Annual Compendium Of Aquatic Rehabilitation Projects For The Watershed Restoration Program 1998 - 1999

Editor
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Watershed Restoration Project Report No. 13

Watershed Restoration Program
Ministry of Environment, Lands and Parks
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Executive Summary Highlights

B.C's Watershed Restoration Program (WRP) was implemented under the Province's Forest Renewal Plan in mid-1994 in response to a historical lack of mechanisms for ensuring rehabilitation of logging-impacted hillslopes, riparian areas and streams. In combination with the Forest Practices Code, WRP provides an important opportunity to improve water quality and reverse fish habitat impairment. A strategic target, established by Forest Renewal BC, is to complete restoration of 20 % of the high priority or key watersheds over the next five years. WRP is a watershed level program in recognition of "top-down" linkages of roads, gullies and streams. Seventy five percent of expenditures are initially directed at hillslopes (reported on elsewhere by the Ministry of Forests). Twenty five percent of expenditures have been directed at streams (reported on here by the Ministry of Environment, Lands and Parks).

Aquatic restoration **facts and figures**:

- Watershed sub-basin level **projects** in 1998/99;
  - **460** aquatic condition assessments
  - **177** aquatic restoration projects
  - **41** effectiveness monitoring projects
- Approximately **$9 million** expended in 1998/99 on restoration works;
  $67,000 average cost for **126** works projects (summaries attached);
- Lead **proponents** in 1998/99;
  - forest licensees (**45 %**)
  - government agencies **(20 %**)
  - First Nations (**12 %**)
  - forest worker/fisher groups (**7 %**)
  - community and environmental stewardship groups (**16 %**)
- As a key indicator, an estimated total of **222 km** treated in 1998/99 (about 3-fold that of 1997/98);
  - fish access restored (**48 %,** largely culvert blockages)
  - in-stream habitat rehabilitated and channels stabilized (**38 %)**
  - off-channel habitat restored or replaced (**14 %)**

BC Environment Region	Off-channel km	In-stream/Channel km	Fish Access km
Vancouver Island	9.4	17.2	9.1
Lower Mainland	19.4	14.5	0
Thompson-Okanagan	1.5	22.8	3.0
Kootenays	0.1	8.1	9.6
Cariboo-Mid-coast	0.4	4.8	72.5
Skeena – QCI	0.3	4.5	0.9
Omineca-Peace	0	11.7	12.0
Total by Type	**31.1**	**83.6**	**107.1**

- In comparison, US Forest Service averaged about **250 km per year** of restoration on federal lands (50 % of Washington plus Oregon) over the past decade;
- Benefits are much broader than restored aquatic resources, and include:
  - community employment operating machines, securing structures, and planting;
  - training/mentoring of 1500 people via courses, workshops and conferences since1995;
  - a sharp increase from a few to 30 experienced stream restoration consulting firms;
  - greater than 90 % functionality of stream restoration projects;
  - positive responses of fish stocks based on initial intensive effectiveness monitoring;
  - positive perceptions within the forest products marketplace.

Preface

The Annual Compendium of Aquatic Rehabilitation Projects for the Watershed Restoration Program is a valuable technical reference to those planning, implementing and monitoring restoration of water quality and fish habitat affected by historical logging practices. This compendium of descriptions by practitioners also provides a useful technical reference for communications information and public education. Program planners and reviewers are provided with an equally important snapshot of aquatic restoration projects facilitated or managed by the Ministry of Environment, Lands and Parks. Close to 100 % of all aquatic restoration projects (excluding condition assessments) undertaken in 1998/99 by the Watershed Restoration Program are summarized in this compendium. Hillslope restoration projects are summarized separately by the Ministry of Forests. A diversity of proponents and their contractors, including forest licensees, government agencies, community and environmental stewardship groups and First Nations were involved in both assessment of aquatic-riparian conditions and restoration throughout the Provincial Forest in 1998/99.

Aquatic restoration, as described in the 1998/99 Compendium, is scientifically founded on several decades of research on watershed processes, limitations to salmonid production in streams, and fish habitat rehabilitation techniques, the latter described in 15 chapters in Slaney and Zaldokas (1997). These techniques provide the basis for a suite of integrated restorative measures to accelerate natural recovery processes in forested watersheds impacted by past practices. Natural recovery would otherwise require several decades (landslides) to 1-2 centuries (stream channels). Success is closely associated with a watershed-scale focus, effectiveness monitoring, and training and education initiatives, including an ongoing BC-US technical exchange with the US Forest Service.

Today there is much greater knowledge of the effects of past forest harvest practices on water quality, fish stock productivity and habitat losses of anadromous and resident fish (summarized in Slaney and Martin 1997). Briefly, most watersheds in the province that have supported intensive forest harvesting activities in the past have altered flow and drainage patterns, resulting in greater sediment delivery to fish-bearing streams and community water supplies. Over the past decade, hillslope failures from roads and gullies have become much more evident as logging has shifted to steeper slopes. Old roads have failed more frequently at drainage crossings or saturated side-casts which incorporated decaying woody debris. Further, most coastal and many interior streams were historically logged to the streambanks, augmenting bank erosion and creating a major deficit in the future supply of large mature wood to stream channels. Large wood is the primary structuring element in forested streams, providing pool habitat and cover for fish rearing in summer as well as critical refuges from extreme winter-spring conditions. Although the role of large wood in streams in providing fish habitat was established earlier, the linkage to the natural riparian-channel process of large wood loss and recruitment was not understood or recognized until the 1980’s (Slaney and Martin 1997). Past fisheries legislation tended to promote large wood removal, and past practices by fisheries and water management agencies that resulted in removal of wood, especially of log jams, has compounded the problem further. Moreover, channelized or uniform sections of streams are also common where streams have been aligned or diverted to protect logging roads, crossings, log sorting and milling sites. Fish passage at road culverts has been a long-standing and universal concern, but it was not appreciated in the past that juveniles frequently require off-channel refuges to successfully over-winter. A lack of stream nutrients, resulting from the combination of watershed impacts and overfishing which reduces salmon carcasses as a source of nutrients and carbon, is a more subtle and unrecognized impact that is only now receiving greater attention as declining trends in escapements of salmon become more evident. Recent tracer studies in the USA and Canada demonstrate the key role of marine-derived nutrients, even in the smaller salmon streams. Finally, early forestry practices favoured natural restocking of trees, which resulted in a dominance of deciduous trees, and promoted damming activity by beavers on small streams utilized by migrant fish species.

