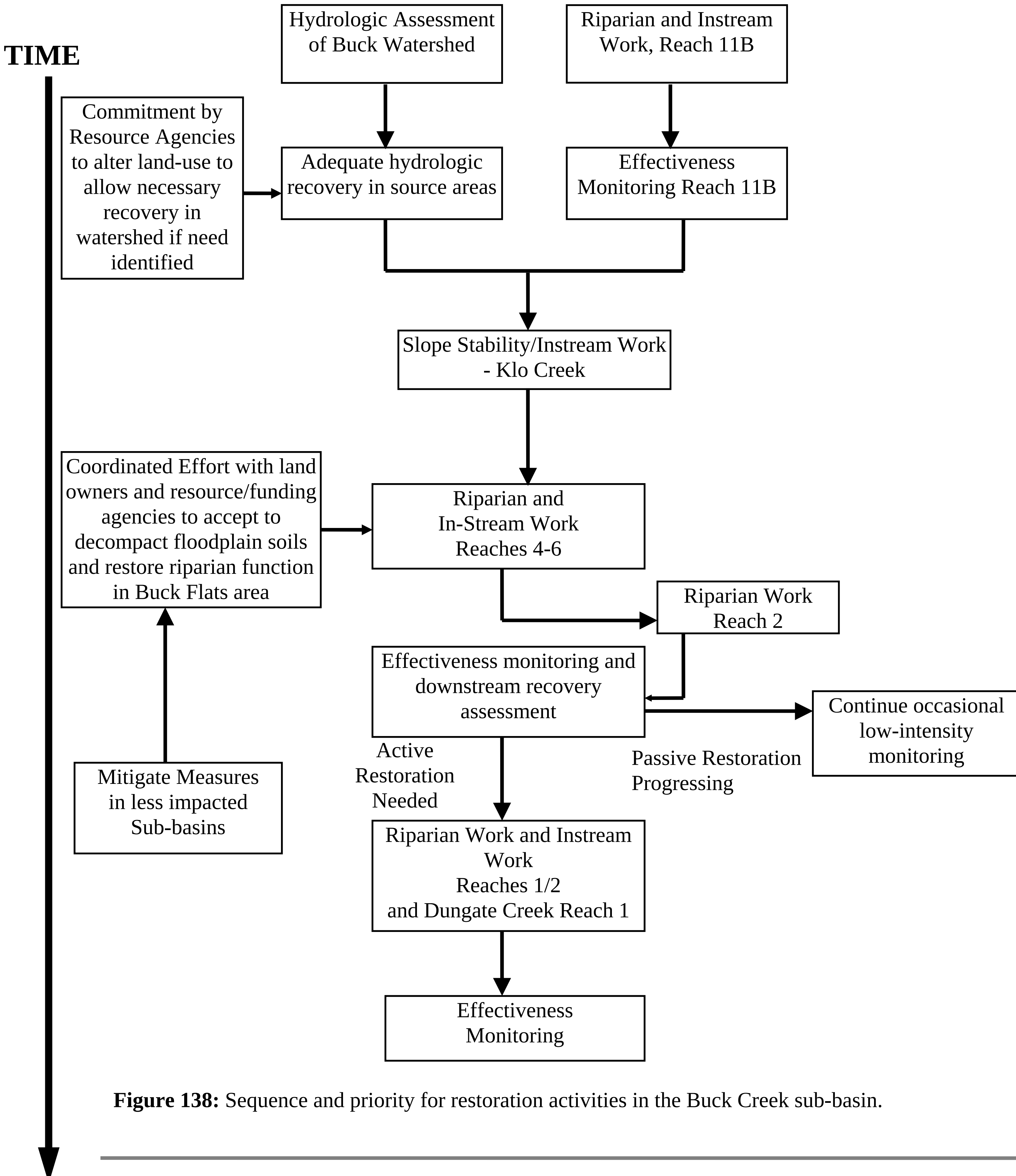


Figure 138: Sequence and priority for restoration activities in the Buck Creek sub-basin.

4.20 Bulkley River Reach 1

Land Uses

Land use between the mouth and 3800 metres upstream consists of occasional areas of hay farming. The railway dissects the riparian zone at 3400 metres on the right bank. From 3800 to 10 605 metres, land use includes the highway corridor, the railway corridor, both of which confine the channel at various points between 4800 and 6300 metres on the left bank, the Michelle Bay FSR cuts through the right valley wall at 4500 metres in the upslope area, a light industrial area and sewage treatment plant occupy the left bank between 8900 and 10 000 metres. The town of Houston water supply is drawn from the Bulkley River floodplain in this area as well. A powerline corridor dissects the riparian zone and crosses the river at 9700 metres.

Although the Equivalent Clearcut Area (ECA) has not been calculated for the Upper Bulkley River watershed, it is expected that extensive land use in the headwaters and on the floodplain has altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 42 polygons occupying a total area of 111 hectares with a riparian zone width of 50 metres (see Bulkley River entry, appendix D). Land-use has modified 32%, or 35.2 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

On the Bulkley River floodplain, the dominant plant community is predicted to be the black cottonwood-dogwood ($59) on lower-bench areas with more frequent overbank flooding and cottonwood-twinberry ($58) seral association on high bench sites. These are 08 floodplain site series seral associations. Point and other types of gravel bars were dominated by pioneering sand and gravel bar communities of willow (likely *salix exigua* (Coyote Willow)), red-osier dogwood, and mountain alder. Cottonwood and twinberry are encountered in these communities further from the water's edge. Pacific willow-mountain alder-lady fern (TEM code=ML) communities are found in low-bench regularly flooded sidechannels of the Bulkley. Above 4000 metres, the reach is confined intermittently on the left bank by steep valley walls of morainal and glaciofluvial materials with a southerly aspect. The presence of abundant *Populus tremuloides* (trembling aspen) and 0-20% slopes indicates spruce-horsetail (07a) on the toe of slopes. These sites are seral associations, and are predicted as aspen-twinberry ($57). Steeper/higher elevation sections with this aspect are probably site series 81/82 grasslands where they have not been disturbed or subject to erosion..

Reach Impact and Restoration Diagnostics

Table 59: Summary of habitat quality indicators by habitat unit category for Bulkley River, reach 1.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	G	H	AR	H	0
Other	S	C	L	AR	N	2
Pool	S	G	L	AR	H	7
Riffle	C	G	M	AR	H	1

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	0	0	0	B	1
Other	2	0	0	OV	1
Pool	2	4	1	LWD	1
Riffle	0	1	0	B	1

Table 60: Reach summary of other indicators of impacts to watershed function and fish habitat for Bulkley River, reach 1.

Functional pieces of LWD/bankfull width	**0.69**
Pool frequency	**9.21**
Bankfull : wetted width ratio	**1.87**
Bankfull : wetted depth ratio	**3.76**
Average temperature differential at summer low flows (°C)	**0.90**
Area of disturbed riparian forest (ha)	**35.2**

Table 61: Mean values for selected parameters which may assist in designing instream restoration works, Bulkley River, Reach 1.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	0.50	1.56	36.78	14.00	570.03	7.78
Riffle	0.50	1.52	34.12	16.20	506.27	7.58
Pool	0.50	1.24	17.53	10.67	390.65	6.18
Reach Mean Estimated Bankfull Discharge					488.98	

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest and soil compaction in areas used for hay farming, and in areas used for homes, parkland, buildings, and streets.
- Removal of riparian forest and disconnection of the channel from the riparian zone due to channelizing in transportation corridors and at housing developments on the floodplain.
- Past harvesting of spruce and cottonwood by landowners preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (white clover, Canada thistle), the possible modification of floodplain and channel features (diversions, landfilling), and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.
- The simplification of surface drainage patterns and compaction of floodplain soils due to extensive paved areas and storm drain system.
- Drawdown of the floodplain water table for the town water supply during drought periods.

Typical riparian polygon photos are found in plates 95,97-98,100.

Channel Characteristics

Reach 1 is a 10 605 metre long RPgw channel flowing between the elevations of 585 and 589 metres a.s.l., with an average gradient of 0.5%, bankfull width of 27.4 metres, and bankfull depth of 1.37 metres. It is a valley bottom depositional reach whose dominant channel-forming mechanism is LWD (log jams). The reach exhibits a downstream progression and cutoffs pattern of lateral activity. The channel is irregularly to tortuously meandering with a low degree of lateral stability and occasional channel islands. Bed paving materials are generally sand and gravel. Upslope areas are occasionally coupled to the active channel between the 3800 and 10 500 metres. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

In this reach, field observations of aggradation were made, with some areas of moderate to severe aggradation. Large elevated mid-channel (medial) bar formation, eroding banks, poor pool frequency, and extensive bars were noted, indicating a high sediment load. This is corroborated to a certain extent by the pool frequency and bed compaction values, as well as by the bankfull:wetted width ration of 1.87 (bankfull width is almost double the wetted width). Field observations of bank erosion were made at all riparian polygons with hay farming, and were most severe on outside corners of meanders. The bankfull:wetted depth ratio (3.76) indicates that the channel is incised.

See plates 96,99-100 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 1 can be characterized as very high value fish habitat. Juvenile coho (0+) and chinook salmon (0+) were captured in reach 1. Adult chinook spawners were observed at 5560, 5765, 6055 and 6130 metres. Several chinook redds were seen at 1400 metres and immediately above and below riffles between the sewage outfall and the confluence with Buck Creek. Resident prickly sculpins, white suckers, and long-nose dace were present at the time of survey. Rainbow/steelhead trout (0+/1+/3+) were also caught in this reach. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout (Tredger, 1984). These species were all present throughout the reach. Sockeye (migrating to Maxan Creek), and pink salmon spawners as well as coho and chinook spawners, and Dolly Varden/bull trout also have a documented presence in the reach (BCCF, 1997). The presence of adult bull trout was established in tributaries to this reach and reach 3, but no Dolly Varden were caught in the extent of the study area in this project. Although standard methods of char identification using the methods of Haas (1996) were not carried out in gathering past fish data, it is likely that char presence cited in references are actually bull trout. Anecdotal information suggested that cutthroat trout were also present in the Bulkley River mainstem. Considering the absence of cutthroat trout from reaches surveyed in all watershed positions throughout the watershed, both above and below impassable barriers, it is unlikely that these references are correct.

This reach, due to its watershed position, its gradient, and dominant channel morphology is a highly important area for holding/migrating, summer rearing, spawning, and overwintering in an unimpacted state in the context of overall watershed productivity and diversity of fish. In particular, species such as steelhead and bull trout will likely not use the mainstem for rearing and spawning, based on habitat preferences for a higher gradient and larger substrate. They may migrate into the mainstem for overwintering, and will certainly use it as a migration corridor between habitats for different life stages. Coho salmon are also unlikely to use the mainstem for spawning and rearing unless habitat conditions in tributaries are generally very poor. The results of this survey suggest that coho will migrate out of the sampled tributaries to rear in the mainstem during late summer to avoid generally poor water quality, high temperatures, and low flows. This is based on numbers of coho captured in tributary reaches versus mainstem reaches. Overwintering in the mainstem and off-channel areas has not been studied at this point in time, however it is likely that both of these parts of the river are important for this purpose given the flow conditions (January/February is the winter low-flow period) in many tributaries during the winter, and the amount of open water area versus iced over area. The critical factors governing good overwintering conditions assuming a waterbody that is not frozen solid include low water velocities, good dissolved oxygen concentrations, refuges from ice formed in the water column, and usual conditions related to survival such as food availability. Off-channel areas. if accessible and wetted, will also provide ideal refuges during high water events.

Habitat conditions are as follows (see tables 1 (page 9) and figure 144):

- Habitat complexity was moderate to good, although the habitat unit tally indicated a proportionately lower number of pools versus riffles and glides. Other (off-channel) units consisted of 10-15% of available habitat. The complexity index of 3.45 indicated a relatively even proportion of units across the spectrum, and in comparison to smaller alluvial channels surveyed was somewhat lower than benchmark reaches. Pool frequency appeared low in comparison to smaller channels in the study area, with a value of 9.21 bankfull widths between pools. Extensive glides and riffles indicate the possibility of pool infilling due to sediment load.
- LWD function was minimal in small size classes, but moderate in large and extra large size classes. Although single pieces of LWD do not significantly effect channel morphology, lateral log jams and function wood at the wetted channel margins was considered as functional. Functional LWD was averaged over the reach for all size classes at 0.69 pieces/bankfull width, and was found functioning in all units sampled with the exception of glides. Its function was greatest in pools, where it was instrumental in pool formation, as well as being (modally) the dominant cover element. Log jams, particularly lateral log jams, occurred frequently throughout the reach.
- Spawning gravels were high in all relevant unit types. Spawning gravels were suitably sized and of suitable area for both resident and anadromous salmonid spawners. Bed compaction was high in glides (including pool tailouts) and moderate in riffles.
- Cover elements showed minimal complexity, but were frequently in-stream types. Boulders were dominant in glides and riffles, overhead vegetation was the modal cover element for off-channel units, and LWD acted as cover in pools.
- Canopy closure was 0-20% on average. The average temperature differential of 0.9 ^{o}C reflected this, with water temperatures (18 ^{o}C) at the time of survey exceeding thermal maxima for spawning in all salmonid species, and was very close to the maximum for successful growth and reproduction of juvenile chinook and coho salmon, so some metabolic stress loading can be assumed. Temperatures were taken during the high air temperature/summer low flow critical period.

Use of habitat by different fish species can be characterized as follows (see figures 140 to 143):

- Pools were used by all species with the exception of white suckers, and eight different age classes (0+ to 2+ range). The most abundant species in pools was 0+ rainbow/steelhead trout, and the least abundant was 0+ coho salmon. This was the only unit type where 2+ prickly sculpins were present. Salmon species were present in highest densities in pools in the reach.
- Riffles were used by all species except coho and chinook. Seven age-classes were present (0+ to 2+ range). The most abundant species/age-class was 0+ rainbow/steelhead trout, and the least was 2+ rainbow/steelhead. This was the only unit type where white suckers were captured. The highest densities of all other species/age classes present were captured in riffles in comparison to other unit categories.

- All species with the exception of white suckers were present in glides, and 10 age classes (0+ to 3+ range). The most abundant species/age class was 0+ rainbow/steelhead, and the least abundant was 1+ prickly sculpins.
- Other (off-channel) habitat was occupied by only 0+ longnose dace and rainbow/steelhead trout in low densities. No large off-channel complexes were sampled, and these numbers are not a good indication of how much these types of habitat are used by different species for summer rearing.

Impact Synopsis

Without a comparison to previous habitat and channel conditions, regional habitat and channel standards, or unimpacted reaches of a similar type, it is difficult to make inferences about habitat damage. Field observations of channel and riparian impacts are somewhat useful in this regard, as well as comparison of certain ratio-based and proportional indices which are not sensitive to changes in scale. In this case, such parameters are pool frequency, functional LWD frequency, the complexity index, and bankfull:wetted width and depth ratios.

Theses results suggest that fish habitat has been damaged in reach 1. Of particular concern are high water temperatures and a low average temperature differential, the effects of a high sediment load on fish habitat such as spawning gravel compaction, substrate embedding and loss of microhabitat for juvenile fish and certain invertebrate species, and the loss of pool frequency and the homogenization of habitat, and the effects of a high sediment load and possibly altered runoff regime on channel pattern and geometry. Effects on the latter magnifies sediment load problems by increasing rates of internal sediment source delivery through bank erosion and avulsions. Impact sources are dominantly not isolated to this particular reach, and are cumulative in nature.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Channelization by the highway, railway and town of Houston increasing water velocities and causing bank erosion downstream, as well as removing riparian forest function and disconnecting the channel from the floodplain.
2) Removal of riparian forest for hay farming and other land use causing bank erosion at various points in the reach.
3) Clearing for the powerline corridor leading to increased surface erosion of an exposed clay valley wall at 9700 metres.
4) Alteration of surface and groundwater flow patterns by the Michelle Bay FSR and (in one case) the road bed of the old highway causing severe erosion of exposed clay valley walls at 4550 and 6800 metres.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows :

1) Loss of pool frequency and volume, and substrate compaction and embedding due to a high sediment load related to upstream sediment sources.
2) Increasing rates of bank erosion, channel incision, and meander cutoff (avulsions) due to increases in discharge and stream power as spring runoff responds to an overall loss of water storage functions in the floodplain, extensive channelizing, and the area of cleared and clearcut land on tributaries and in the headwaters. This is in turn related to an increasing sediment load.
3) Loss of riparian forest cover throughout the mainstem and tributaries causing elevated summer water temperatures and lower water levels, and decreased lateral stability and bank erosion.
4) Aggradation, channel homogenization, channel widening leading to lower water levels and increased water temperatures.

Prescriptions

Prescription sites are on private land in reach 1, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 1 are summarized in appendix F. They relate to slope stabilization, bank stabilization, stream shading, future sources of LWD and sediment filtering. The prescription for polygons BUL29 and BUL32 are integrated with impact prescription #1.

One impact prescription site has been identified based on impacts outlined above, and physical and biological goals for mainstem reaches presented in section 3 of this report. It relates to mitigating upslope sources of sediment at slope failures below the Michelle Bay FSR (see appendix G).

This reach has a moderate priority for restoration as indicated by the reach prioritization table in appendix H

4.21 Bulkley River Reach 2

Land Uses

Land use in reach 2 for the first 1350 metres upstream is related to residential occupation of the floodplain, including flood dyking in several areas. The highway bridge crosses the river at 1350 metres. Land-use from 1350 to the reach break is dominantly hay farming and cattle ranching. Private landowners own huge tracts of floodplain, and have extensively developed it through logging/clearing, hay farming on fertile valley bottom soils and in natural grassland openings, and cattle ranching by opening up the forest canopy to forage production on slopes and on the floodplain. The highway and railway dissect the floodplain on the downstream right for the entire length of the reach, and encroach on the active channel in many locations. These sites are generally rip-rapped to bankfull height to prevent the river from undercutting the railroad bed. Channelizing of the river by the railroad, and removing access to many off-channel ponds is considered one of several significant cumulative land-use impacts in this reach. A CNR railway bridge crosses the river at 2100 metres upstream from the reach break. The Knockholt bridge crosses the river and channelizes it at 12 860 metres upstream. A private bridge crosses the river at Henry Murphy's property. There is some private logging in several locations in the upper part of the reach, mostly on the downstream left floodplain and slope.

Although the Equivalent Clearcut Area (ECA) has not been calculated for the Upper Bulkley River watershed, it is expected that extensive land use in the headwaters and on the floodplain has altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 204 polygons occupying a total area of 261 hectares with a riparian zone width of 50 metres (see Bulkley River entry, appendix D). Land-use has modified 63%, or 164 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

On the Bulkley River floodplain, the dominant plant community is predicted to be the black cottonwood-dogwood ($59) on lower-bench areas with more frequent overbank flooding and cottonwood-twinberry ($58) seral association on high bench sites. These are 08 floodplain site series seral associations. Point and other types of gravel bars were dominated by pioneering sand and gravel bar communities of willow (likely *Salix exigua* (Coyote Willow)), red-osier dogwood, and mountain alder. Black cottonwood and twinberry are encountered in these communities further from the water's edge. Pacific willow-mountain alder-lady fern (TEM code=ML) communities are found in low-bench

Reach Impact and Restoration Diagnostics

Table 62: Summary of habitat quality indicators by habitat unit category for Bulkley River, reach 2.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	G	G	M	AR	H	13
Other	S	G	L	R	L	6
Pool	S	G	L	R	L	4
Riffle	G	S	L	AR	H	2

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	4	8	1	OV, SWD	1
Other	1	3	2	SWD, OV	1
Pool	2	2	0	SWD, OV	1
Riffle	1	1	0	SWD	1

Table 63: Reach summary of other indicators of impacts to watershed function and fish habitat for Bulkley River, reach 2.

Functional pieces of LWD/bankfull width	**0.91**
Pool frequency	**9.97**
Bankfull : wetted width ratio	**2.17**
Bankfull : wetted depth ratio	**2.81**
Average temperature differential at summer low flows (^{O}C)	**2.02**
Area of disturbed riparian forest (ha)	**164**

Table 64: Mean values for selected parameters which may assist in designing instream restoration works, Bulkley River, Reach 2.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	0.5	0.77	17.91	7.33	103.93	3.85
Riffle	0.5	0.66	28.69	7.36	108.74	3.31
Pool	0.5	1.39	17.28	4.78	462.45	6.93
				Reach Mean Estimated Bankfull Discharge	225.04	

regularly flooded sidechannels of the Bulkley. North to northwesterly-facing slopes were common where the river was confined by the southern valley wall, and these were dominated by spruce-twinberry coltsfoot (06) site series at the toe of the slope in the riparian zone.

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest and soil compaction in areas used for hay farming/powerlines/grazing, and in areas used for homes, parkland, buildings, and streets.
- Loss of the shrub/herb layer and associated root system and soil compaction from cattle grazing carried out in areas where the overstory still exists
- Removal of riparian forest and disconnection of the channel from the riparian zone due to channelizing at transportation corridors and at housing developments on the floodplain. Past harvesting of spruce and cottonwood by landowners preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the

introduction of invader species (white clover, Canada thistle), the modification of floodplain and channel features (diversions, landfilling), and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.

- The simplification of surface drainage patterns and compaction of floodplain soils due to extensive paved areas and storm drain system in the confines of the Houston townsite.

Typical riparian polygon photos are found in plates 104,107,110-111.

Channel Characteristics

Reach 2 is a 25 512 metre long RPgw channel flowing between the elevations of 589 and 605 metres a.s.l., with an average gradient of 0.5%, bankfull width of 20.2 metres, and bankfull depth of 0.91 metres. It is a valley bottom depositional reach whose dominant channel-forming mechanism is LWD (log jams). The reach exhibits a downstream progression and cutoffs pattern of lateral activity. The channel is tortuously meandering with a low degree of lateral stability and no channel islands. Bed paving materials are generally sand and gravel. Upslope areas are occasionally coupled to the active channel at various point where it is confined by the southern valley wall. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

In this reach, field observations of aggradation were made, with some areas of moderate to severe aggradation. Large elevated mid-channel (medial) bar formation, homogeneous substrate (sand or clay) eroding banks, poor pool frequency, and extensive bars were noted, indicating a high sediment load. This is corroborated to a certain extent by the pool frequency and bed compaction values, as well as by the bankfull:wetted width ratio of 2.17 (bankfull width is more than double the wetted width). Field observations of bank erosion were made at all riparian polygons with hay farming and cattle grazing, and were most severe at the upstream corners on meander necks and outside corners of meanders where this land use existed. Banks just downstream of armoured banks adjacent to the railway were often eroding heavily as well. The bankfull:wetted depth ratio (2.81) indicates that the channel is incised.

See plates 106,108 and 110 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 2 can be characterized as very high value fish habitat. Coho (0+) and chinook salmon (0+/1+) juveniles were captured in this reach. Adult chinook spawners were observed at 9300, 10 455, 13 937, 17 101, 21 863 and 20 636 metres. Resident prickly sculpins (0+/1+), mountain whitefish (1+/2+), white suckers (0+), and coarsescale suckers (0+/1+2+), and long-nose dace (0+/1+/2+) were present at the time of survey. Rainbow/steelhead trout (0+/1+/2+/3+) were also caught in this reach. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout (Tredger, 1984). These species were all present throughout the reach. Sockeye (migrating to Maxan Creek), and pink salmon spawners as well as coho and chinook spawners, and Dolly Varden/bull trout also have a documented presence in the reach (BCCF, 1997). The presence of adult bull trout was established in tributaries to this reach and reach 3, but no Dolly Varden were caught in the extent of the study area in this project. Although standard methods of char identification using the methods of Haas (1996) were not carried out in gathering past fish data, it is likely that char presence cited in references are actually bull trout. Anecdotal information suggested that cutthroat trout were also present in the Bulkley River mainstem. Considering the absence of cutthroat trout from reaches surveyed in all watershed positions throughout the watershed, both above and below impassable barriers, it is unlikely that these references are correct.

This reach, due to its watershed position, its gradient, and dominant channel morphology is a highly important area for holding/migrating, summer rearing, spawning, and overwintering in an unimpacted state in the context of overall watershed productivity and diversity of fish. In particular, species such as steelhead and bull trout will likely not use the mainstem for rearing and spawning, based on habitat preferences for a higher gradient and larger substrate. They may migrate into the mainstem for overwintering, and will certainly use it as a migration corridor between habitats for different life stages. Coho salmon are also unlikely to use the mainstem for spawning and rearing unless habitat conditions in tributaries are generally very poor. The results of this survey suggest that coho will migrate out of the sampled tributaries to rear in the mainstem during middle to late summer to avoid generally poor water quality, high temperatures, and low flows. This is based on numbers of coho captured in tributary reaches versus mainstem reaches. Overwintering in the mainstem and off-channel areas has not been studied at this point in time, however it is likely that both of these parts of the river are important for this purpose given the flow conditions (January/February is the winter low-flow period) in many tributaries during the winter, and the amount of open water area versus iced over area. The critical factors governing good overwintering conditions assuming a waterbody that is not frozen solid include low water velocities, good dissolved oxygen concentrations, refuges from ice formed in the water column, and usual conditions related to survival such as food availability. Off-channel areas. if accessible and wetted, will also provide ideal refuges during high water events.

Habitat conditions are as follows (see table 1 (page 9) and figure 149):

- Habitat complexity was good. Other (off-channel) units consisted of 10-15% of available habitat. The complexity index of 3.45 indicated a relatively even proportion of units across the spectrum, and in comparison to smaller alluvial channels surveyed was somewhat lower than benchmark reaches. Pool frequency appeared low in comparison to smaller channels in the study area, with a value of 9.97 bankfull widths between pools.
- LWD function was moderate in all size classes, with less than 50% function. Although single pieces of LWD do not significantly effect channel morphology, lateral log jams and function wood at the wetted channel margins was considered as functional. Functional LWD was averaged over the reach for all size classes at 0.91 pieces/bankfull width, and was found functioning in all units. Its function was greatest in pools and glides. Log jams, particularly lateral log jams, occurred frequently throughout the reach.
- Spawning gravels were high in glides (including pool tailouts) and riffles. Spawning gravels were suitably sized and of suitable area for both resident and anadromous salmonid spawners in these units. Bed compaction was moderate in glides and low in riffles, pools, and off-channel units. Sand was the dominant or subdominant substrate (modally) in all unit categories except glides.
- Cover elements showed good complexity, and at least one element was frequently an in-stream types. Small woody debris (mostly in the form of willow root balls and clumps of other deciduous vegetation) was the dominant cover type in all units, and overhead vegetation in glides off channel units, and pools.
- Canopy closure was 0-20% on average. The average temperature differential of 2.02 ^{o}C did not reflect this however, and water temperatures (16 ^{o}C) at the time of survey did not exceed thermal maxima for any summer spawners, nor any other critical thermal maxima. Temperatures were taken during the high air temperature/summer low flow critical period.

Use of habitat by different fish species can be characterized as follows (see figures 147-148,150,152):

- Pools were used by all species present except prickly sculpins and white suckers. Age-classes were diverse, with 12 present (0+ to 2+ range). The most abundant species/age-classes sampled were 0+ coarsescale suckers and longnose dace (0.73 fish/m^3), for which pool densities were the highest of all unit types sampled. The least abundant were 0+ coho and 1+ mountain whitefish (0.03 fish/m^3). Pools were the only units in which coho were caught, underlining the importance of maintaining pool habitat quality for these fish. Other unique presence includes 2+ mountain whitefish. Highest densities of 3+ rainbow/steelhead trout were also caught in pools.

- Riffles were used by longnose dace, chinook salmon, coarsescale suckers, white suckers, and rainbow/steelhead trout. Seven age-classes were present (0+ to 2+ range). The most abundant species/age-class in riffles was 0+ longnose dace, and the least abundant was 0+ white suckers. The highest densities of 0+ chinook salmon were present in riffles, although they were only marginally higher than in other unit types. Riffles in this reach are important rearing habitat in that they are areas of higher dissolved oxygen, and generally better and cleaner substrate (gravels and cobbles) for key invertebrate orders (*Ephemeroptera, Plecoptera, Trichoptera, Diptera*) from the salmonid invertebrate diet than in glides and pools, as well as having higher water velocities and a higher concentration of food drift. They are also islands of well-aerated, cleaner, and suitably sized spawning gravels, which do not generally occur in pools and glides.
- All species except coho were present in glides, and these units had a high diversity of age-classes (0+ to 3+ range). The most abundant species/age-class was 0+ longnose dace, and the least abundant were 1+ prickly sculpins. These were the only units where 1+ sculpins were captured. Moderate densities of other species were present.
- Other (off-channel) habitat was occupied by all species with the exception of coho and white suckers, and had the greatest diversity of age-classes (0+ to 3+ range). These were the only units where 1+ chinook salmon were sampled, and generally high densities of this species were encountered. 0+ chinook were the most abundant species in off-channel units, and 1+ prickly sculpins, 1+ chinook, 2+ coarsescale suckers, and 2+ longnose dace were the least dominant species.

Impact Synopsis

Without a comparison to previous habitat and channel conditions, regional habitat and channel standards, or unimpacted reaches of a similar type, it is difficult to make inferences about habitat damage. Field observations of channel and riparian impacts are somewhat useful in this regard, as well as comparison of certain ratio-based and proportional indices which are not sensitive to changes in scale. In this case, such parameters are pool frequency, functional LWD frequency, the complexity index, and bankfull:wetted width and depth ratios.

Theses results suggest that fish habitat has been damaged in reach 2. Of particular concern are the effects of a high sediment load on fish habitat such as spawning gravel smothering, substrate embedding and loss of microhabitat for juvenile fish and certain invertebrate species, and the effects of a high sediment load and possibly altered runoff regime on channel pattern and geometry. Effects on the latter magnifies sediment load problems by increasing rates of internal sediment source delivery through bank erosion and avulsions. Impact sources occur both within and upstream of this particular reach, and are cumulative in nature.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Channelization by the highway and secondary roads, railway and town of Houston increasing water velocities and causing bank erosion downstream, as well as removing riparian forest function and disconnecting the channel from the floodplain.
2) Removal of riparian forest for hay farming, cattle grazing, logging, and powerline corridors causing bank erosion at various points in the reach. Areas having greatest impacts on channel pattern and rates of bank erosion in the context of the reach channel geometry include the upstream corner of the meander neck and the outside bend of the meander where the angle and amount of shear stress are considered to be highest. Bank erosion in these areas have the greatest potential to cause avulsions and to perpetuate further erosion (both at the site and downstream).
3) Removal of riparian forest and LWD from low bench areas (backwaters, oxbows, and relic channels), particularly from the floodplain at the top of the reach, as well as landfilling of these features and diversion of the river away from the floodplain, leading to disconnection of the channel from the floodplain, channel incising and lower baseflows, soil compaction and decrease in the infiltration capacity of the soil in lower horizons, loss of floodplain off-channel access to fish and the processes which create these types of habitats, and probably greater flood damage and higher sediment loads in large overbank floods whose energies are not dissipated by riparian forest and the debris and sediment catchment effects of LWD on the floodplain.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows :

4) Loss of pool frequency and volume, and substrate compaction and embedding due to a high sediment load related to upstream sediment sources
5) Increasing rates of bank erosion, channel incision, and meander cutoff (avulsions) due to increases in discharge and stream power as spring runoff responds to an overall loss of water storage functions in the floodplain, extensive channelizing, and the area of cleared and clearcut land on tributaries and in the headwaters. This is in turn related to an increasing sediment load.
6) Loss of riparian forest cover throughout the mainstem and tributaries causing elevated summer water temperatures and lower water levels, and decreased lateral stability and bank erosion.
7) Aggradation, channel homogenization, channel widening leading to lower water levels and increased water temperatures.

Prescriptions

Prescription sites are on private land in reach 2, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 2 are summarized in appendix F. They relate to slope bank stabilization, and stream shading. The prescription for polygon BUL129 is integrated with impact prescription #2.