Case studies that examine biological benefits of watershed restoration at a watershed or reach level are sparse, but there is compelling evidence that selected aquatic techniques are successful. Off-channel fish habitat projects have a high incidence of success because of a lengthy history in British Columbia; typical egg-to-fry and juvenile survivals are much higher than in mainstems. Evidence supporting stabilization of logged hillslopes and channels, or restoration of large wood in streams, is largely from a few US case studies. For example, hillslope and channel stabilization at Deer Creek, Washington, have reduced sediment transport and in-filling of boulder substrates and pools. There, adult coho salmon and summer steelhead have been documented to have recovered to 60-80 % of historical abundance, from a low of 10-20 % a decade ago. Also, the effects of restoration of large wood in three debris-poor streams were monitored at Porter Creek (Washington) and at tributaries of the Alsea and Nestucca Rivers (Oregon). Smolt outputs increased 3-5-fold from the treated streams compared to controls. Results have been less conclusive from monitoring of 14 km of large wood restoration at a higher gradient stream at Fish Creek, Oregon, where the boulder substrate provided some of the habitat structure. More recent effectiveness monitoring of restoration projects in British Columbia are providing additional support, as documented at the Keogh River for anadromous fish and at the West Kettle River for resident fish, and preliminary results are summarized in the 1998/99 Annual Compendium. For example, watershed level treatments of the Keogh system, including road-gully stabilization, annual nutrient replacement, off-channel habitat restoration or replacement, and ongoing instream fish habitat rehabilitation have been recently associated with strong upward trends in the abundance and average sizes of both coho salmon and winter steelhead trout.

It is assumed that restoration of structural diversity and nutrient sources (often salmon carcasses) will accelerate recovery of aquatic communities and biodiversity of disturbed aquatic ecosystems. Large, old growth trees in stream channels with their massive rootwads as anchors are the type of structure that cannot be easily duplicated or replaced. This is the rationale for cable-anchoring of woody complexes to streamside trees and instream boulders, at least on the first pass. Salmon spawners and kokanee, in particular, are keystone species as the vital link between aquatic and terrestrial communities, especially within the riparian zone. For the long term, riparian restoration needs to be implemented and maintained to accelerate recovery of riparian functions, providing future desired conditions for fish and wildlife resources; shrubs and deciduous trees for leaf litter mixed with mature coniferous trees for large wood recruitment and fluvial-resistive root systems. Most of the projects outlined in the Compendium are focused on the short term (20-50 years), but riparian projects are increasingly focused on the long term.

Practitioners of restoration have little control over fish harvest rates, or climatic conditions that cause shifts in migrant survivals. However, recent measures in British Columbia to preserve stocks-at-risk, improve management of weak stocks and rebuild other stocks should ensure more rapid positive responses to watershed restoration.

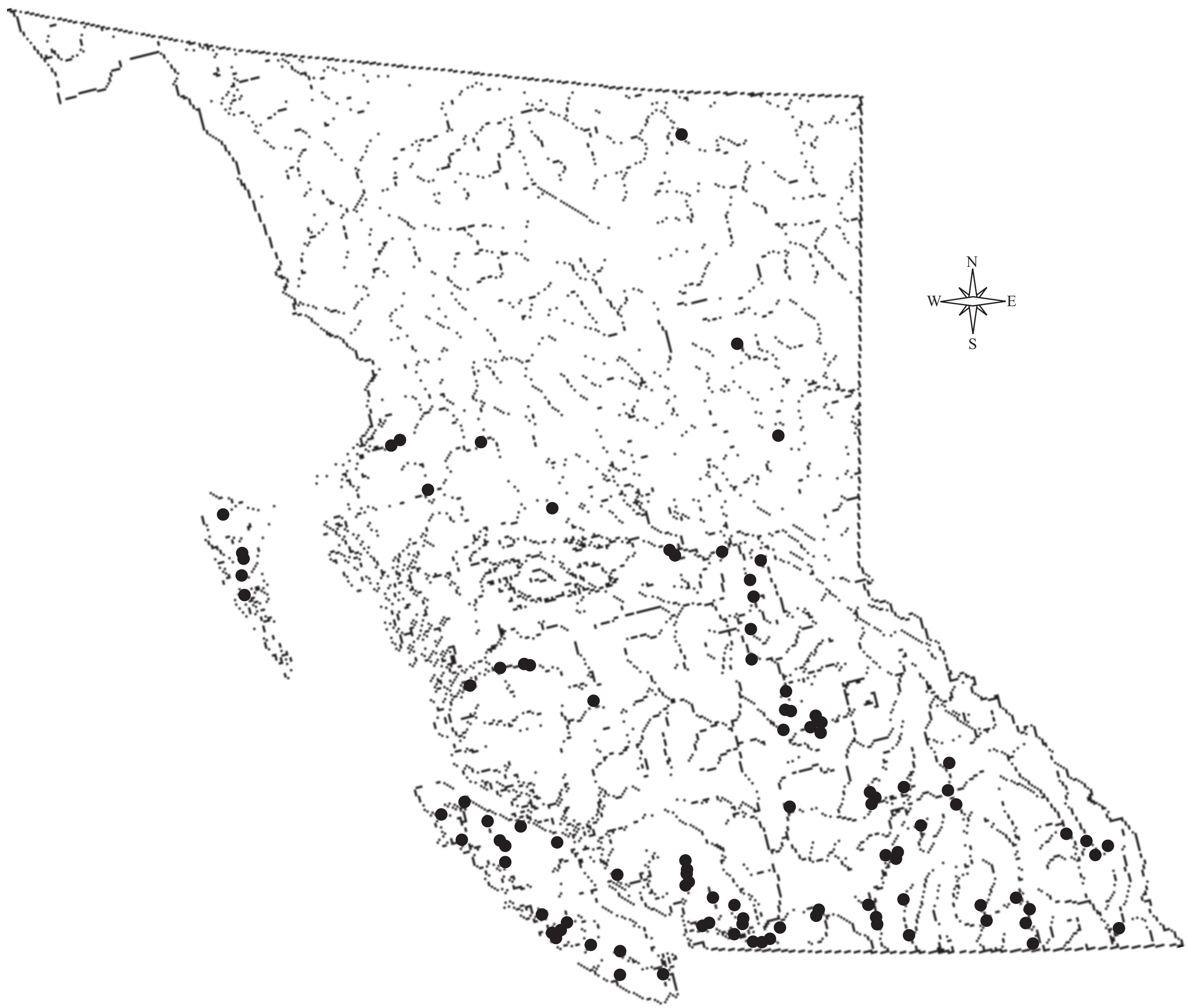
Pat A. Slaney, Technical Coordination Manager
Watershed Restoration Program
Ministry of Environment, Lands and Parks