Three impact prescription site have been identified based on impacts outlined above, and physical and biological goals for mainstem reaches presented in section 3 of this report. They relate to reestablishing channel morphology at an avulsion site, restoring heavily eroding banks, and buffering floodplain sites from erosion in future floods(see appendix G).

This reach has a moderate priority for restoration as indicated by the reach prioritization table in appendix H

4.22 Bulkley River Reach 3

Land Uses

The floodplain of reach 3 of the Bulkey River has been used extensively for agriculture (ranching and hay production) for decades. Hay fields and rangeland are present on both sides of the river at the reach break near North Bulkley. Moving upstream from the reach break the railroad/ highway corridor confines the channel on the downstream left bank at 800 metres, 1600 metres, 3600 metres and 4000 metres with areas of rip-rap and channel confinement. A rancher has installed a wooden structure to house a pump at 1550 metres. At 1750 metres CN Rail has removed a large LWD jam in order to protect the railroad and at 1850 metres a large section of bank failure related to the railroad was observed. Land use upstream of this reach includes cattle ranching and hay harvesting, forestry, roads and highways, residential housing and powerline corridors. Although the Equivalent Clearcut Area (ECA) has not been calculated for the Upper Bulkley River watershed, it is expected that extensive land use in the headwaters and on the floodplain has altered the runoff regime.

Riparian Assessment

The riparian area of this reach was divided into 38 polygons occupying a total area of 63.6 hectares with a riparian zone width of 50 metres (see Bulkley River entry, appendix D). Land-use has modified 35.06%, or 22.3 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool (SBSdk), with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

On the Bulkley River floodplain, the dominant plant community is predicted to be the black cottonwood-dogwood ($59) on lower-bench areas with more frequent overbank flooding and cottonwood-twinberry ($58) seral association on high bench sites. These are 08 floodplain site series seral associations. Point and other types of gravel bars were dominated by pioneering sand and gravel bar communities of willow (likely *Salix exigua* (Coyote Willow)), red-osier dogwood, and mountain alder. Black cottonwood and twinberry are encountered in these communities further from the water’s edge. Pacific willow-mountain alder-lady fern (TEM code=ML) communities are found in low-bench regularly flooded sidechannels of the Bulkley. North to northwesterly-facing slopes were common where the river was confined by the southern valley wall, and these were dominated by spruce-twinberry coltsfoot (06) site series at the toe of the slope in the riparian zone.

Reach Impact And Restoration Diagnostics

Table 65: Summary of habitat quality indicators by habitat unit category for Bulkley River, reach 3.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	G	M	AR	H	7
Other	S	G	L	AR	N	3
Pool	S	G	L	AR	L	11
Riffle	C	G	M	A	H	5

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	2	5	0	LWD	1
Other	1	2	0	OV	1
Pool	5	3	3	LWD	1
Riffle	3	3	0	B, LWD	1

Table 66: Reach summary of other indicators of impacts to watershed function and fish habitat for Bulkley River, reach 3.

Functional pieces of LWD/bankfull width	**0.69**
Pool frequency	**14.90**
Bankfull : wetted width ratio	**2.09**
Bankfull : wetted depth ratio	**2.19**
Average temperature differential at summer low flows (^{O}C)	**1.14**
Area of disturbed riparian forest (ha)	**22.30**

Table 67: Mean values for selected parameters which may assist in designing instream restoration works, Bulkley River, Reach 3.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	0.50	0.85	20.47	13.67	115.29	4.23
Riffle	0.50	0.66	12.84	13.20	47.46	3.30
Pool	0.50	1.19	11.27	5.33	229.40	5.93
				Reach Mean Estimated Bankfull Discharge	130.72	

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- A complete loss of riparian forest and soil compaction in areas used for hay farming, and in areas used for homes, parkland, buildings, and streets.
- Removal of riparian forest and disconnection of the channel from the riparian zone due to channelizing in transportation corridors and at housing developments on the floodplain.
- Past harvesting of spruce and cottonwood by landowners preceded many of these impacts. Insidious impacts on riparian plant communities from land-use include the introduction of invader species (white clover, Canada thistle), the possible modification of floodplain and channel features (diversions, landfilling), and the removal of LWD which controls lateral channel movement and plant community distribution on the floodplain.
- The simplification of surface drainage patterns and compaction of floodplain soils due to extensive paved areas and storm drain system.
- Drawdown of the floodplain water table for the town water supply and irrigation during drought periods.

Typical riparian polygon photos are found in plates 118-120.

Channel Characteristics

Reach 3 is a 6360 metre long RPgw channel flowing between the elevations of 641 and 645 metres a.s.l., with an average gradient of 0.5%, bankfull width of 13.34 metres, and bankfull depth of 0.85 metres. It is a valley bottom depositional reach whose dominant channel-forming mechanism is LWD (log jams). The reach exhibits a downstream progression and cutoffs pattern of lateral activity. The channel is irregularly meandering with a low degree of lateral stability and occasional channel islands. Bed paving materials are generally sand and gravel. Upslope areas are occasionally coupled to the active channel between 600 and 1500 metres and between 3000 and 5800 metres. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

In this reach, field observations of aggradation were made, with some areas of moderate to severe aggradation. Large elevated mid-channel (medial) bar formation, eroding banks, poor pool frequency, and extensive bars were noted, indicating a high sediment load. This is corroborated to a certain extent by the pool frequency and bed compaction values, as well as by the bankfull:wetted width ratio of 2.09 (bankfull width is double the wetted width). Field observations of bank erosion were made at all riparian polygons with hay farming, and were most severe on outside corners of meanders. The bankfull:wetted depth ratio 2.19 indicates that the channel is incised.

See plates 118-122 for visual examples of channel condition and character.

Fish and Fish Habitat Assessment

Reach 3 can be characterized as very high value fish habitat. 0+ coho and chinook salmon were captured in this reach. Adult chinook spawners were observed at the reach break and at 425, 2100, 4400, 4550 and 6100 metres. Resident white and largescale suckers, and longnose dace were present at the time of survey. Rainbow/steelhead trout (0+/1+/2+/3+/adult) were also caught in this reach. The 0+ and 1+ age-classes are assumed to be dominantly steelhead trout (Tredger, 1984). These species were all present throughout the reach. Sockeye (migrating to Maxan Creek), and pink salmon spawners as well as coho and chinook spawners, and Dolly Varden/bull trout also have a documented presence in the reach (BCCF, 1997). The presence of adult bull trout was established in tributaries to this reach and reach 2, but no Dolly Varden were caught in the extent of the study area in this project. Although standard methods of char identification using the methods of Haas (1996) were not carried out in gathering past fish data, it is likely that char presence cited in references are actually bull trout. Anecdotal information suggested that cutthroat trout were also present in the Bulkley River mainstem. Considering the absence of cutthroat trout from reaches surveyed in all watershed positions throughout the watershed, both above and below impassable barriers, it is unlikely that these references are correct.

This reach, due to its watershed position, its gradient, and dominant channel morphology is a highly important area for holding/migrating, summer rearing, spawning, and overwintering in an unimpacted state in the context of overall watershed productivity and diversity of fish. In particular, species such as steelhead and bull trout will likely not use the mainstem for rearing and spawning, based on habitat preferences for a higher gradient and larger substrate. They may migrate from tributaries into the mainstem for overwintering, and will certainly use it as a migration corridor between habitats for different life stages. Coho salmon are also unlikely to use the mainstem for spawning and rearing unless habitat conditions in tributaries are generally very poor. The results of this survey suggest that coho will migrate out of the sampled tributaries to rear in the mainstem during late summer to avoid generally poor water quality, high temperatures, and low flows. This is based on numbers of coho captured in tributary reaches versus mainstem reaches. Overwintering in the mainstem and off-channel areas has not been studied at this point in time, however it is likely that both of these parts of the river are important for this purpose given the flow conditions (January/February is the winter low-flow period) in many tributaries during the winter, and the amount of open water area versus iced over area. The critical factors governing good overwintering conditions assuming a waterbody that is not frozen solid include low water velocities, good dissolved oxygen concentrations, refuges from ice formed in the water column, and usual conditions related to survival such as food availability. Off-channel areas. if accessible and wetted, will also provide ideal refuges during high water events.

Habitat conditions are as follows (see table 1 (page 9) and figures158):

- Habitat complexity was moderate to good, although the habitat unit tally indicated a proportionately lower number of pools versus riffles and glides. Other (off-channel) units consisted of 10-15% of available habitat. The complexity index of 3.38 indicated a relatively even proportion of units across the spectrum, and in comparison to smaller alluvial channels surveyed was somewhat lower than benchmark reaches. Pool frequency appeared much lower in comparison to smaller channels in the study area, with a value of 14.90 bankfull widths between pools. Extensive glides and riffles indicate the possibility of pool infilling due to sediment load.

- LWD function was minimal in the extra large size class, but moderate in small and large size classes. Although single pieces of LWD do not significantly effect channel morphology, lateral log jams and functional wood at the wetted channel margins was considered as functional. Functional LWD was averaged over the reach for all size classes at 0.69 pieces/bankfull width, and was found functioning in all units sampled. Its function was greatest in pools, where it was instrumental in pool formation, as well as being (modally) the dominant cover element. Log jams, particularly lateral log jams, occurred frequently throughout the reach.
- Spawning gravels were high in glides and riffles and low in pools. No spawning gravels were observed in other (off-channel) units. Spawning gravels were suitably sized and of suitable area for both resident and anadromous salmonid spawners except in riffles where the large particle size limits use by resident fish.. Bed compaction was moderate in glides and riffles (including pool tailouts) and low in pools and others.
- Cover elements showed minimal complexity, but were frequently in-stream types. LWD was dominant in glides and pools with riffles being dominated by boulders as well as LWD. Overhead vegetation was the modal cover element for off-channel units.

Canopy closure was 0-20% on average. The average temperature differential of 1.14 ^{o}C reflected this, with water temperatures (15.5 ^{o}C) at the time of survey exceeding thermal maxima for preferred juvenile rearing and Dolley Varden spawning and meeting the maximum temperature for rainbow trout spawning, so some metabolic stress loading can be assumed. Temperatures were taken during the high air temperature/summer low flow critical period.

Use of habitat by different fish species can be characterized as follows (see figures 154 to 157):

- Pools were used by the greatest diversity of species and age-classes of fish in this reach and were the only unit in which white suckers were captured. These units showed the highest density of 0+ coho, chinook and largescale suckers in this reach. Four age-classes of rainbow trout were captured in these units with 1+ juveniles being the most abundant.
- Riffles were used by coho (0+), longnose dace and rainbow trout. Rainbow trout dominated these units with the highest density of 0+ juveniles encountered in this reach.
- Chinook, coho rainbow trout/ steelhead, longnose dace and largescale suckers were present in glides in low densities when compared to riffles and pools. Glides in this reach tended to be long and deep with concentrated cover elements which accounts for the low densities of fish present. 0+ chinook and 0+ and 1+ rainbow trout/ steelhead

were the most abundant species captured in glides.
Other (off-channel) habitat was occupied by largescale suckers, longnose dace, rainbow trout/ steelhead and very few 0+ chinook.

Impact Synopsis

Without a comparison to previous habitat and channel conditions, regional habitat and channel standards, or unimpacted reaches of a similar type, it is difficult to make inferences about habitat damage. Field observations of channel and riparian impacts are somewhat useful in this regard, as well as comparison of certain ratio-based and proportional indices which are not sensitive to changes in scale. In this case, such parameters are pool frequency, functional LWD frequency, the complexity index, and bankfull:wetted width and depth ratios.

These results suggest that fish habitat has been damaged in reach 3. Of particular concern are high water temperatures and a low average temperature differential, the effects of a high sediment load on fish habitat such as spawning gravel compaction, substrate embedding and loss of microhabitat for juvenile fish and certain invertebrate species, and the loss of pool frequency and the homogenization of habitat, and the effects of a high sediment load and possibly altered runoff regime on channel pattern and geometry. Effects on the latter magnifies sediment load problems by increasing rates of internal sediment source delivery through bank erosion and avulsions. Impact sources are dominantly not isolated to this particular reach, and are cumulative in nature.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) Channelization by the railway increasing water velocities and causing bank erosion downstream, as well as removing riparian forest function and disconnecting the channel from the floodplain.
2) Removal of riparian forest for hay farming and other land use causing bank erosion at various points in the reach.
3) Alteration of surface and groundwater flow patterns by ranchers and farmers for irrigation purposes.
4) Removal of LWD jams by CN Rail to protect the railroad tracks at 1750 metres.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows :

1) Loss of pool frequency and volume, and substrate compaction and embedding due to a high sediment load related to upstream sediment sources.

Increasing rates of bank erosion, channel incision, and meander cutoff (avulsions) due to increases in discharge and stream power as spring runoff responds to an overall loss of water storage functions in the floodplain, extensive channelizing, and the area of cleared and clearcut land on tributaries and in the headwaters. This is in turn related

to an increasing sediment load.
2) Loss of riparian forest cover throughout the mainstem and tributaries causing elevated summer water temperatures and lower water levels, and decreased lateral stability and bank erosion.
3) Aggradation, channel homogenization, channel widening leading to lower water levels and increased water temperatures.

Prescriptions

Prescription sites are on private land in reach 3, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 1 are summarized in appendix F. They relate to slope stream shading, and creating future sources of LWD. There are no impact prescriptions for reach 3.

This reach has a moderate priority for restoration as indicated by the reach prioritization table in appendix H

4.23 Emerson Creek Reach 1

Land Uses

Land-use in reach 1 includes a railway and road crossing (bridges) with a long channelized (rip-rap) section between 316 and 425 metres upstream, and continued presence of the Walcott road on the upper valley wall (downstream right) to 1800 metres upstream. The roadcut is only in a position to impact the creek for short sections up to 900 metres upstream where it is directly above the creek in confined sections of steep valley walls. Upstream land uses include forestry and forest access roads. The Equivalent Clearcut Area (ECA) of the Emerson sub-basin is 21.5% (BCCF, 1997). Land-use in the headwaters may possibly have altered the runoff regime, as the ECA falls within the 20-25% range where basin hydrologic response to land clearing is variable.

Riparian Assessment

The riparian area of this reach was divided into 13 polygons occupying a total area of 20.8 hectares with a riparian zone width of 30 metres (see Richfield Creek entry, appendix D). Land-use has modified 6.2%, or 1.28 hectares of this. The BEC classification for this reach is sub-boreal spruce/dry-cool, with several different site series predicted from bank texture, species presence, floodplain/channel characteristics, and general field observations.

On the alluvial fan of Emerson Creek, the dominant plant community is predicted to be the cottonwood-twinberry ($58) seral association with areas of black cottonwood-dogwood ($59) on mid-bench areas with less frequent overbank flooding. These are 08 floodplain site series seral associations. Where the reach becomes more confined at 2700 metres, hillside site series are predicted as spruce-twinberry-coltsfoot (06).

Land-use impacts affecting watershed function, channel morphology, and fish habitat in the riparian zone include:

- Loss of riparian forest and channelizing at the railway/road crossing (110 metres in length). This is leading to bank erosion both upstream and downstream of the channelized area.
- A small area of conifer/cottonwood harvesting leading to extreme lateral channel movement at 681 metres upstream
- Several areas of slope instability on the valley wall below the Walcott road between 790 and 1100 metres upstream from the mouth.

A typical riparian polygon is found in plate 124.

Reach Impact and Restoration Diagnostics

Table 68: Summary of habitat quality indicators by habitat unit category for Emerson Creek, reach 1.

Unit Category	Modal Dom. Substrate Size-Class	Modal Subdom. Substr. Size-Class	Modal Bed Compaction	Modal Spawning Gravel Type	Modal Spawning Gravel Amount	Mean Total LWD Tally (Funct./Non-Funct.)
Glide	C	G	M	AR	H	3
Other	G	S	H	AR	L	3
Pool	G	C	L	AR	H	5
Riffle	C	G	H	AR	H	5

Unit Category	Mean Small Funct. LWD Tally (10-20 cm)	Mean Large Funct. LWD Tally (20-50 cm)	Mean Extra Large LWD Tally (50+ cm)	Modal Dom. Cover Types	Modal Canopy Closure Category (%)
Glide	2	1	0	OV	1
Other	1	2	0	OV	2
Pool	3	3	0	LWD, OV	1
Riffle	1	4	0	OV, C	1

Table 69: Reach summary of other indicators of impacts to watershed function and fish habitat for Emerson Creek, reach 1.

Functional pieces of LWD/bankfull width	**0.58**
Pool frequency	**9.69**
Bankfull : wetted width ratio	**1.46**
Bankfull : wetted depth ratio	**1.71**
Average temperature differential at summer low flows (^{O}C)	**11.00**
Area of disturbed riparian forest (ha)	**11.9**
Length of disturbed channel (m)	**1738**

Table 70: Mean values for selected parameters which may assist in designing instream restoration works, Emerson Creek, Reach 1.

Unit	Gradient (%)	Bankfull Depth (m)	Bankfull Width (m)	D (cm)	Est. Q (m3/s)	Trac. Force (kg/m2)
Glide	1.69	0.45	9.85	11.75	42.44	7.55
Riffle	1.75	0.53	10.82	17.00	51.36	9.21
Pool	1.63	0.81	6.85	8.17	130.76	13.08
				Reach Mean Estimated Bankfull Discharge	74.86	

Channel Assessment

Reach 1 is a 2600 metre long RPcw channel flowing between the elevations of 563 and 606 metres a.s.l., with an average gradient of 1.34%, bankfull width of 6.1 metres, and bankfull depth of 0.47 metres. It is a semi-confined depositional valley bottom reach whose dominant channel-forming mechanism is LWD. Streambanks are composed of a mix of unconsolidated alluvial materials (sand/gravel/cobble) with areas of cohesive clay banks, and consolidated slump/earthflow deposits (clay/cobble/boulders) and colluvium (boulders). The latter two types are found near the upper end of the reach which is more confined and dominated by hillslope erosional processes. Emerson Creek and other creeks draining the northeasterly aspect of the Telkwa mountains cut through the glaciofluvial terrace of the Bulkley River and weathered lava flow terraces, and valley walls within these canyons are highly erodible and susceptible to land-use induced mass movements. The channel is irregularly wandering with a moderate degree of lateral stability. Upslope areas are sporadically connected to the active channel except in the lower end of the reach (0-800 metres) which is disconnected from upslope areas. The floodplain plays a key role in an unmodified state in channel morphology, and maintaining fish habitat, and riparian plant communities through LWD recruitment, buffering streamflows, moderating temperatures, acting as a sink and source for sediment/bedload, and creating diverse habitat through lateral movement.

Channel assessment in reach 1 indicated that 67% (1738 metres) of channel is moderately to severely disturbed. In these channel disturbance polygons, the channel was classified as both aggrading (A2-A3) and degrading (D2) (see appendix C). The section of degradation is isolated, and related to channelizing at the road/railway crossing. Dominant indicators of disturbance in this section extensive areas of scour, long riffles, minimal pool area, and poor LWD function. Dominant indicators of disturbance in aggraded sections include sediment wedges, extensive bars, elevated mid-channel bars, abandoned channels, and eroding banks. It was noted in field observations that beavers, which appear to have historically made use of the main channel are now dominantly damming wetted floodplain areas. Many beaver ponds which would have been fed by the mainstem were dry or breached at the time of survey. This may indicate an increase in the rate of lateral movement and/or extremes in flow. Bankfull:wetted width and bankfull:wetted depth ratios (1.46 and 1.71 respectively) indicate a similarity to benchmark conditions. Sources of aggradation include one very large slope failure and debris flow in reach 2 off a firebreak of cutblock FLA-16828-CP424-01 (forest cover map 93L.046, opening #12), and two slope failures related to surface and groundwater flow alteration and concentration below the Walcott Road. Internal sediment sources due to bank erosion must be included here as well. See plate 124 for a visual example of channel condition and character.

Fish and Fish Habitat Assessment

Reach 1 can be characterized as very high value fish habitat. Chinook salmon (0+), and resident Dolly Varden (0+/1+/2+), and bull trout (0+/1+) were present at the time of survey. Rainbow/steelhead trout (0+/1+/2+) were also captured. The 0+ and 1+ age-

classes are assumed to be dominantly steelhead trout due to a lack of barriers upstream from the mainstem (Tredger, 1984). All species were captured throughout the reach. An impassable falls is located at approximately 3200 metres upstream from the mouth (UTM=9.6033600.639800) The reach had not been sampled by any known government or private agency prior to this project, and therefore no historic data was available for comparison, and established use by other species in different seasons.
Reach 1, due to its position relative to the mainstem, its gradient, and dominant channel morphology is an important area for juvenile bull trout production in an unimpacted state in the context of overall watershed productivity and diversity of fish. Juvenile bull trout were not sampled at any point during surveys of tributaries to the Upper Bulkley River, although several adults were. The proximity of this creek to the Upper Bulkley River, and the abundance of juvenile bull trout indicate the importance of this reach as a population center and critical refuge area for this species in the context of adult populations in the Morice and Upper Bulkley River systems. Temperature, substrate, and flow conditions also indicated its importance as a summer rearing and spawning area for anadromous and resident salmonids. Its use by salmon species in particular may depend on densities of inter- or intra-specific competitors (for space and resources) in the mainstem and downstream tributaries, as well as habitat condition.

This reach exhibits marginally degraded habitat relative to benchmark conditions (see figure 166 and table 1 (page 9)). Habitat complexity falls within 1 standard deviation of the benchmark with a complexity index of 3.38. Riffles dominate the spectrum of habitat units, although not by an extreme margin. Cascades become more frequent towards the end of the reach. Compaction was high in riffle and off-channel units, moderate in glide units, and low in pools. Spawning gravels were abundant in pool tailouts, riffles, and glides, all of which had gravel sizes suitable to resident and anadromous spawners. LWD function is moderate to low in all size classes except extra large which is in low supply in the active channel. Functional LWD frequency is 0.58 pieces/bankfull width (see figure 165 and table 69). The latter value is within 1 standard deviation of the benchmark value and as such is considered within the bounds of benchmark conditions. On average, functional LWD (affecting cover, morphology) is found in all unit categories, although no extra large functional LWD was present in any of the units sampled. Pool frequency is 9.69 bankfull widths between pools, which falls 1.6 standard deviations from the benchmark of 3.67, and is considered to be responding to land-use impacts. Cover elements showed moderate complexity, with little in-stream cover except in pools. Cover usually consisted of overhead vegetation, as well as cutbanks in riffles, and LWD in pools. Modal canopy closure was 0-20%. The average temperature differential of 11 ^{o}C did not reflect this, with maximum water temperatures (11.5 ^{o}C) not exceeding thermal maxima for any species present at the time of survey (extreme summer temperatures/lowest water levels).

Use of habitat by different fish species can be characterized as follows (see figures 161 to 164):

- Pools were used by a diverse range of species and age-classes, mostly larger juveniles (0+ salmon, and 1+/2+ char and trout). This was the only unit category where 2+

Dolly Varden were captured, and as such are considered a critical habitat for this species/life stage. Other species were present in moderate densities, with the exception of 2+ rainbow/steelhead which were in higher densities than riffles.

- Riffles were occupied by bull trout, Dolly Varden, and rainbow/steelhead, with 6 age-classes present (dominantly smaller juveniles). 0+ bull trout were the dominant species in riffles, followed by 0+ rainbow/steelhead. Riffles do not appear to be critical rearing habitat for any of these species based on densities encountered in the field.
- Four species and seven age-classes were present in glides, mostly smaller juvenile fish. Highest densities of chinook salmon, and 1+ rainbow/steelhead were present in glides, indicating their importance to these species. Moderate densities of other species/age-classes were present.
- Other (off-channel) habitat yielded 3 species and 5 age-classes. Highest densities of Dolly Varden and bull trout were present in off-channel habitats.

Impact Synopsis

Land-use in this reach has marginally damaged fish habitat quantity and quality. Of particular concern are the low pool frequency and extensive channel disturbance. Impact sources are dominantly isolated to this particular reach, and are not cumulative in nature. However, the large debris flow in reach 2 will also be having a significant impact on downstream habitat.

Category 1 Impacts

Isolated, point-source impacts in this reach are as follows:

1) The channelized section between 316 and 425 metres upstream is leading to habitat simplification, bank erosion, channel straightening and aggradation downstream, aggradation and bank erosion upstream (the channel is not widening in response to a higher sediment load and therefore bedload/sediment builds up upstream). Aggradation, channel straightening and bank erosion are propagating downstream leading to pool infilling, loss of complexity and LWD function and compaction/embedding of spawning substrate (field observations).
2) Slope instability at two points below the Walcott road (and from the reach 2 debris flow) are increasing sediment loads downstream, and combined with poor bank strength at the small cutblock at 680 metres upstream, is leading to extensive bank erosion and channel widening and subsequent effects on LWD function, pool frequency, and spawning habitat.

Category 2 Impacts

Cumulative and non-point source impacts in this reach are as follows:

Upstream sediment sources and possible changes to the runoff regime may be leading to downstream sediment delivery and increased lateral channel movement. This potential will certainly increase if proposed cutblocks are approved in the current five year forest development plan.

Prescriptions

Prescription sites are on private land in reach 1, and therefore only conceptual prescriptions are presented.

Riparian prescriptions for reach 1 are summarized in appendix F. They relate to slope stabilization, bank stabilization, stream shading, and sediment filtering. The prescription for polygons EME2 is integrated with impact prescription #1, and EME6 and 7 are integrated with impact prescription #2.

One impact prescription site has been identified based on impacts outlined above, and physical and biological goals for mainstem reaches presented in section 3 of this report. It relates to mitigating upslope sources of sediment at slope failures below the Michelle Bay FSR (see appendix G).

Priority and sequence of prescriptions for the Emerson Creek sub-basin is presented in figure 167. This reach has a high priority for restoration as indicated by the reach prioritization table in appendix H.

Emerson Creek Sub-Basin Restoration Priorities

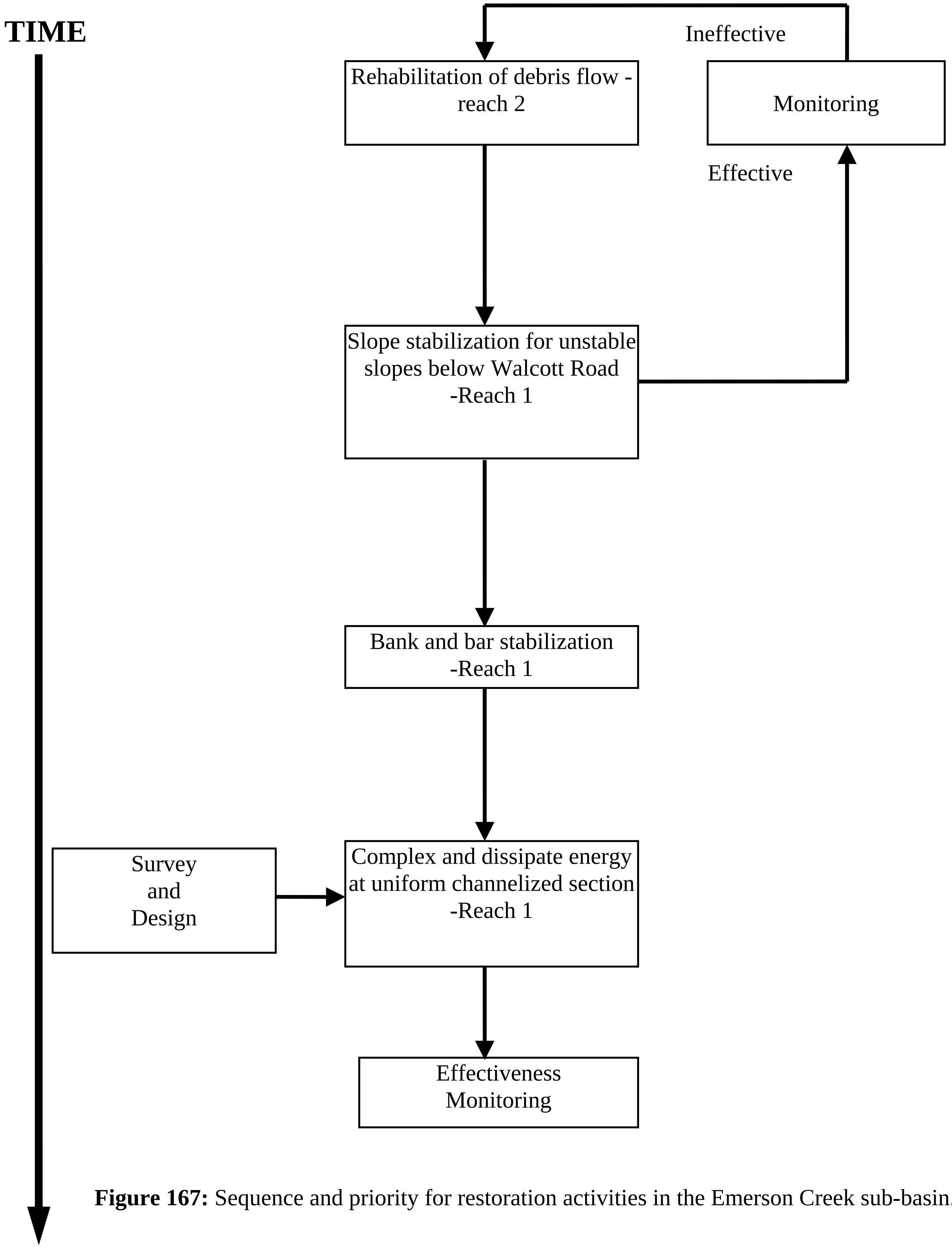


Figure 167: Sequence and priority for restoration activities in the Emerson Creek sub-basin.

Dockrill Creek Reach 1

Dockrill Creek was surveyed and sampled throughout the reach. Fish sampling determined that the reach had extremely low fisheries values, except at its confluence with the Bulkley River for the first 100 metres upstream. The creek is glacial fed, without any significant sediment sinks such as wetlands along its length. Consequently, water temperatures are very cold, the water is very turbid, the creek carries a naturally high sediment load, and gradients are steep even in reach 1 which is an alluvial fan. This is compounded by seasonally high discharges in the summer due to glacial meltwater.

The results of the survey will only be presented in an abridged fashion, as no restoration is prescribed for this reach. The highly active floodplain, gradient, high sediment load, and flashy discharge would require extensive planning and higher investment to restorative works with a high probability of failure. Furthermore, the low fisheries values do not indicate a thriving aquatic ecosystem, nor has there been any historic documentation of higher historic fisheries values in this system.

Land-use in this reach includes the Walcott Road crossing, railway crossing, and two clearcuts on the floodplain. Upstream land use is confined to forest harvesting activities. Future planned forestry is low (BCCF, 1997).

Fish species present include rainbow/steelhead, chinook salmon, longnose suckers, and Dolly Varden (juveniles, 0+ to 1+ age classes). Two mountain whitefish adults were observed holding in a deep glide. One mountain whitefish carcass was found (not a spawner) upstream of the Walcott Road bridge. All fish were caught below 500 metres upstream and in very low densities. Chinook salmon were only caught in the first 100 metres from the Bulkley River confluence.

5.0 Recommendations

Reach priority for restoration, as outlined in section 3 of this report, is presented in appendix H. Sub-basin priority for restoration is presented in table 71a. A prioritized list of restoration work is presented in table 71b, including costs for those sites on crown land. A prioritized list of assessment, survey, and design work is presented in table 72, including cost for work required on crown land. These priorities follow watershed level physical and biological goals for different physiographic groups in each sub-basin, as presented in section 3 of this report.