Summary of WRP stream and riparian assessment and restoration projects, by Ministry of Environment, Lands and Parks region/subregion, which were undertaken in the 1998/99 fiscal year, whereby numbers are derived on a watershed sub-basin or tributary level.

	Channel Assessments	Habitat Assessments	Riparian Assessments	Culvert Assessments	Habitat Channel Restoration	Riparian Restoration	Fish Passage Restoration	Project Effectiveness Monitoring[1]
Vancouver Island	4	35	11	6	20	4	1	8
Lower Mainland	10	24	16	4	23	11	0	15
Southern Interior	12	8	3	0	16	16	0	1
Kootenay	3	7	4	1	19	1	1	2
Cariboo	0	24	1	12	8	1	10	2
Skeena	3	30	16	1	13	4	3	8
Omineca	3	15	7	6	6	4	0	4
Peace	4	4	4	182	6	1	9	1
Totals	**39**	**147**	**62**	**212**	**111**	**42**	**24**	**41**

[1] These projects are not routine monitoring.

WRP Project Locations in British Columbia (1998-99)



Acknowledgements

The Ministry of Environment, Lands and Parks, Watershed Restoration Program, wishes to thank their staff and agencies, forest companies, First Nations groups and consulting firms whose staff contributed to this compendium as authors, reviewers or advisors, photographers or conducted the work, including Fisheries and Oceans Canada, Habitat and Enhancement Branch; Alouette River Management Society; Habitat Conservation Trust Fund; Ministry of the Attorney General, Alouette River Correctional Centre and Stave Lake Correctional Centre; EcoTec Environmental Consultants; the British Columbia Conservation Foundation; J.A. Taylor and Associates; MacMillan Bloedel Ltd.; LGL Limited; Te'mexw Treaty Association; Northwest Ecosystem Institute; Tla-o-qui-aht First Nation; Central Westcoast Forest Society; Thornton Creek Enhancement Society; Instream Fisheries Consultants; Ministry of Fisheries, Fisheries Branch, Research and Development Section; Fisheries Renewal BC; West Coast Sustainability/Regional Aquatic Management Society; Northwest Hydraulic Consultants Ltd.; Aquaterra Environmental Services; Western Forest Products Ltd., North Island Division and Mainland/Islands Region; Kyuquot Management Board; Nuu'Chah'Nulth Tribal Council; Interfor, Kingcome Enhanced Forestry Division, Mid Coast Division and Adams Lake Lumber Division; Canfor, Englewood Logging Division and Fort St. John Division; 'Namgis First Nation; International Woodworkers of America (IWA); Alby Systems Ltd.; Steelhead Society Habitat Restoration Corp.; Pacheedaht Band; Sooke Renfrew Forestry Society; San Juan Enhancement Society; Cowichan Lake Forest Coop.; Renfrew Community Association; TFL Forest Ltd.; Huu-ay-aht First Nation; Ostapowich Engineering Services Ltd.; M.C. Wright and Associates; Hupacasath First Nation; Community Futures Development Corp. of the North Fraser; Piscofile; Sliammon Development Corp.; J.S. Jones Holdings Ltd., Pitt Lake Logging Division; Ardew Wood Products Ltd.; Ministry of Forests; Chase Creek Community Association; Riverside Forest Products Ltd.; EBA Engineering Consultants Ltd.; Whitevalley Community Resource Centre; Tolko Industries Ltd., Lavington Division and Louis Creek Division; Skeetchestn Indian Band; Riverside Forest Products, Lumby Division; Hudson Creek Preservation Society; Kingfisher Environmental Interpretive Centre Society; Spallumcheen First Nations; The Corporation of the District of Peachland; Edgewater Pines Mobile Home Park; First Nations of the Okanagan and Similkameen Environmental Protection Society; Penticton Indian Band; Silvatech Consulting Ltd.; The Corporation of the District of Summerland; Timberland Consultants Ltd.; Integrated Resource Consultants Inc.; Pope and Talbot Ltd., Boundary Timber Division and Midway Division; Downie Street Sawmills Ltd.; Ktunaxa Kinbasket Development Corp.; Deverney Engineering Services Ltd.; G.G. Oliver and Associates; Meadow Creek Cedar Ltd.; Revelstoke Community Forest Corp.; Slocan Forest Products Ltd., Slocan Division, Radium Division and Fort Nelson Woodlands; Crestbrook Forest Industry Ltd.; Kalesnikoff Lumber Co. Ltd.; Hay and Company Ltd.; Global Forestry Ltd.; Wynndel Box and Lumber Co. Ltd.; Kokanee Forests Consulting Ltd.; Central Coast Regional District; Central Coast Fisherman's Protective Association; Weldwood of Canada Ltd., 100 Mile House Operations and Williams Lake Division; Bioterra Consulting; Kleena Kleene Resource Associaton; West Fraser Timber Ltd., Quesnel Division; Ainsworth Lumber Co. Ltd.; Husby Forest Products Ltd.; Coast Forest Management Ltd.; Haida Fisheries Program; Gwaalagaa Naay Corp.; Nisga'a Tribal Council; Gitsegukla Band Council; Kitsumkalum Band Council; Terrace Salmonid Enhancement Society; Naden Harbour Timber Ltd.; Old Massett Village Council; MTE Inc.; AquaFor Consulting Ltd.; Northwood Inc.; Saik'uz First Nation; Conor Pacific Environmental Tech Inc.; Summit Environmental Consultants Ltd.; North Thompson Indian Band; ARC Environmental; Winlaw Watershed Association and equipment contractors. Diana McPhail of Dragonfly Designs provided the desktop publishing and graphics services. Kerry Baird compiled the UTM coordinates (NAD 83 zones; northings and eastings); watershed codes and waterbody identifiers. Marc Porter converted the waterbody identifiers into Albers northings and eastings and produced the maps.