A general recommendation can be made concerning work on private land. FRBC watershed restoration funds have traditionally been available only for work on public (crown) lands related to forest harvesting impacts. Several exceptions have been made recently where works are shown to be related to upstream forest harvesting impacts, and the net result of carrying out restoration on crown lands only will not be sufficient for watershed restoration objectives to be met. FRBC investments are protected by designating the works as “fish habitat” under the Fisheries Act and Fish Protection Act, and with a signed agreement by the landowner not to alter the works. Should the proponent and/or implementing partners succeed in ratifying such an agreement with both the landowner and FRBC, it is recommended that priority work on private lands proceed. Private land overlaps critical fish habitat and floodplain areas in the watershed, and it is paramount that these areas be addressed fully and in proper sequence in carrying out restoration activities (i.e.- in accordance with sub-basin restoration plans).

Table 71a: Sub-Basin priority for restoration based on ranks assigned for fish values, relative watershed value (basin size, position), level of land-use impacts, and level of cumulative impacts. For the latter, a lower rank is assigned for a lower level of impact. Highest priority is 1 and lowest is 8.

Sub-Basin	Fish Values	Watershed Value	Level of Impact	Cumulative Impacts	Rank
Richfield	6	3	2	1	**1**
Emerson	2	8	1	2	**2**
McQuarrie	7	4	3	3	**3**
Barren	5	6	4	4	**4**
Aitken	8	2	5	6	**5**
Byman	4	5	6	5	**6**
Buck	3	1	7	7	**7**
Bulkley	1	7	8	8	**8**

Table 71b: Prioritized list of riparian and in-stream restoration work by sub-basin.

Sub-Basin	Project Priority	Reach	Impact Prescription Site	Riparian Prescription Polygon ID	Cost Estimate	Assessment/Survey/ Design Required?	Comments
Richfield	1	1	3	RIC11	N/A	no	
	2	1	-	RIC008/009	N/A	no	
	3	1	2	-	N/A	no	Upstream of highway only
	4	1	1	RIC007	N/A	yes	
	5	1	-	RIC002, 004	N/A	no	
	6	1	2	-	N/A	no	Downstream of highway
Byman	1	1	2	BYM008 to 020	N/A	no	Passive riparian restoration work only
	2	1	1	BYM015, 017	N/A	yes	Slope stabilization part of prescriptions
	3	1	2	BYM008 to 020	N/A	yes	Active riparian restoration if required
	4	1	1	-	N/A	yes	Active in-stream restoration
McQuarrie	1	3	1	MCQ19	$73 000	yes	
	2	1	-	MCQ001/002	N/A	no	
	3	1	-	MCQ003 to 005	N/A	no	
	4	3	-	MCQ015	$5 200	yes	After road work completed under MOF WRP funding
	5	1	-	MCQ009	N/A	no	
	6	1	1	MCQ008	N/A	no	
	7	1	2	-	N/A	yes	
Barren	1	2	-	BAR018 to 023	$29 000	no	Land tenure unknown
	2	4	4	BAR017	$49 800	yes	Land tenure unknown
	3	2	3	-	N/A	no	
	4	2	2	BAR008	N/A	no	
	5	1	1	BAR003	N/A	yes	
Aitken	1	3A	1	AIT025	N/A	no	All work to occur after hydrologic assessment
	2	3A	2 and 3	AIT029, 030 to 033, 035	N/A	no	
	3	3A	4	AIT037	N/A	no	
Buck	1	11B	1	UB008	$29 350	yes	All works to occur after basin-wide hydrologic ass't
	2	11B	-	UB001 to 007	$21 000	yes	
	3	Klo 2	1	KLO021 and 022	N/A	yes	
	4	6		BUC172, 199, 207, 228	N/A	no	
	5	6	-	BUC169, 177, 185, 192, 194	N/A	no	
	6	5	-	BUC139 and 157	N/A	no	

Table 71b: Prioritized list of riparian and in-stream restoration work by sub-basin cont'd.

Sub-Basin	Project Priority	Reach	Impact Prescription Site	Riparian Prescription Polygon ID	Cost Estimate	Assessment/Survey/ Design Required?	Comments
Buck	7	5	-	BUC090, 098-100, 108/109, 112/113, 125, 143/144	N/A	no	
	8	4	1	-	N/A	no	
	9	4	-	BUC064/065, 078, 087	N/A	yes	Land tenure unknown, may need SP
	10	2	-	BUC023, 042/043, 045, 048/049, 055	N/A	no	
	11	Dungate 1	-	DUN001 to 003a	N/A	no	
	12	2	1	-	N/A	no	If active restoration required
	13	1	2	BUC010 to 012	N/A	yes	If active restoration required
	14	1	1	BUC004, 006/007	N/A	yes	If active restoration required
Emerson	1	1	2	EME006/007	N/A	no	Land tenure unknown. To be carried out after upstream sediment source mitigated.
	2	1	-	EME005	N/A	yes	Land tenure unknown.
	3	1	1	EME001/002	N/A	yes	Land tenure unknown.
Bulkley	1	3		BUL262, 267, 268	N/A	no	
	2	2	3		N/A	yes	
	3	1/2/3		All rip-rap planting prescriptions	N/A	no	
	4	2	2	All bank stabilization prescriptions	N/A	no	
	5	2	1	BUL063	N/A	yes	Avulsion reset after upstream bank stabilized
	6	1	1	BUL029 and 032	N/A	yes	
	7	1		All bank stabilization prescriptions	N/A	no	
				Total estimated cost for crown land sites			**$207 350**

Table 72: Priority list of assessment/survey/design work by sub-basin

Sub-Basin	Sub-Basin Priority	Site Priority	Description	Cost
Richfield	1	4	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
Byman	2	2	Consultation and site visit with P. Geo	N/A
		4	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
McQuarrie	3	1	Survey, material sizing, engineering drawings by river and road engineers	$10 200
		4	Silviculture prescription	$1 600
		7	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
Barren	4	2	Survey, material sizing, engineering drawings by river and road engineers	$8 600
		5	Consultation with river engineer/geomorphologist, site survey and prescription drawings. Off-channel assessment (water quality, hydrogeology).	N/A
Buck	6	1	Survey, material sizing, engineering drawings by river and road engineers. Silviculture prescription	$10 200
		2	Silviculture prescription	$1 600
		3	Consultation and site visit with P. Geo. Silviculture prescription	$4 660
		13	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
		14	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
Emerson	7	2	Silviculture prescription required if land tenure is crown	$1 600
		3	Consultation with river engineer/geomorphologist, site survey and prescription drawings.	$8 600
Bulkley	8	2	Consultation with river engineer/geomorphologist, site survey and prescription drawings. Flood channel mapping and site selection.	N/A
		5	Consultation with river engineer/geomorphologist, site survey and prescription drawings	N/A
		6	Site visit and consultation with P.Geo.	N/A
			Total estimated cost for crown land sites	**$47 060**

References and Bibliography

Anonymous. 1998a. Habitat Restoration Prescription Guidebook. MELP, Watershed Restoration Program, Victoria, BC. 19 pp.

Anonymous. 1998b (Draft). Riparian Assessment and Prescription Procedures. Watershed Restoration Technical Circular No. 6. MELP, Victoria ,BC. 43 pp.

Banner, A., W. MacKenzie, S. Haeussler, S. Thomson, J. Pojar and R. Trowbridge. 1993. A Field Guide to Site Identification and Interpretation for the Prince Rupert Forest Region, Parts 1 and 2. MOF. Victoria, BC. 503 pp.

BC Conservation Foundation. 1997. Mid-Bulkley Overview Fish and Fish Habitat Assessment for Watershed Restoration. BCCF. Smithers, BC

Chatwin, S.C., D.E. Howes, J.W. Schwab and D.N. Swanston. 1994. A Guide for Management of Landslide-Prone Terrain in the Pacific Northwest, Second Edition. MOF. Victoria, BC. 220 pp.

Donat, M. 1995. Bioengineering Techniques for Streambank Restoration: A Review of Central European Practices. Watershed Restoration Project Report No. 2. MELP, MOF. Victoria, BC. 86 pp.

Doppelt, B., M. Scurlock, C. Frissell, J. Karr. 1993. Entering the Watershed: A New Approach to Save America's River Ecosystems. The Pacific Rivers Council. Island Press. Washington, D.C., Covelo, California. 462 pp.

Haeussler, S. 1998. Rare and Endangered Plant Communities of the Southeastern Skeena Region MELP, Smithers, BC. 88 pp.

Hogan, D.L. and D.J. Wilford. 1989. A Sediment Transfer Hazard Classification System: Linking Erosion to Fish Habitat. pgs. 143 to 155. **in** E.B. Alexander (ed.). 1989. Proceedings of Watershed '89: A Conference on the Stewardship of Soil, Air and Water Resources. USDA Forest Service, Alaska Region. Juneau, AK.

Johnston, N.T. and P.A. Slaney. 1999. Fish Habitat Assessment Procedures. Watershed Restoration Technical Circular No. 8. MELP, Victoria , BC. 97 pp.

Mackay, S.D. 1998. Integrated Fish Habitat/ Channel Assessment Field Procedure. Skeena Region Watershed Restoration Technical Addendum. MELP, Smithers, BC. 9 pp.

MacKinnon, A., J. Pojar. and R. Coupe (eds.). 1992. Plants of Northern British Columbia. Lone Pine Publishing. Vancouver, BC. 345 pp.

McPhail, J.D. and R. Carveth. 1994. Field Key to the Freshwater Fishes of British Columbia. Aquatic Inventory Task Force of the Resources Inventory Committee (RIC). Victoria, BC. 233 pp.

Newbury, R.W. and M.N. Gaboury. 1993. The Evaluation of Stream Behaviour and Characteristics. pgs. 53 to 90 **in**: R.W. Newbury and M.N. Gaboury. 1993. Stream Analysis and Fish Habitat Design *A Field Manual*. Manitoba Fisheries Branch, Winnipeg.

Newsholme, C. Chapter Two: General Characteristics of Willows and Chapter Three: Management and Cultivation. pgs. 22 to 43. **in** C. Newsholme. Willows the Genus Salix. Timber Press. Portland, Oregon.

Oikos Environmental Services Ltd. 1998. A Field Guide for Identification and Interpretation of Seral Deciduous Forests in the Sub-Boreal Spruce Dry Cool Subzone (SBSdk) and the Interior Cedar Hemlock Moist Cold Subzone (ICHmc2) Prince Rupert Forest Region. Prince Rupert Forest Region, Smithers, BC. 53 pp.

Pacific Rivers Council, Inc., The. 1996. Healing the Watershed: A Guide to the Restoration of Watersheds and Native Fish in the West. The Pacific Rivers Council. Eugene, Oregon. 212 pp.

Pojar, J. and A. MacKinnon (eds.). 1994. Plants of Coastal British Columbia Including Washington, Oregon and Alaska. Lone Pine Publishing. Vancouver, BC. 527 pp.

Porter, G.L. 1990. Willow Species of Disturbed Sites in the Sub-Boreal Spruce Zone in North-central British Columbia. MOF. Victoria, BC. 67 pp.

Rhodes, J.J., D.A. McCullough and F.A. Espinosa Jr. 1994. A Coarse Screening Process for Evaluation of the Effects of Land Management Activities on Salmon Spawning and Rearing Habitat in ESA Consultations. Columbia River Inter-Tribal Fish Commission. Portland, Oregon. 127 pp.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada (Bulletin 184) Fisheries Research Board of Canada, Ottawa, ON. 966 pp.

Slaney, P.A. and D. Zaldokas. 1997. Fish Habitat Rehabilitation Procedures. Watershed Restoration Technical Circular No. 9. MELP. Victoria, BC.

Soto, C. 1997a. Barriers and Obstructions to Fish Passage: Culverts. pgs. 10 to 14 **in** C. Soto (ed.) Streamline: BC’s Stream Restoration Technical Bulletin, Vol. 2, No. 2. Watershed Restoration Program. Vancouver, BC. 20 pp.

Soto, C., A. Wilson, D. Heller, R. Ragan. 1997b. Lateral and Mid-Channel Bar

Stabilization. pgs. 1 to 4. **in** C. Soto (ed.). Streamline: BC's Stream Restoration Technical Bulletin, Vol. 2, No. 3. Watershed Restoration Program. Vancouver, BC. 20 pp.

Valentine, K.W.G., P.N. Sprout, T.E. Baker and L.M. Lavkulich (eds.). 1986. The Soil Landscapes of British Columbia. BC Ministry of Environment. Victoria, BC. 197 pp.

Sub-Basin: Richfield
Creek: Richfield
Reach:1
Prescription #:1
Related Riparian Prescription: RIC007
Category:2
Location:0+850 metres upstream from mouth, UTM 9.6044150.672380, Highway 16 crossing
Land Tenure: Private, highway right-of-way
Impact Description: Channelizing on both banks with rip-rap to bankfull height, two pipe-arch culverts, one impassable at most flows, both impassable at low flows.

Prescription Photo: Representative shot of impacted area showing culverts with summer low flow water levels.

Goal(s): To complex habitat and dissipate hydraulic energy. To provide access upstream to juvenile salmonids during the summer low-flow period.

Master Plan Objectives:
1) Reestablish upstream access to resident and anadromous fish species where barriers have been created by land-use.
2) Reestablish spatial habitat diversity and quality, and hydraulic energy dissipation in areas that have been channelized. A long-term goal which requires cooperation between private landowners and regulatory agencies is the de-channelizing of these areas and their reconnection to normal floodplain functioning, which is beyond the scope of this project.

Description of Proposed Works (see figure 175)**:**

- Build three riffle structures (one above culvert, two below) to initiate vertical variability in hydraulic energy and the sorting of stream substrate to form a riffle:pool morphology. The first riffle below the culvert will have a higher crest and length (maintaining the same grade on the face of the riffle) to backwater the culvert at summer low flows. Initial design specifications are presented in the conceptual prescription drawing. Other design data relating to D, tractive force, and estimated bankfull discharge are presented in the reach impact and restoration diagnostics.
- Clean rock and concrete debris from in front of both culverts and in their plunge pools which will obstruct access and/or interfere with pool formation.
- Plant the rip-rap with live cuttings of deciduous trees and shrubs (see riparian prescription)

Technical References:

- Newbury et al., 1997
- Soto, 1997
- Donat, 1995
- Newbury and Gaboury, 1993

Sub-Basin: Richfield
Creek: Richfield
Reach:1
Prescription #:2
Related Riparian Prescription: none
Category: 1
Location: 0 to 0+390 metres and 1+050 to1+923 metres upstream from the mouth
Land Tenure: Crown (within bankfull width), private land on both banks throughout prescription area
Impact Description: Extensive point and mid-channel bars due to upstream sources of sediment and bedload.

Prescription Photo: Representative photo of extensive aggradation, showing elevated lateral bar at 0+160 metres upstream.

Goal(s):
To stabilize aggraded areas which will continue to promote channel instability despite upstream restoration efforts for some time if not actively restored. This step is not to be carried out until all other restoration work in the reach is complete.

Master Plan Objectives:
6) Stabilize extensive bars and promote channel narrowing and deepening where feasible and when upstream sources of disturbance have been alleviated.

Description of Proposed Works (see figure 176)**:**

- Place several large to extra-large size-class LWD with rootwads facing the current in a cross-wise pattern armouring the top of the bar. Bury the top half of these trees in the streambed. This configuration will promote sedimentation downstream, and an excellent environment for the seed and whips of shrubs and trees to colonize the tail end of the bar. LWD is to be transported from a road site and moved into place with the aid of a horse logging company and a crew to assist in fine-tuning the placements of logs.
- In the voids between crossed logs, whole willow root-balls (select a nearby gravel bar colonizing species such as coyote willow) are to be planted in the substrate following one bankfull flood's sedimentation. This will serve to speed the stabilization of the bar.

Technical References:

- Soto et. al., 1997b

Sub-Basin: Richfield
Creek: Richfield
Reach: 1
Prescription #: 3
Related Riparian Prescription:RIC011
Category: 1
Location: 2+478 metres upstream from the mouth, UTM 9.6045100.672300
Land Tenure: Private
Impact Description: Rotational slump on right valley wall, sand and clay slump block sliding on a sandy stratum. Below cleared and grazed land. Cattle use of several benches on the face is probably exacerbating the problem.

Prescription Photo: Showing slump in background and extensive aggradation downstream. Note the many small areas of slumping on the slump block face.

Goal(s): To mitigate downstream sediment delivery from this site. Channel disturbance and land use is minimal in reach 2 upstream.

Master Plan Objectives:

5) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probablity of success despite upstream sources of disturbance, and/or when passive restoration needs to be integrated with active restoration.

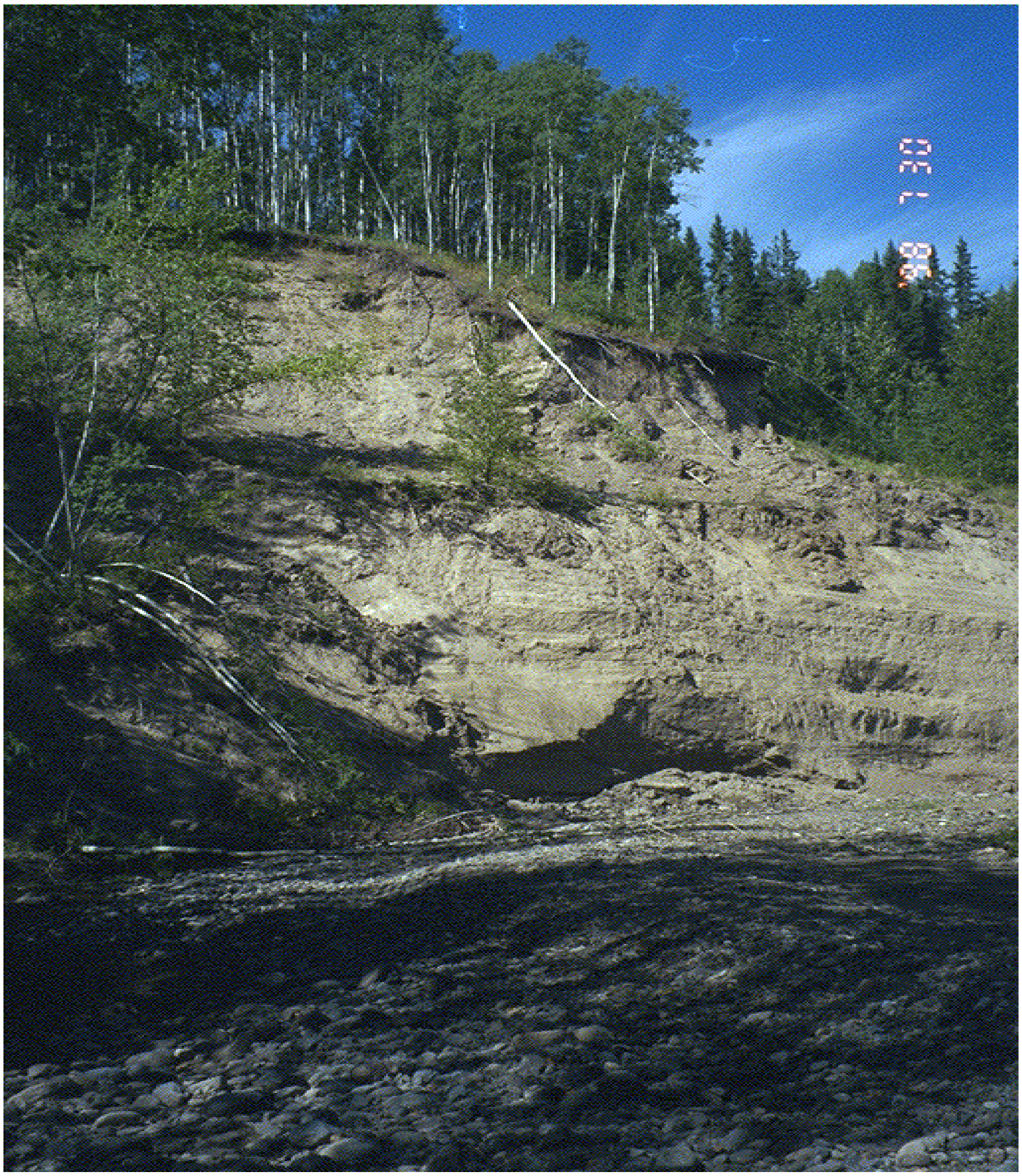
Description of Proposed Works:

- Armour the toe of this slope (approximately 50 m long) with large cobble size class rip-rap and carry out the related riparian prescription. Toe armouring should be placed to a level below the existing thalweg to ensure that works are not undercut by scour. Access should be arranged with the landowner, for which there is a secondary road to within 200 metres of the site. A chainsaw winch could be used to haul the rock the remaining distance. Alternately, a hoe and driver with low impact tires could be employed to do this, as well as a team of draft horses from a horse-logging outfit.

Technical References:

- Donat, 1995
- Chatwin et al., 1994

Sub-Basin: Byman
Creek: Byman
Reach: 1
Prescription #: 1
Related Riparian Prescriptions: BYM15 and BYM17
Category: 1
Location: 2+045 metres, 2+421 metres, and 2+625 metres upstream from the mouth on the (downstream) right bank.
Land Tenure: Private



Prescription Photo: One of two large slides on the right valley wall in the reach (location = 2+045m). Photo taken looking upstream.

Impact Description: Constant diverting of the creek away from the alluvial fan and confining it to the valley upstream has lead to significant slope instability in two areas.

Goal(s): To mitigate downstream sediment delivery from this site.

Master Plan Objectives:

5) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probablity of success despite upstream sources of disturbance, and/or when passive restoration needs to be integrated with active restoration.

Description of Proposed Works:

- Armour toe of slope with several rootwads cabled together and into the substrate using duckbill anchors. Construct an upstream repelling groyne from angular rock to redirect flow away from the toe of the slope toward the middle of the channel (but not towards opposite banks) to reduce toe scour. Carry out riparian prescription where soil conditions allow (much of the lower slope consists of “hardpan” clays)

Technical References:

- WRP Technical Circular #9, Chapter 6
- Donat, 1995
- Chatwin et al., 1994

Sub-Basin: Byman
Creek: Byman
Reach:1
Prescription #:2
Related Riparian Prescriptions: BYM8 to BYM10
Category:2
Location: 1+030 to 1+660 metres upstream from the mouth. Left and right banks. UTM 9.6044300.666280 to 9.6044350.666910
Land Tenure: Private
Impact Description: Diversion of the creek using a long straight dyke (circa 1948) away from the Bulkley River floodplain and West to connect with Perow Creek. This has caused extensive degradation and channel feature homogenization. Combined with extensive cattle grazing and the removal of upstream LWD, this has severely damaged fish habitat in this section.

Prescription Photo: Long, straight diverted section below the highway, Habitat characterized as long shallow glides and riffles with almost no pool habitat. Picture taken at low flows looking upstream.

Goal(s): To complex habitat and dissipate hydraulic energy. To provide increased quantity and quality of summer rearing habitat for juvenile salmonids, particularly coho and chinook salmon.

Master Plan Objectives:

1) Reestablish upstream access to resident and anadromous fish species where barriers have been created by land-use.
2) Reestablish spatial habitat diversity and quality, and hydraulic energy dissipation in areas that have been channelized. A long-term goal which requires cooperation between private landowners and regulatory agencies is the de-channelizing of these areas and their reconnection to normal floodplain functioning, which is beyond the scope of this project.

Description of Proposed Works (see figure 176)**:**

- In concert with riparian prescriptions to restore floodplain and bank stability functions. Create a series of nine upstream v-wier LWD structures at 70 metre intervals. Design specifications and configuration are indicated in the conceptual drawing. The first wier will serve to backwater the highway culvert and increase access to and from upstream reaches during the summer low-flow period.

Technical References:

- WRP Technical Circular #9, Chapter 8
- Donat, 1995
- Newbury and Gaboury, 1993

Sub-Basin: McQuarrie
Creek: McQuarrie
Reach:1
Prescription #:1
Related Riparian Prescription: MCQ8
Category: 1
Location: 0+900 metres upstream from the mouth. UTM 9.6044350.663900
Land Tenure: Private
Impact Description: Sediment delivery from a rotational slump of fine-textured materials. Impact vectors are thought to be cattle trampling/grazing and removal of overstory/shrub vegetation at the top of the slope altering surface and subsurface drainage patterns in the slope, and removing the stabilizing and strengthening effect of plant roots.

Prescription Photo: Representative shot of impact site. There is a cattle corral and path for cattle at the lip of the slope which is not shown in the picture.

Goal(s): To mitigate the delivery of sediment downstream by continued mass movement of this slope.

Master Plan Objectives:
5) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probablity of success despite

upstream sources of disturbance, and/or when passive restoration needs to be integrated with active restoration.

Description of Proposed Works:

- In concert with riparian prescription, to armour the toe of the slope with angular rock to form a rock toe key. Depth of this key should be to a depth just beyond that of the deepest portion of the thalweg in cross-section to prevent scouring of rock away from the toe. Create a hook groyne with available materials to dissipate energy moving downstream from the site.

Technical References:

- WRP Technical Circular #9, Chapter 6
- Donat, 1995
- Chatwin et al., 1994

Sub-Basin: McQuarrie
Creek: McQuarrie
Reach:1
Prescription #:2
Related Riparian Prescription:MCQ1 and 2
Category:2
Location:0 to 0+420 metres upstream from the mouth, both banks. UTM
Land Tenure: Private, CNR and highway right-of-ways
Impact Description: Channelizing on both banks with rip-rap to bankfull height eliminating riparian/floodplain function and creating homogeneous riffle/glide habitat.

Goal(s): To complex habitat and dissipate hydraulic energy.

Master Plan Objectives:

2) Reestablish spatial habitat diversity and quality, and hydraulic energy dissipation in areas that have been channelized. A long-term goal which requires cooperation between private landowners and regulatory agencies is the de-channelizing of these areas and their reconnection to normal floodplain functioning, which is beyond the scope of this project.

Description of Proposed Works:

- Refer to works designed for Richfield Creek reach 1 (impact prescription #1), Byman Reach 1 (impact prescription #2) and Emerson Creek reach #1.(impact prescription #1) for concepts. With an interval of 6-7 channel widths between structures (60-70 metres), there will a total of 6 riffle, weir, or groyne structures required. Average riffle length should be based on maintaining a 10% (10:1) slope on the riffle face. Material sizing should be approximately the average D (27 cm) times a safety factor of 1.5. This would yield materials sizes in the vicinity of 40cm (on the b-axis) diameter.

Technical References:

- Newbury et al., 1997
- Soto, 1997
- Donat, 1995
- Newbury and Gaboury, 1993

Sub-Basin: McQuarrie
Creek: McQuarrie
Reach:3
Prescription #:1
Related Riparian Prescription: MCQ19
Category:2
Location:1+828 metres upstream from reach break. UTM 9.6048080.656500. Michelle Bay FSR crossing.
Land Tenure: Crown
Impact Description: Undersized culvert is a barrier to upstream fish passage at low flows, and is undersized for flood flows in the reach, causing fill slope erosion at the road crossing, and channel disturbance downstream.

Prescription Photo: Culvert on McQuarrie Creek at Michelle Bay FSR. Note extensive erosion of fill and size of culvert versus bankfull width.

Goal(s): To reestablish upstream fish access during summer low-flow periods, and to mitigate downstream sources of channel disturbance due to flow concentration and subsequent velocity increase.

Master Plan Objectives:
1) Reestablish upstream access to resident and anadromous fish species where barriers have been created by land-use.
2) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been

removed and/or where restoration will have a high probablity of success despite upstream sources of disturbance

Description of Proposed Works (see figure 177)**:**
- Replace the existing culvert with a bridge. Bridge designed to withstand 1 in 100 year flood magnitude. Design will incorporate regrading the channel as a series of riffle steps to ensure fish passage and to avoid further channel disturbance by locally increasing channel gradient. Channel below bridge will be excavated to old channel grade prior to culvert installation. Design specifications are included in conceptual drawing.
- Bar stabilization of large sediment/bedload wedge upstream of existing culvert, as outlined in riparian prescription.
- Riparian planting as outlined in riparian prescription.

Technical References:
- Soto, 1997a
- WRP Technical Circular #9, Chapter 5

Survey and Design Work Required:
- Engineering survey to create plan/profile drawings and proper design specifications for bridge and installation features.
- Creation of field report summarizing detailed cost estimate, engineering drawings and design specifications and workplan.
- Silviculture Prescription formulation, site visit with RPF, and RPF sign-off.

Survey and Design Cost Estimate:
- Engineering Survey Fees=Professional engineer for 6 days@$600/day=$3600, two surveyors for one day@$300/day=$600 (Total=$4200)
- Engineering Survey Expenses= Equipment and vehicle rental=$250, per diems=$150, travel and accomodation=$3000, report materials=$500, project management and administration=$500 (Total=$4400)
- Silviculture Prescription= Ecologist for 2 days@$300/day, RPF for 1 day@$500/day+$500 expenses (Total=$1600)
- Total cost estimate= $10 200

Estimated Cost of Implementing Works:
- Culvert Replacement with Bridge=$64 000
- Creation of stonelines to facilitate fish passage=$30000/km x 0.1 km=$3000
- Armouring and stabilizing upstream bar= $5800 (acquiring/shipping LWD@$1000, moving/placing LWD on bar @$2200 (horselogger fees + labour and expenses), planting bar and riparian prescription area @$2600)
- Total cost estimate= $73 000

Approvals Required:
- Federal Fisheries Act (MELP fisheries branch)
- BC Water Act, section 9 notification and approval

- Forest Practices Code Silviculture Prescription (Ministry of Forests)

Sub-Basin: Barren
Creek: Barren
Reach:1
Prescription #:1
Related Riparian Prescription:BAR003
Category:2
Location:0 to 0+270 metres upstream from mouth. UTM 9.6038760.660650 to 9.6038850.660450. Upstream end bounded by the Highway 16 crossing
Land Tenure: Private
Impact Description: Upstream sediment sources causing extensive aggradation of fine sandy materials in this area, coupled with extensive cattle grazing and bank compaction.

Prescription Photo: Representative shot of impact site. Channel is highly aggraded (as indicated by bars and height of highway culvert above water surface at low flows versus likely height at installation), and wanders with no cohesive banks.

Goal(s): Reestablish a single channel thread and provide access to oxbow pond adjacent to the channel.

Master Plan Objectives:
1) Reestablish upstream access to resident and anadromous fish species where barriers have been created by land-use.
2) Reestablish spatial habitat diversity and quality, and hydraulic energy dissipation in areas that have been channelized. A long-term goal which requires cooperation

between private landowners and regulatory agencies is the de-channelizing of these areas and their reconnection to normal floodplain functioning, which is beyond the scope of this project.

3) Passively restore riparian areas wherever possible with landowner cooperation to limit land-use to areas outside of the riparian zone.
4) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probablity of success despite upstream sources of disturbance, and/or when passive restoration needs to be integrated with active restoration.
5) Stabilize extensive bars and promote channel narrowing and deepening where feasible and when upstream sources of disturbance have been alleviated.

Description of Proposed Works (see figure 178)**:**

- Once upstream sources of sediment have been mitigated, excavate new channel in a meandering pattern with channel geometry based on average bankfull width (see conceptual prescription drawing). Armour meander bends with angular rock down to below thalweg depth to prevent scour of toe and collapse of bank. Aim to restore channel gradient to that of reach 2 upstream. Restoring channel pattern and gradient should restore a riffle:pool pattern without expensive construction of channel features. Effectiveness monitoring should identify whether LWD additions are needed.
- Carry out off-channel assessment of oxbow pond to determine feasibility for restoration (groundwater yield and water quality).
- Restore access to oxbow pond by excavating and armouring a channel which connects with Barren Creek with a gradient suitable to maintaining design water levels in the pond and access between the two water bodies. Build a berm to protect the oxbow during floods from the Bulkley River and Barren Creek. This could probably be constructed from excavated fill from the pond.
- Carry out riparian prescriptions as outlined.