Funding for the development and production of this compendium on WRP aquatic rehabilitation projects was provided by Forest Renewal BC.

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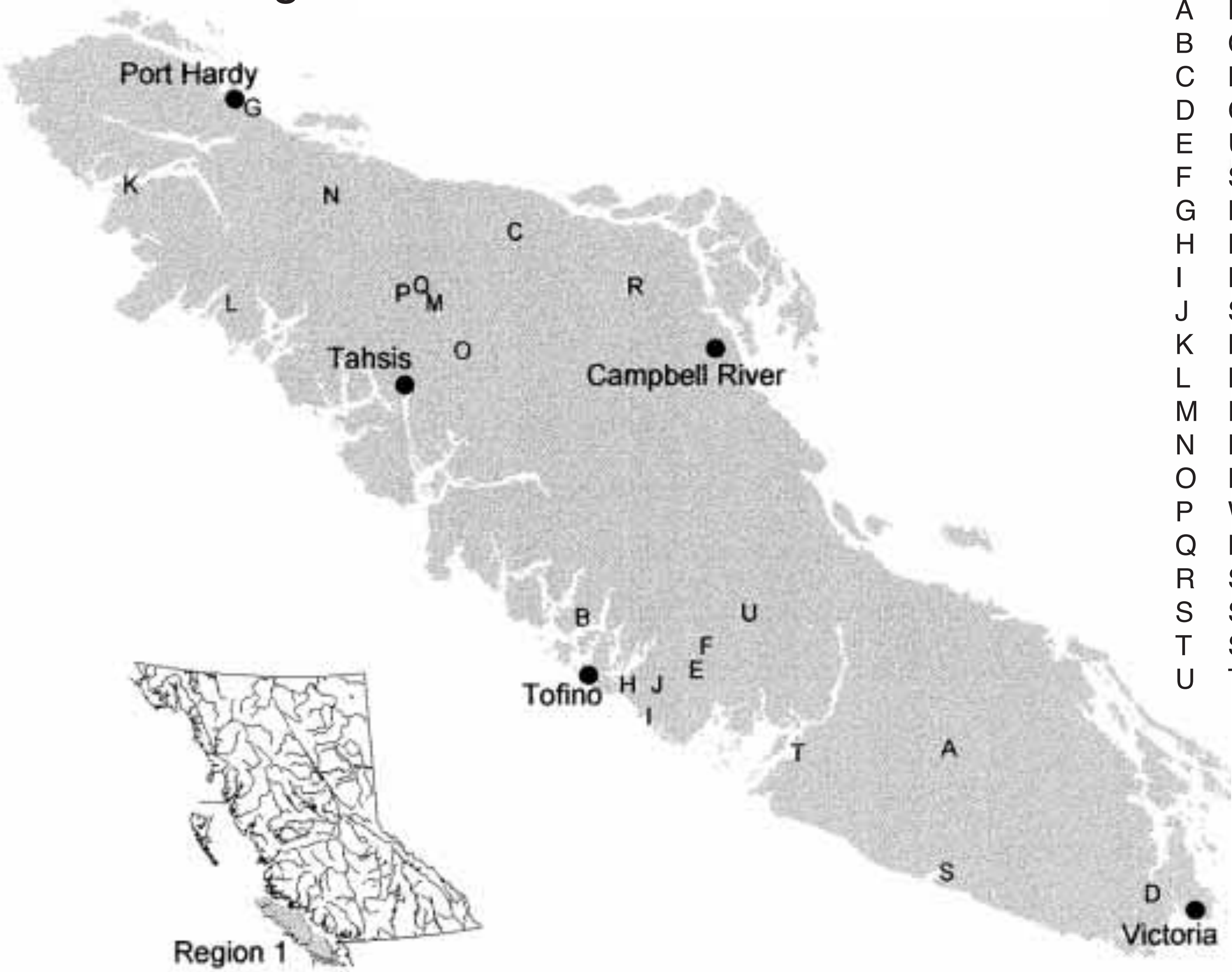
Map showing WRP project locations in Region 7, Omineca-Peace.
UTM (NAD 83) zones, northings and eastings, watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 7, Omineca-Peace.

Late Submissions

Vancouver Island Region

Region 1. Vancouver Island



WRP Projects

A Nixon Creek
B Cypre River
C Montague Creek
D Goldstream River
E Upper Kennedy River
F Stump Creek
G Keogh River (Mon./Rest.)
H Kootowis Creek
I Lost Shoe Creek
J Staghorn Creek
K Mahatta River
L Malksope River
M Davie River
N Kilpala River
O KO51 (Lutz) Creek
P WB9 (Unnamed) Creek
Q Lukwa Creek
R Spirit Creek
S San Juan River
T Sarita River
U Taylor River