Technical References:

- Newbury and Gaboury, 1993
- WRP Technical Circular #9, Chapters 6, 7, and 12

Sub-Basin: Barren
Creek: Barren
Reach:2
Prescription #:2
Related Riparian Prescription:BAR008
Category:1
Location:0+275 metres upstream of reach 1/2 break, UTM 9.6037900.660350
Land Tenure: Private
Impact Description: Slumping hillside below land clearing combined with toe erosion caused by a log jam (lateral movement of thalweg)

Prescription Photo: Slide at 0+274 metres. Note how slide is beginning to restore naturally by reaching a new planform that does not result in further slumping. The toe is naturally armoured by debris until the forces of erosion remove it. However, surface erosion is till a major problem here.

Goal(s): Add lifespan to natural toe armouring and restore ground and vegetation cover to mitigate surface erosion.

Master Plan Objectives:

5) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probablity of success despite

upstream sources of disturbance, and/or when passive restoration needs to be integrated with active restoration.

Description of Proposed Works:

- See riparian prescription in appendix F

Technical References:

- Chatwin et al., 1994
- Donat, 1995

Sub-Basin: Barren
Creek: Barren
Reach:2
Prescription #:3
Related Riparian Prescription: N/A
Category: 1
Location:1+050 metres upstream from reach break. UTM 9.6038100.660100 to 6038300.660020.
Land Tenure: Private
Impact Description: Landowner has diverted creek away from their powerline (from which all riparian vegetation was removed), and straight into the forest. This diversion is a huge source of sediment as indicated by field observations. This is only one of several diversions by the landowner to straighten the channel in the vicinity.

Prescription Photo: Site of diversion. Abandoned channel is in the distance. Powerline poles are visible in photo to right.

Goal(s): To restore channel morphology, mitigate bank erosion problems in old channel, and block off new channel and baffle with LWD.

Master Plan Objectives:

5) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probablity of success despite upstream sources of disturbance, and/or when passive restoration needs to be integrated with active restoration.

Description of Proposed Works (see figure 179)**:**

- Plans for this work are presented in the conceptual drawing. The general steps are to carry out restoration work in the old channel, planting riparian vegetation and making tree revetments on outside banks, then to block off the new channel and restore flow to the old channel, followed by baffling of the old channel with LWD laid cross-wise with root-wads forward to mitgate any flood damage which might occur should the creek jump the berm created to maintain flow in the old channel.
- Tree stocking and species selection for riparian planting are consistent with those prescribed for Barren impact prescription #1.

Technical References:

- Donat, 1995
- WRP Technical Circular #9, Chapter 6

Sub-Basin: Barren
Creek: Barren
Reach:2
Prescription #:4
Related Riparian Prescription:BAR017
Category: 2
Location: 2+300 metres upstream from reach break. UTM 9.6039000.659600. Michelle Bay FSR crossing.
Land Tenure: Private/ MOF and BC Hydro right-of-way
Impact Description: Poor culvert installation at Michelle Bay FSR is a barrier to upstream fish passage by salmonids. It is also highly undersized, and has caused a greate deal of channel disturbance above it. Backwatering during floods has led to scouring of unvegetated banks at the powerline and increased toe erosion of a slope upstream. This sediment is aggrading upstream and being delivered downstream.

Prescription Photo: Culvert at impact site. Note drop of approximately 1 metre over angular boulders. This rubble pile is also 1 metre long, and there is no plunge pool below it or at the end of it, as the rubble is disspating stream energy, and upstream sediment has infilled any pool created at higher discharges.

Goal(s): To restore access to juvenile and adult salmonids, particularly coho salmon and steelhead trout and to restore channel damage once the culvert has been replaced.

Master Plan Objectives:
1) Reestablish upstream access to resident and anadromous fish species where barriers have been created by land-use.
2) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probablity of success despite upstream sources of disturbance, and/or when passive restoration needs to be integrated with active restoration.

Description of Proposed Works (see figure 180)**:**
- Replacement of current culvert with and open-bottom culvert sized to a 1 in 100 year flood event, and with a width equal to or greater than the average bankfull width. Gradient of streambed with new culvert installation should not exceed 3%. Bed for new culvert should be pre-road substrate. Stream substrate placed arbitrarily or otherwise over fine textured road fill will result in loss of substrate downstream.
- Installation of baffles in the culvert to facilitate fish passage at higher flows.
- Installation of snow deflectors on either side of road above culvert to minimize the amount of sediment entering the stream in snow removed from the road surface.
- Bar and slope stabilization related to upstream impacts caused by the existing undersized culvert.

Technical References:
- Soto, 1997a
- Soto, 1997b
- WRP Technical Circular #9, Chapter 5 and 6
- Donat, 1995
- Chatwin et al, 1994

Survey and Design Work Required:
- Engineering survey to create plan/profile drawings and proper design specifications for bridge and installation features.
- Creation of field report summarizing detailed cost estimate, engineering drawings and design specifications and workplan.

Survey and Design Cost Estimate:
- Engineering Survey Fees=Professional engineer for 6 days@$600/day=$3600, two surveyors for one day@$300/day=$600 (Total=$4200)
- Engineering Survey Expenses= Equipment and vehicle rental=$250, per diems=$150, travel and accomodation=$3000, report materials=$500, project management and administration=$500 (Total=$4400)
- Total cost estimate= $8600

Estimated Cost of Implementing Works:
- Culvert Replacement=$28 000

- Related works (fill armouring, snow deflector construction, baffling)=$10 000
- Armouring and stabilizing upstream bar= $5800 (acquiring/shipping LWD@$1000, moving/placing LWD on bar @$2200 (horselogger fees + labour and expenses), planting bar and riparian prescription area @$2600)
- Slope stabilization= $6000 (250 m^2*1 hour/square metre*labour cost/hour)
- Total cost estimate= $49 800

Approvals Required:
- Federal Fisheries Act (MELP fisheries branch and DFO)
- BC Water Act, section 9 notification and approval
- Ministry of Forests approval to work on FSR.

Sub-Basin: Aitken
Creek: Aitken
Reach:3
Prescription #:1
Related Riparian Prescription:AIT25
Category: 1
Location: 1+226 metres upstream from the reach break, UTM 9.6034200.663300
Land Tenure: Private
Impact Description: Surface compaction, loss of vegetation leading to gully failure from upslope cutblock (see figure 181).

Goal(s): To rehabilitate slide and mitigate surface erosion from exposed face.

Master Plan Objectives:
1) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probablity of success despite upstream sources of disturbance.

Description of Proposed Works:
- works are outlined in riparian prescription

Technical References:
- Donat, 1995
- Chatwin et. al, 1994

Sub-Basin: Aitken
Creek: Aitken
Reach:3A
Prescription #:2 and 3
Related Riparian Prescriptions:AIT29, 30-33, 35
Category:1
Location:1+560 to 1+705 metres, 1+800 to 2+095 metres, 2+649 to 2+829 metres
Land Tenure: Private
Impact Description: Riparian forest had undergone extensive clearcutting in the 1970's to the streambanks and is not naturally regenerating, floodplain function is poor, and has high rates of lateral movement.

Prescription Photo: One of several areas of extensive clearcutting to the streambank that was carried out on private land in the 1970's. 1+560 metres, looking upstream.

Goal(s): To restore forest cover in the riparian zone and thus aid in restoring bank stability, LWD sources, and stream shading.

Master Plan Objectives:

1) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probablity of success despite upstream sources of disturbance.

2) Carry out passive and active restoration to reduce soil compaction on the active floodplain, reconnect the channel to the active floodplain, and restore key features such as LWD.

Description of Proposed Works (see figure 181)**:**

- as outlined in riparian prescriptions

Sub-Basin: Aitken
Creek: Aitken
Reach:3A
Prescription #:4
Related Riparian Prescription:AIT37
Category:1
Location:3+723 metres upstream from reach break. UTM 9.6037900.660350
Land Tenure: Private
Impact Description: Slope failure related to concentration of surface water onto unstable slope above creek.

Prescription Photo: Impact site in background, note point of water concentration in centre of face above slide.

Goal(s): To divert and slow surface drainage from this area, and to rehabilitate the slide surface to mitigate surface erosion and sediment delivery to the creek.

Master Plan Objectives:
1) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probablity of success despite upstream sources of disturbance.

Description of Proposed Works (see figure 182)**:**
- outlined in riparian prescriptions

Technical References:

- Donat, 1995
- Chatwin et al., 1994

Sub-Basin: Buck
Creek: Klo
Reach: 2
Prescription #: 1
Related Riparian Prescription: KLO21 and 22
Category: 1
Location: 2+400 metres and 2+750 metres upstream from the reach break. Below cutblock 93L.028, FLA 16827-CP314-02 (fprest cover map opening #10).
Land Tenure: Crown
Impact Description: Forest harvesting to lip of slope and gully headwalls decreasing wind resistance and causing increased water load in gullies. A great deal of windthrow at block boundaries is suspected to have been responsible for several small gully failures and partial gully failures. The effects of this problem will likely worsen as root networks continue to decay after harvesting.

Prescription Photo: One of several small gully failures intiated along the lip of the offending cutblock.

Goal(s): To prevent further slope instability prior to major failures occurring

Master Plan Objectives:
1) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability

Description of Proposed Works:
- outlined in riparian prescription
- prescription to be completed following further assessment of areas for riparian restoration
- workplan phases will consist of assessment/survey/design, bioengineering stock acquirement, windthrow prevention measures, pole drain construction, check dam construction, field reporting, and monitoring plan development
- all field work to be carried out with crew of three labourers and crew leader

Access: cutblock

Technical References:
- Chatwin et al., 1994
- Anonymous, 1995a
- Donat, 1995

Survey and Design Work Required:
- Consultation and site visit with Professional Geoscientist, including short report prepared by P.Geo. outlining their interpretations, concerns, and input into the riparian prescription including identifying other areas for preventative maintenance/restoration along the cutblock boundary.
- Silviculture Prescription formulation, site visit with RPF, and RPF sign-off.

Survey and Design Cost Estimate:
- Geoscientist consultation fees=professional geoscientist for 3 days@$600/day=$1800, project leader/coordinator for 3 days@$300/day=$900 (total=$2700)
- Geoscientist consultation expenses=vehicle rental=$130, per diems=$80,, report materials=$100, project management and administration=$50 (Total=$360)
- Silviculture Prescription= Ecologist for 2 days@$300/day, RPF for 1 day@$500/day+$500 expenses (Total=$1600)
- Total cost estimate= $4660

Approvals Required:
- Federal Fisheries Act (MELP fisheries branch)
- BC Water Act, section 9 notification and approval
- Forest Practices Code Silviculture Prescription (Ministry of Forests)

Environmental Measures: No work during rain events. Sediment routing downslope is unlikely given the location of work on the gully headwall, and installed check dams should act as sediment dams for the period shortly after construction.

Sub-Basin: Buck
Creek: Upper Buck
Reach:11B
Prescription #: 1
Related Riparian Prescription: UB8
Category:2
Location:FSR 2417 crossing of unnamed tributary to Buck Creek at upstream end of study area. UTM 9.6003100.678400
Land Tenure: Crown
Impact Description: Undesized and perched culvert is blocking upstream access to rainbow trout, and causing bank erosion and aggradation downstream by increasing water velocities and stream power.

Prescription Photo: FSR-2417 Crossing of Unnamed Creek, with perched culvert in foreground and disturbed channel in background. Note: Extensive bank erosion to left of photo.

Goal(s): To restore fish passage and mitigate channel impacts.

Master Plan Objectives:
1) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability
2) Reestablish upstream access to areas which have been blocked for resident fish passage by land-use activities

Description of Proposed Works (see figure 182)**:**

- Replacement of existing culvert with an open bottom culvert sized to a 1 in 100 year flood event and with a width equal to or greater than the average bankfull width of the creek.
- Complexing and armouring of the pool below the culvert with LWD rootwads keyed into the bank and ballasted with boulders.
- Planting of conifers and shrubs to improve banks stability on the creek between the road crossing and its confluence with Buck Creek (0.6 ha of planting). Conifer planting sites will be manually brushed and screefed. through existing vegetation. Shrubs (red osier dogwood, highbush cranberry) will be planted densely on banks where required.
- Design details are included in the conceptual prescription drawing (see over)

Technical References:

- Soto, 1997a
- Soto, 1997b
- WRP Technical Circular #9, Chapter 5 and 6
- Donat, 1995
- Chatwin et al, 1994

Survey and Design Work Required:

- Engineering survey to create plan/profile drawings and proper design specifications for bridge and installation features.
- Creation of field report summarizing detailed cost estimate, engineering drawings and design specifications and workplan.
- Silviculture Prescription formulation, site visit with RPF, and RPF sign-off.

Survey and Design Cost Estimate:

- Engineering Survey Fees=Professional engineer for 6 days@$600/day=$3600, two surveyors for one day@$300/day=$600 (Total=$4200)
- Engineering Survey Expenses= Equipment and vehicle rental=$250, per diems=$150, travel and accomodation=$3000, report materials=$500, project management and administration=$500 (Total=$4400)
- Silviculture Prescription= Ecologist for 2 days@$300/day, RPF for 1 day@$500/day+$500 expenses (Total=$1600)
- Total cost estimate= $10 200

Estimated Cost of Implementing Works:

- Culvert Replacement=$14 000
- Related works (rock armouring, baffling)=$10 000
- Complexing/armouring pool with rootwads=acquiring/moving LWD=$500, acquiring/moving boulders=$250, materials placement (excavator x 1 day)=$1600, cabling and fastening (labour+materials)=$1000 (Total= $2350)
- Riparian planting= $2400 (labour) + $600 (conifer stock) (Total=$3000)
- Total cost estimate= $29 350

Approvals Required:

- Federal Fisheries Act (MELP fisheries branch)
- BC Water Act, section 9 notification and approval
- Forest Practices Code Silviculture Prescription and road alteration approvals (Ministry of Forests)

Sub-Basin: Buck
Creek: Buck
Reach:1
Prescription #:1
Related Riparian Prescription:BUC004,006 and 007
Category:2
Location:0+980 to 1+650
Land Tenure: Private (municipal)
Impact Description: Channelizing of both banks and diversion of creek away from townsite. Has lead to major habitat simplification, downstream sedimentation and erosion, and aggradation upstream and downstream, as well as loss of floodplain and riparian function within the channelized section.

Prescription Photo: Extensive aggradation, log jams, and lateral movement below channelized section of reach 1, Buck Creek.

Goal(s): To increase the spatial complexity of salmonid habitat and decrease stream power in this section, thereby mitigating impacts downstream.

Master Plan Objectives:
1) Reestablish spatial habitat diversity and quality, and hydraulic energy dissipation in areas that have been channelized. A long-term goal which requires cooperation between private landowners and regulatory agencies is the de-channelizing of these areas and their reconnection to normal floodplain functioning, which is beyond the scope of this project.

Description of Proposed Works:

- See Emerson reach 1 or Richfield reach 1 for an example of prescription concept.
- With an interval of 6-7 channel widths between structures (100-120 metres) there will a total of 8 to 9 riffle, weir, or groyne structures required. Average riffle length should be based on maintaining a 10% (10:1) slope on the riffle face. Material sizing should be approximately the average D (23.5 cm) times a safety factor of 1.5. This would yield materials sizes in the vicinity of 35-36 cm (on the b-axis) diameter.

Technical References:

- Newbury et al., 1997
- Soto, 1997
- Donat, 1995
- Newbury and Gaboury, 1993

Sub-Basin: Buck
Creek: Buck
Reach:1
Prescription #:2
Related Riparian Prescription:BUC010-012
Category:2
Location:0 metres to 0+980 metres
Land Tenure: Private, municipal
Impact Description: Increased water velocities generated in the straight channelized section are leading to a gradual strightening of the channel pattern donwstream, as avulsions are slowly occurring. These will eventually lead to a straight channel all the way to the mouth.

Goal(s): Maintain channel morphology and prevent forthcoming avulsions.

Master Plan Objectives:
1) Not in master plan objectives.