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 1,Vancouver Island.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
A	**Vancouver Island**	Cowichan River	Nixon Creek	10	5417354	399268	920-257700-91900	00000COWN
B		Cypre River	Cypre River	10	5462196	288082	930-368500	00000CLAY
C		Eve River	Montague Creek	9	5580422	699253	920-758000	00000TSIT
D		Goldstream River	Goldstream River	10	5370333	459475	920-21190	00000VICT
E		Kennedy River	Upper Kennedy River	10	5444678	322380	930-306400	00000CLAY
F		Kennedy River	Stump Creek	10	5451912	325846	930-306400-41800	00000CLAY
G		Keogh River	Keogh River (Restoration & Monitoring)	9	5615301	616725	920-866900	00000NIMP
H		Kootowis Creek	Kootowis Creek	10	5441122	301010	930-300800	00000CLAY
I		Lost Shoe Creek	Lost Shoe Creek	10	5431131	306959	930-260600	00000ALBN
J		Staghorn Creek	Staghorn Creek	10	5440866	310134	930-306400-11900	00000CLAY
K		Mahatta River	Mahatta River	9	5590185	580508	930-823900	00000BRKS
L		Malksope River	Malksope River	9	5555200	612734	930-722200	00000TAHS
M		Nimpkish River	Davie River	9	5563257	673341	920-825900-61000	00000NIMP
N		Nimpkish River	Kilpala River	9	5589430	642009	920-825900-17000	00000NIMP
O		Nimpkish River	KO51 (Lutz) Creek	9	5543328	684491	920-825900-77900-35500	00000NIMP
P		Nimpkish River	WB9 (Unnamed) Creek	9	5565066	668762	920-825900-55500-06100	00000NIMP
Q		Nimpkish River	Lukwa Creek	9	5564269	671737	920-825900-59200	00000NIMP
R		Salmon River	Spirit Lake	10	5563264	308666	920-725300	00231SALM
S		San Juan River	San Juan River	10	5379476	396747	930-053800	00000SANJ
T		Sarita River	Sarita River	10	5418043	352704	930-110800	00000ALBN
U		Taylor River	Taylor River	10	5461615	339253	930-137400-99100-99100	00000ALBN

Nixon Creek Off-channel Habitat

Objectives
To increase stable off-channel habitat for spawning and rearing salmonids, by extending and complexing existing flood and relic side channel habitat on Nixon Creek.

FRBC Region/MELP Region/MOF Region
Pacific / Vancouver Island / Vancouver

Author
Deborah Epps, Russ Doucet, Mel Sheng, and Graham Hill.

Proponent
Ministry of Environment, Lands and Parks.

Watershed
Cowichan River

Location
The groundwater channel is on the left side of Nixon Creek. It is located approximately 3.0 km above Lake Cowichan, parallel to the Caycuse Main logging road.

Introduction
Nixon Creek is the fifth largest tributary to Cowichan Lake, and contributes to the fishery production of the world renowned Cowichan River. Nixon Creek supports cutthroat (*Oncorhynchus clarki clarki*) and rainbow trout (*O. mykiss*), Dolly Varden char (*Salvelinus malma*), and limited numbers of steelhead trout (*O. mykiss*). Cowichan Lake's tributaries also support a coho (*O. kisutch*) population that is said to be in decline. Sporadic chinook (*O. tshawytscha*) spawning has also been reported.

A majority of the Cowichan River watershed is privately owned by Timberwest Ltd. A few small blocks through the lower valley are crown land (TFL 46, managed by Timberwest). The area selected on Nixon Creek for rehabilitation falls within the TFL 46 boundary.

The salmonid habitat degradation of Nixon Creek is not unique in the Cowichan Valley, which has been impacted by decades of logging. Most of the watershed was logged about 40 years ago. Logging was conducted for the most part, to the stream's edge, with no streamside buffers maintained. Overall, logging has caused an increase in the magnitude of flood flow rates which has accelerated bank erosion and caused excess gravel to be deposited in the lower reaches of the creek. Because of this aggradation, creek sections experience subsurface flow for up to three months of the year. For fish, the result is a decrease in stable spawning and rearing habitat, both in the mainstem, and in the off-channel habitat area that becomes inaccessible from the mainstem during periods of low flow.

Assessments and Prescriptions
An assessment of Nixon Creek conducted by Timberwest in March 1995, determined that fish production was limited because of summer dewatering and high fall/winter discharge. Results indicated that excessive bedload in the lower 2000 m (approx.) of Nixon Creek created an environment where no water was available during the summer months, despite a summer wetted width of 15 m and a low flow of approximately 8 cfs upstream of the area.

The recommendation to improve the habitat in the area, was for gravel to be removed in the lower 2000 m of the creek. This recommendation was not a feasible option for the Watershed Restoration Program, because of associated private land and sediment source issues.

During 1996, Fisheries and Oceans Canada (DFO) staff, Mel Sheng and Russ Doucet became involved in the project through discussions with both Timberwest and the Cowichan Watershed Council (Ted Burns). It became apparent that an extensive network of complex side channels existed in Reach 2 and restoration opportunities were available. Test pits were excavated to monitor groundwater throughout the summer and winter of 1996. Results indicated that the historic channel could feasibly be restored to provide safe spawning and rearing habitat. The channel would benefit all life stages of coho, and spawning and rearing stages for steelhead and cutthroat trout.

Rehabilitation Work
In the summer of 1997, the first phase of the

project was initiated. A 150 m test channel was excavated (Fig. 1-1). This channel was built to a width of 3-5 m, and a depth of 2-3 m. The channel was monitored throughout the year for water quality and flow rate. Some fish utilization was also monitored which identified that juvenile coho and trout species were quick to inhabit the new channel. Designs were developed to extend the channel and complex the entire length during the summer of 1998.

In July of 1998, the second phase of the channel was built. The channel built in 1997 was extended upstream an additional 175 m. A 75 m secondary channel was also built for a total project length of 400 m and area of about 1400 m^2. The excavated material consisted of good quality gravel, suitable for use as spawning gravel in the channel.

Both channels were heavily complexed with large woody debris (Figs. 1-2 and 1-3). Approximately 175 rootwads were imported from a nearby clear-cut logged area, and placed in the channels to provide woody debris habitat for salmonids.

Two track excavators (Case 9040, Cat 320L) and 3 tandem axle gravel trucks were used to move the material (Fig. 1-4). Approximately 15,000 m^3 of overburden and gravel was hauled to a nearby storage area. Timberwest contributed half of the trucking costs because the excavated material could be used for road building. All construction activities, including riparian revegetation, were completed by September 1998.

Cost Summary

WRP labour	$ 11,259
WRP materials, equipment	$ 45,305
Phase 1 (1997)	$ 4,000
DFO (in-kind)	$ 3,000
Timberwest	$ 11,000
Total	$ 74,564

Production Estimates
Approximately 1400 m^2 of salmonid spawning and rearing habitat was created. At an expected density of 1-3 juveniles per m^2, this project could produce 1400 to 4200 juvenile salmonids annually.

For Further Information, Contact:
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Habitat Enhancement Branch
4166 Departure Bay Rd.
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Tel: (250) 756-7005 / 756-7016

Figure 1-1. The first phase of the project completed in 1997, was 150 m long.

Figure 1-2. A large volume of wood was placed into the main channel to provide cover for adults and rearing salmonids.

Figure 1-3. The secondary reach is 75 m long and is also heavily loaded with woody debris.

Figure 1-4. A Case 9040 excavator removed the overburden first to reduce the possible sediment load to the channel when it was excavated to grade.

Cypre River Groundwater Channel Construction

Objectives
Assessment of the Cypre River identified loss of overwintering/off-channel areas as a primary constraint to coho production (Taylor et al. 1998). Throughout much of the Cypre River, fish access to side channels is restricted by gravel bar formation at the entrance. In many cases, loss of connectivity to the mainstem is coupled with low habitat quality in the channels due to infilling with fines and lack of pools (Taylor and Ebell 1997).

These problems were addressed by the construction of a groundwater-fed side channel, in 1998. The primary objective was to provide overwintering and refuge habitat for coho and other salmonids such as rainbow and cutthroat trout. It was anticipated that spawning by coho would also occur in the channel.

FRBC Region/ MELP Region/ MOF Region
Pacific / Vancouver Island / Vancouver

Authors
John Taylor and John Ebell

Proponent
MacMillan Bloedel

Watershed
Cypre Watershed

Location
The Cypre River is located approximately 15 km northeast of Tofino in the coastal temperate rainforest of Clayoquot Sound, on the West Coast of Vancouver Island. The watershed drains an area of approximately 60 km^2.

Introduction
The Cypre River is of significant historical importance to the Ahousaht First Nations and represented an important source of salmon prior to the impacts to fish habitat resulting from logging. Logging has been conducted over approximately 40% of the Cypre River watershed. Initial limited harvesting between 1940 and 1973 comprised only 0.3% of forest cover, with a further 12% between 1974 and 1979 and 14% between 1980 and 1985 (Brown et al. 1987). Logging has not been conducted since 1997.

Observable changes to the Cypre River that have occurred as a consequence of logging are typically related to increased bedload and associated aggradation in low gradient sections of the river. The hydrology of the river has been modified by a combination of loss of forest cover and road construction, both of which facilitate the movement of precipitation into tributaries and the mainstem. The extensive loss of riparian vegetation (43% of all stream channels have been logged to at least one bank) has eliminated the supply of high quality LWD.

Assessments and Prescriptions
Since 1996 work has been conducted to provide a comprehensive assessment of the Cypre River leading to implementation of an appropriate strategy for watershed restoration. The principal components of restoration include stabilization and control of sediment sources, re-establishment of a riparian corridor along the mainstem and tributaries and rehabilitation of degraded fish habitat that has resulted from forest practices.

The proponent, MacMillan Bloedel, in partnership with the Ahousaht First Nations and the Nuu-chah-nulth Tribal Council is presently engaged in a program of road deactivation and rehabilitation within the watershed. Riparian concerns have been identified (Taylor et al. 1996), however, detailed assessment has yet to be conducted within the watershed and remains a priority for future planning.

Prescriptions for watershed restoration were developed in 1997/8 (Taylor et al. 1998). The highest restoration priority focused on the loss of protected winter habitat as potentially the greatest direct constraint to coho production in the system. Consequently, construction of a groundwater-fed side channel was proposed. The proposed channel was an extension to an existing side channel that enters the mainstem at 8+970 m.

The groundwater channel design was prepared by Mel Sheng and Russ Doucet of the Department of Fisheries and Oceans, Habitat Enhancement Branch. Construction was initiated on July 6, 1998.

Equipment and Labour
Construction activities in 1998, included the following: 603.7 hours of excavators; 203 hours of dump truck plus 19 hrs. standby, 10 hours of a boat, and 211.1 days of direct employment for 7 people of which 50.5% (106.5 person days) was local First Nations people. In addition to the substantial equipment component ($123,778), the project generated $26,190 for local business in the area, primarily for travel and accommodations.

Rehabilitation Work
The completed channel added approximately 690 m to the existing side channel, providing an additional 4420 m^2 of wetted area. Channel excavation required 5 passes, in each case working in an upstream direction. The first of these was a shallow cut to remove top soil (Fig. 1-5). This material was saved for use as a top cover on the set-back dyke. During preliminary excavation care was taken to preserve the existing coniferous forest on the southeast bank (Fig. 1-6). The second cut reached almost to the water table, removing mixed gravels and soils. This material was used for construction of the set-back dyke as were the subsequent cuts to a final grade level of 74.5 m. The final bed grade approximated 0%. Average channel width was 4 to 7 m with a side slope of 2:1 on the single disturbed bank. Discharge at the upper end of the channel exceeded the anticipated 5cfs.

The set-back dyke was constructed from two or more lifts of channel material and varied in width at the top from 3 to 10 m with an average slope of 1.5:1. The final dyke height was 82 m, providing protection from 1:100 year floods. An access road was constructed along the dyke, also from side-cast channel material. This originated as a 4 - 6 m wide construction bench which was created between the base of the dyke and the top of the western bank (Fig. 1-6).

Eight alcoves and 5 pond areas were incorporated into the channel. Five shallow inverts were created to provide approximately 35 m of riffle habitat. Additional habitat for juvenile salmonids was provided through channel complexing (Figs. 1-7 and 1-8). General training in the techniques of channel complexing were provided by John Ebell in conjunction with on-site visits from an experienced machine operator, Mr. Rick Hunter and an experienced habitat technician Mr. Bob Brown. The main components of training included:

- familiarizing the crew with natural high quality fish habitat;
- field reviewing similarly constructed channels;
- describing how various types of habitat are used by fish for different purposes, i.e., holding, feeding etc.;
- identifying the natural components of fish habitat, LWD, boulders, cutbanks, etc;
- describing how artificial elements of cover can simulate natural habitat;
- describing and practicing the techniques required in creating habitat complexity; and
- training the crew in safe work practices around construction machinery.