Description of Proposed Works (see figure 183)**:**
- Bank armouring of ouside meander banks at the edge of the bankfull width below the existing channelized section to maintain channel morphology and prevent avulsions. Energies are too high here to consider the use of organic materials, so large angular rock structures to bankfull height are prescribed. All rock toe armouring should be installed to below the deepest portion of the thalweg to prevent scouring and undercutting of bank toes and therefore structure failure. The structures should be appropriately engineered to withstand 1 in 50 to 1 in 100 year flood events. Structures should not infringe on the bankfull width, but should be installed at either edge of the bankfull width, allowing the channel to adjust its pattern somewhat to changes in discharge.
- Riparian prescriptions outline riparian restoration to be carried out in concert with this prescription to restore stream shading and long-term LWD supply.

Technical References:
- WRP Technical Circular #9, Chapter 6
- Donat, 1995

Sub-Basin: Buck
Creek: Buck
Reach: 2
Prescription #: 1
Related Riparian Prescription: N/A
Category: 2
Location: 1+700 metres upstream from the reach 1/2 break. UTM 9.6028000.653720
Land Tenure: Private, lot 2094
Impact Description: Loss of sediment storage function at geomorphic notch point (log jams at canyon mouth) due to decreasing upstream LWD supply and an altered basin runoff regime. This is leading to cumulative sediment impacts propogating downstream and exacerbating impacts there.

Prescription Photo: 60 cm dbh cottonwood stem parallel to flow within first canyon on Buck Creek (downstream of impact prescription site). Indicative of general loss of LWD and sediment storage function within this part of the reach.

Goal(s): Reestablish log jam in geomorphic notch point to store upstream sediment and LWD.

Master Plan Objectives:
3) Reestablish sediment storage functions such as log jams in geomorphic notch points where they are lacking. Maintain anadromous access through these areas in concert with the former goal where applicable.

Description of Proposed Works:

- See Buck Creek reach 4 for example of prescription concept.
- Construction of one debris catcher on each side of channel using 50-60 cm dbh conifer stems and boulders. Boulders are cabled to stems for ballast, and main logs are keyed into banks up to 3 metres of their length. Logs used in debris catchers are to be 6-9 metres long. As opposed to the prescription presented for Buck Creek reach 4, these debris catchers are to be constructed approximately across from each other. With a Chezy velocity of 1.82 m/s, ballast requirements should be identical to Buck reach 4 prescription unless longer logs are used. Assuming five equally sized logs, the ballast requirements for the structure with 9 metre long logs is (180 kg/m x 45 m)= 8100 kg. Using one large anchor boulder (a third of the ballast requirements) and four smaller anchor boulders, ballast requirements could be met with one 1.3 metre diameter boulder (2430 kg) and four 0.95 metre diameter boulders (1420 kg).

Technical References:

- WRP Technical Circular #9, chapter 9

Sub-Basin: Buck
Creek: Buck
Reach: 4
Prescription #: 1
Related Riparian Prescription: N/A
Category: 2
Location: 5+350 metres upstream from the reach 3/4 break. UTM 9.6019120.652980. Nearest road access at Buck Flats road, approximately 500 metres downstream.
Land Tenure: Private, lot 5205
Impact Description: Loss of sediment storage function at geomorphic notch point (log jams at canyon mouth) due to decreasing upstream LWD supply and an altered basin runoff regime. This is leading to cumulative sediment impacts propogating downstream and exacerbating impacts there.

Goal(s): Reestablish log jam in geomorphic notch point to store upstream sediment and LWD.

Master Plan Objectives:

III. Reestablish sediment storage functions such as log jams in geomorphic notch points where they are lacking. Maintain anadromous access through these areas in concert with the former goal where applicable.

Description of Proposed Works (see figure 184)**:**

- Construction of two staggered lateral debris catchers to catch logs and create a full-spanning log jam at the notch point. The downstream debris catchers will be approximately 25-30 linear metres below the upstream catcher. A staggered configuration on such a sharp bend in the creek will enhance the potential and effectiveness of creating a full-spanning log jam. The lack of floodplain here will minimize the probability of lateral movement compromising the integrity of the works.
- Construction will consist of a five log triangular configuration ballasted with cabled boulders. Main logs are to be keyed into the bank. Suggested dimensions for logs are 50-60 cm dbh and 6 m lengths. Logs should be coniferous stock to maximize longevity. Ballast requirements for each entire structure, based on single-log calculations for ballast, are 5400 kg. One large boulder and four smaller boulders are suggested. The largest boulder is to be cabled to the apex of the structure in the area of greatest stress and loading. Smaller boulders are cabled to single logs throughout the debris catcher to enhance the integrity of logs keyed into the bank. Suggested specifications for the largest boulder are 1.1 metres b-axis diameter (2000 kg), and the four smaller boulders are 0.8 metres diameter (850 kg) each.

Technical References:

- WRP Technical Circular #9, chapter 9
- *Streamlines* (WRP technical bulletin) vol.3, no.2, pgs.17-18

Sub-Basin: Bulkley
Creek: Bulkley River
Reach: 1
Prescription #: 1
Related Riparian Prescription: BUL29 and BUL32
Category: 1
Location: Site 1= 4+553 to 4+750 metres (UTM 9.6030100.648600) upstream from the Bulkley/Morice confluence and Site 2= 5+940 to 6+080 metres (UTM 9.6029800.649100) upstream from the Bulkley/Morice confluence. Both sites are downslope from the Michelle Bay FSR.
Land Tenure: Private, lots 2114 and 2116
Impact Description: Subsurface and surface runoff diversion and concentration downslope by the Michelle Bay FSR (both sites) and a section of the old highway (site 1) are causing extensive surface erosion and slumping of the valley walls. These sites are large sources of fine sediment in runoff and mass movements to the Bulkley River.

Prescription Photo: Representative shot of site #1 looking upstream. Note old bridge pilings in background where old highway crossing existed. The old roadbed which used to go up the slope to the left has now been completely eradicated by slumping and erosion.

Goal(s): To stabilize slopes and mitigate fine sediment inputs from these sites to the river.

Master Plan Objectives:

V. Stabilize upslope point sources of sediment through consideration of surface and groundwater pathways, as well as shear stresses and toe erosion.

Description of Proposed Works:

- Survey and design and site visits with road and hydrologic engineers.
- Recompact and revegetate old highway road surface above site #1. Divert drainage at multiple points to ensure that erosive power of surface water is minimized on the road surface and downslope.
- Carry out FSR-related rehabilitation through the WRP roads/hillslopes/gullies funding envelope.
- Carry out slope bioengineering as per riparian prescriptions when upslope impact vectors have been addressed.

Technical References:

- Donat, 1995
- Chatwin et al., 1994

Sub-Basin: Bulkley
Creek: Bulkley River
Reach: 2
Prescription #: 1
Related Riparian Prescription: BUL63
Category: 2
Location: 3+263 to 3+852 metres upstream of the reach 1/2 break. UTM 9.6033300.655300. TRIM mapsheet 93L.047.
Land Tenure: Private, lot 1166
Impact Description: Removal of riparian forest for hay farming upstream of a meander neck led to extensive bank erosion. The bank erosion caused a change in the angle of attack of the main flow (thalweg) on the outside bank of the meander downstream. The increased shear stress on the meander neck lead to an avulsion in the spring, 1997 flood.

Prescription Photo: Upstream end of avulsion showing avulsion channel (foreground) and abandoned channel (background). Flow is left to right. Photo taken from hay field (note grasses in extreme foreground).

Goal(s): To increase river sinuosity and channel complexity by restoring flow to original channel. Avulsion channel will be blocked off and revegetated.

Master Plan Objectives: No objective in master plan.

Description of Proposed Works:

- Consult with river engineer/geomorphologist to ensure project is feasible and practical, and to size material to design specifications.
- Carry out riparian prescription to stabilize upstream bank erosion at hay field.
- Fill in avulsion channel with a matrix of SWD and LWD and typical unsorted sand/gravel/cobble granular spoil. Carry out landfilling by weaving wood and then adding spoil in successive layers, rather than all wood and then all spoil in two stages. This will ensure that all voids around wood are filled and subsurface flow routing will not undermine the works.
- Carry out bank armouring as required on upstream end of avulsion, and revegetate landfilled avulsion channel.

Sub-Basin: Bulkley
Creek: Bulkley River
Reach: 2
Prescription #: 2
Related Riparian Prescription: BUL129
Category: 1
Location: 12+860 metres upstream from the reach 1/2 break, and 0 to 150 metres upstream of the Knockholt Bridge (McKilligan Road) on the downstream left bank. UTM 9.6037350.660800.
Land Tenure: Private, lots 2617 and 2087
Impact Description: Severe bank erosion of fine-textured soils and aggradation at agricultural (hay) land due to channel constriction at the Knockholt Bridge and removal of riparian forest/soil compaction by agricultural machinery. The channel constriction by the bridge downstream of the impact site is causing bank scouring and erosion as a large eddy is formed above. The circular motion of the eddy is undercutting the bank toe.

Prescription Photo: Extensive bank erosion just upstream of the Knockholt Bridge, reach 2, Bulkley River. Note the large lateral bar. Photo taken at low water (August), indicating the potential for installing works as presented in the conceptual drawing. Upstream view.

Goal(s): To rehabilitate the stream bank and stabilize bars, promoting sediment deposition and natural bar recolonization. To narrow the bankfull channel width in this area.

Master Plan Objectives:

III. Increase bank stability through passive and active restoration of root networks at cleared land, and restocking of appropriate site-series specific vegetation when and if upstream disturbances have been alleviated.

IV. Stabilize extensive bars and promote channel narrowing and deepening where feasible and when upstream sources of disturbance have been alleviated.

Description of Proposed Works (see figure 185)**:**

- Armour streambanks with whole logs/rootwads (5-7 m in length, 40-50 cm dbh), incorporating ballast, footer logs, and soil stabilizing vegetation as shown in conceptual drawing, and as described in technical references.
- Construct vegetated rip-rap groynes to catch sediment and increase channel roughness. This will act to decrease erosive power of the current in the destabilized area, and create excellent conditions for recolonization of extensive bars by shrubs.
- Carry out riparian prescription as outlined.

Technical References:

- WRP Technical Circular #9, chapter 6
- Donat, 1995
- *Streamlines* (WRP Technical Bulletin) Vol. 2, no.3, pgs. 1-4

Sub-Basin: Bulkley
Creek: Bulkley River
Reach: 2
Prescription #: 3
Related Riparian Prescription: N/A
Category: 2
Location: Bulkley River floodplain overbank flow channels, downstream right floodplain between highway and river at the upstream end of reach 2. This is an extensive area of historic lateral movement and sediment deposition as the river channel becomes less confined downstream of reach 3. See TRIM mapsheet 93L.048. The area of interest is roughly bound by a square with corners with coordinates UTM 9.6039000.661600, 9.6038500.662000, 9.6040100.662700, and 9.6039900.663200.
Land Tenure: Private, lots 3467, 3313 and 200.
Impact Description: Extensive floodplain development for hay cultivation, and diversion of the river has led to poor floodplain and riparian function and extensive surface erosion during overbank floods.

Goal(s): To restore floodplain functions, rehabilitate riparian forest and reduce surface erosion of unforested and compacted soils by restoring and revegetating overbank flood channels.

Master Plan Objectives:

I. Restoring floodplain function and lateral channel movement where feasible to increase spatial habitat diversity and improve overwintering and summer rearing habitat, buffer high and low water levels and water temperatures downstream, and increase overbank sediment storage.
II. Mitigate flood damage by overbank flooding and improve off-channel habitat creation and access to the mainstem on cleared land by revegetating and reconnecting floodplain flood channels and baffling them with LWD in key locations.

Description of Proposed Works:

- Assess and map feasible flood channels in this area for restoration, provided landowner cooperation can be secured.
- Using large cottonwood stems, baffle the floodplain channels with LWD. Stems should be oriented in twos in a v-formation with the apex of two stems pointing upstream. This will promote deepening of these channels and concentration of the flow in the next overbank flood, rather than the opposite effect.
- Extensively plant the channels with shrub species and the margins of the channels with climax vegetation. There should be a 30-50 metre buffer strip of vegetation around each flood channel. Fence the areas off to livestock if they are present.

(**Note**: This is a relatively untested method and capital intensive prescription which may yield significant positive results. The potential for a combination of restoring floodplain function and rare floodplain riparian forest and creating abundant off-channel habitat in this geomorphically important and active area is promising. However, there is also a significant risk of failure and damage to private land and the fisheries resource (stranding and sedimentation of downstream habitat) if the appropriate specialists (geomorphologist, river engineer) are not consulted**.** The survey and design phase is crucial in this prescription.)

Sub-Basin: Emerson
Creek: Emerson
Reach: 1
Prescription #: 1
Related Riparian Prescription: EME2
Category: 2
Location: 0+425 to 0+535 metres upstream from mouth. UTM 9.6035500.641720. Walcott road and CNR railway crossing.
Land Tenure: Private, road and CNR right-of-way, lot 741
Impact Description: Channelizing and straightening of creek on both banks through bridge-crossing area has led to habitat simplification, loss of riparian forest and floodplain functions, donstream bank erosion and aggradation and upstream aggradation.

Goal(s): To complex channelized section with hard structures, dissipate stream power, increase habitat area and diversity, and restore stream shading and overhead cover for fish through riparian shrub planting.

Master Plan Objectives:

2) Reestablish spatial habitat diversity and quality, and hydraulic energy dissipation in areas that have been channelized. A long-term goal which requires cooperation between private landowners and regulatory agencies is the de-channelizing of these areas and their reconnection to normal floodplain functioning, which is beyond the scope of this project.

Description of Proposed Works (see figure 186)**:**

- Survey and design phase including consultation with a river engineer and/or geomorphologist.
- Construction of two attracting groynes and one set of opposing wing deflectors using hard materials in-stream. Structures are constructed at 27 metre intervals from each other. Attracting groynes are oriented 45^o downstream from the bank. Rock material is placed in a trench dug to 1 metre below the bed surface to reduce the chance of undercutting. Lateral grade from the bank to the apex of the groyne is 1:50. The height of the groyne is the average wetted depth in the channelized section. Size of materials should be 25.5 cm b-axis diameter or larger (average D in riffles in this reach times a safety factor of 1.5). The opposing wing deflectors are constructed at 45^o up and downstream from the bank on either axis. Rock material is placed in trenches dug to 1 metre below the existing bed surface. Lateral grade from the bank to the apex of the deflector should ensure that the bank end (root) is to bankfull height and the apex is 0.3 metres above the mean water level. Rock material on the upstream face should be larger than downstream (recommended size in WRTC#9 is 2 m diameter on upstream face). The interior of the deflector can be filled with smaller granular spoil.
- Low growing and overhanging shrubs are planted in the rip-rap as per the riparian prescription. Signs are to be placed indicating the riparian works to railway and road maintenance crews.

Technical References:

- Donat, 1995
- WRP Technical Circular #9, chapters 6 and 11

Sub-Basin: Emerson
Creek: Emerson
Reach: 1
Prescription #: 2
Related Riparian Prescription: EME6 and EME7
Category: 1
Location: 0+792 and 1+080 metres upstream from the mouth, right bank. UTM 9.6035400.641700 and 9.6035180.641500 respectively. Both sites are directly downslope from the Walcott Road.
Land Tenure: Private, lot 741.
Impact Description: Diversion of surface and subsurface drainage by the Walcott Road causing two slope failures and inputs of sediment and debris. Sediment input is due to the failures themselves and chronic surface erosion of the exposed mineral soils.

Goal(s): To stabilize and revegetate the slopes by altering drainage patterns from the road ditchlines and using bioengineering techniques when the road works have proven effective.

Master Plan Objectives:

5) Stabilize upslope and riparian sources of sediment and prevent further occurrence of slope and bank instability when and if upstream sources of disturbance have been removed and/or where restoration will have a high probablity of success despite upstream sources of disturbance, and/or when passive restoration needs to be integrated with active restoration.

Description of Proposed Works:

- Consultation with road and hydrologic specialists to assess road impacts on drainage patterns in the slope.
- Road works carried out through the WRP roads/hillslopes/gullies funding envelope.
- Carry out riparian prescriptions to stabilize slope and filter surface sediments when road works have proved effective.

Technical References:

- Donat, 1995
- Chatwin et al., 1994