The components of channel complexing completed in 1998 were:

<u>Brush Bundles and Revetments</u>

- Brush bundles were used to create cover in both the existing and new channel. A total of 4 lateral revetments composed of juvenile conifers covering approximately 80 m of channel (each approx. 20 m long by 6 m wide) were installed.

<u>Artificial Undercuts</u>

- Two concrete undercuts and 8 log cut banks were installed for a total of 55 m of channel bank. Each concrete undercut provided an area of 6 m^2 while log structures averaged approximately 4 m^2. Installation of a log undercut is illustrated in Figure 1-9.

<u>Refuge Pits</u>

- Refuge pits were constructed from 42” diameter PVC culvert, placed in an excavation in the channel to a depth of approximately 3 m. Two refuge pits were installed in the new channel to provide wetted habitat during extreme low flows.

<u>Rip-rap</u>

- In total, 60 truck loads (each 20 yd^3) of 40 – 85 cm angular rock, was used along the channel to provide interstitial habitat for juvenile coho. Approximately 325 m of channel was lined on both sides to a depth of 0.5 m with rip-rap.

LWD Cover

- LWD was used in a variety of ways to provide cover and promote hydraulic diversity. A majority of logs and rootwads were placed as piled log structures providing complex refuge areas. In other areas logs were placed across or projected into the channel. In the lower, existing channel, logs were placed to dissipate high winter velocities, and to provide additional cover.

At the conclusion of side channel construction the set-back dyke and channel sides were seeded with a clover and grass mixture.

Cost Summary

Funding for this project was primarily provided by Forest Renewal BC: $168,635 plus additional funds for training ($11,180). The Department of Fisheries and Oceans contributed approximately $8,000 in in-kind costs for design and surveying and an additional $23,384 for excavator time and associated costs. Fisheries Renewal BC provided funding through the Regional Aquatic Management Society (RAMS) for channel complexing and associated disbursements ($19,436). Channel construction, complexing and related activities totaled approximately $222,635 as below:

Biological Monitor Project	
Labour and overhead	$ 64,359
Machine time	$ 123,778
Travel/accommodations	$ 21,558
Equipment, rentals, misc.	$ 12,940

Restoration Results

The completed channel added approximately 4420 m^2 of new habitat to the existing channel. Based on surveys conducted in 1997 and 1998 (Taylor and Ebell 1998), this area should support up to 3100 overwintering coho juveniles, as well as contribute annual production of approximately 4000 juvenile coho to the system from adult spawning. During spawner surveys conducted in October/November 1998, adult coho salmon were observed in the channel and one spawned chum salmon (*O. keta*) carcass was found. The potential for chum salmon spawning in the channel is an unanticipated bonus.

Proposed Work

Juvenile sampling is planned for February 1999 to assess the initial utilization by overwintering populations. This will be part of a training program for First Nations and a Tofino Enhancement Society member. Other aspects of the program will cover spawner enumeration techniques.

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Figure 1-5. First pass overburden removal in the lower portion of the Cypre side channel.

Figure 1-6. Site 18 in the upper portion of the Cypre side channel, with completion of the fourth pass to grade. As much of the southeast bankside vegetation as possible was retained during channel construction.

Figure 1-7. Site 18 following completion of the access road. The channel sides have been armoured with rip-rap, and complexing with wood is largely finished.

Figure 1-8. Channel complexing using rootwads, lateral revetments and LWD piles.

a

b

c

Figure 1-9a,b,c. Construction of an undercut bank using logs supported on boulders, covered with landscape fabric to minimize infilling and backfilled.

Goldstream River Bank Rehabilitation and Large Woody Debris Placement

Objectives
The primary purpose of this project is to provide rearing habitat for juvenile coho and steelhead by enhancing bank and instream features to promote scour and provide cover elements. A secondary purpose is to enhance holding habitat (deep pools with cover) for returning adult coho and chum spawners.

FRBC Region / MELP Region / MOF Region
Pacific / Vancouver Island / Vancouver

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Proponent
Te'mexw Treaty Association

Watershed
Goldstream River

Location
Goldstream River flows into the head of Saanich Inlet just north of Victoria on southern Vancouver Island. The lower, salmon-bearing portion of the watershed is within the Goldstream River Provincial Park and the upper portion of the watershed is within the Greater Victoria Water District, which has recently been designated an ecological reserve.

Introduction
Chum, coho and chinook salmon and steelhead trout use the lower Goldstream River for spawning and rearing. The river and its tributaries within the Capital Regional District water supply lands have been managed to supply water to the municipality of Greater Victoria. Both storage and diversion of water for municipal supply have affected the hydrology of the Goldstream River.

Logging has taken place in the watershed from 1938 to 1995. The total area harvested since 1938 was 8.6 km^2 or 15% of the total watershed area.

Reach 1 of the Goldstream is a depositional area for sediments. In the past, gravel has been removed and various works have been constructed in this part of Goldstream River to control gravel deposits. Some bank erosion has occurred along the banks of the Goldstream River due to flow diversions by gravel deposits. The course of the main channel in Reach 1 has changed in recent history.

Assessments and Prescriptions
The fish habitat assessment concluded that the availability of good quality side channel or main-stem rearing habitat for juvenile salmonids was lacking in Goldstream River. Pool habitat and off-channel habitat appeared to be lacking and cover within the stream was low. A high priority for restoration was given to reaches 1, 2, 3 and 4; while a medium priority was given to reaches 5, 6, 7, and 8.

Bank erosion along Reach 1 was identified as a problem and can be attributed to devegetation of the riparian zone and intensive foot traffic by humans using the park.

The study team felt that rehabilitation measures for the mainstem Goldstream, designed to stabilize banks, promote scour, and increase cover, would improve fish habitat despite the reduced flow regime from water withdrawal in this community watershed.

Coho, steelhead and chum salmon were identified as the target of stream rehabilitation in the Goldstream River. Adult spawners would benefit from an improved number of deep pools with cover for holding prior to spawning while coho and steelhead juveniles would benefit from creation of more main channel pool habitat (with cover) as well as off-channel habitat.

Rehabilitation Work
Works were conducted in September of 1998, and were limited to:

- Bank reconstruction to effectively narrow a 30 m section of the mainstem channel in Reach 1 to a normal bankfull width. This was accomplished by placing several 0.6 m logs end to end and backfilling with rip-rap and coarse gravel (Fig. 1-10). The instream face of the logs was covered with rip-rap to reduce erosion.
- Construction of 3 large woody debris structures, each consisting of 5-10 pieces of LWD (Fig. 1-11). Additional single log

placements were made in specific locations. These LWD additions were intended to promote scour, provide cover, and re-establish natural channel geometry.

Additional bank stabilization and LWD placement is scheduled for 1999 as well as some off-channel development.

Cost Summary
The following costs are for 30 m of bank stabilization, 3 complex LWD structures, and 3 smaller LWD placements in Reach 1 of the Goldstream River.

Construction and materials	$ 15,000
Supervision, design and labour	$ 10,000
Total	$ 25,000

Production Estimates
The stabilization of banks along Reach 1 was intended to narrow the over-widened channel. LWD placements were intended to promote pool formation and provide cover for juvenile and adult salmonids. Visual assessments of the structures during the chum spawning period indicated extensive use of the LWD structures by adult chum for holding. The LWD structures also performed extremely well as carcass "catchers" which is an important function for the retention of nutrients in the system.

Monitoring and assessment of the structures for juvenile use will take place during low flow conditions in 1999. It is expected that the LWD structures will provide important rearing habitat for coho juveniles.

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Figure 1-10 . Photograph of Site 2 in Reach 1 of the Goldstream River where the left bank was reconstructed using logs, rip-rap and gravel.

Figure 1-11 . Photograph of Site 7 where a typical lateral log spur was constructed along the right bank.

Upper Kennedy River Side Channel and Stump Creek Side Channel

Objectives
To address degraded habitat conditions, fragmented salmon habitat use and associated salmon stock production declines, we have identified, designed and initiated stream restoration projects in the Kennedy Watershed. Projects are designed to assist in the rebuilding of selected salmon stocks where the case for historic to recent logging impacts appear strong and the future benefits relative to cost appear high. During the past years, 2 rehabilitation projects (1 large and 1 small project) were completed in the watershed, while another 15 projects are in the pre-implementation review stage. During 1998, the upper Kennedy side channel (Fig. 1-12) and the Stump Creek side channel projects were completed.

Restoration goals for the upper Kennedy River side channel in 1998 included:

- Completion of channel complexing, rock/riffle structures and final elevations on flood protection set-back dykes (Figs. 1-13, 1-14, 1-15, 1-16).
- Completion of a rating curve for flow control through an intake structure and slide gates.
- Completion of physical and biological monitoring.

Restoration goals for the Stump Creek side channel in 1998 included:

- Construction of 1 multiple LWD structure anchored with rock ballast (Fig. 1-17).
- Excavation of a pool in association with a LWD structure.

FRBC Region/MELP Region/MOF Region
Pacific / Vancouver Island / Vancouver

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Fisheries and Oceans Canada
MacMillan Bloedel Ltd.
Central Westcoast Forest Society
Thornton Creek Enhancement Society

Watershed
Kennedy River Watershed

Location
The Kennedy Watershed is located within Clayoquot Sound on the west coast of Vancouver Island. The upper Kennedy side channel is located 2 km north of Kennedy Lake on the right bank of the upper Kennedy River. Stump Creek side channel is located 11km north of Kennedy Lake on the left bank of the upper Kennedy River.

Introduction
Anadromous salmon occupy at least 300 km of streams and shorelines within the Kennedy watershed and its habitat and salmon production values are considered high among other watersheds within Clayoquot Sound. Anadromous salmon and resident salmonids that use the Kennedy watershed include: sockeye (*O. nerka*), coho, chinook, steelhead, chum, and pink (*O. gorbuscha*) salmon; rainbow trout, cutthroat trout and Dolly Varden char. Given the size and complexity of the watershed, there are dozens of identifiable local populations of salmon and trout, exhibiting a diversity of life history traits. Of the known habitats used by salmonids in the watershed, greater than 75% of these areas (streams 135 km/ shoreline 92 km) have been impacted by past logging practices.

Sockeye and coho have historically had the highest escapement in the Kennedy watershed, with peak returns of over 150,000 and over 25,000 adults, respectively (Johannes et al. 1999). Both recent and historic escapement surveys have indicated a dramatic decline in the relative stock abundance of sockeye, coho, and chinook salmon as well as the extinction of both local chum and pink salmon stocks. Logging-related activities such as road construction and clearcuts in combination with terrain and climate conditions have created high sediment erosion along with frequent debris and landslide events in many higher elevation sub-basins in the watershed. These processes, in combination with changes to riparian zone canopy cover as well as altered recruitment of large woody debris supplies, have had considerable impact on habitat conditions and salmon production.

Assessments and Prescriptions

Extensive logging in the upper Kennedy River watershed has led to severe deterioration of salmon spawning and rearing habitats in both the upper Kennedy River side channel and the Stump Creek side channel.

In the upper Kennedy side channel, aggraded sediments have reduced habitat conditions to the point where little or no water flow exists. During 1997, the upper 1250 m of the side channel was excavated to grade and an intake control structure was installed to support controlled flows from the Upper Kennedy River. Flood protection was constructed in 1997, in the form of set-back dykes. Discussion of 1997 activities can be found in Zaldokas (1998) and Johannes and Hyatt (1998). Planned restoration activities on the upper Kennedy side channel during 1998 included: channel complexing with single and multiple LWD structures, bank stabilization, rock / riffle construction, revegetation, intake control and water system testing and site cleanup.

In the Stump Creek side channel, degraded substrate has created paved conditions across much of the 650 m channel length. This side channel experiences peak flood conditions (1:50) where discharge reaches 250 $m^3 \cdot s^{-1}$. The challenge for restoration prescriptions was to plan a series of ballasted LWD structures which would survive peak flood conditions and locally support aggradation of sediments and maintain pool formation for salmon spawning and rearing. Planned restoration activities on the Stump Creek side channel during 1998 included construction of a single multiple LWD structure to support scour in an accompanying excavated pool.

Equipment and Labour

Construction activities in 1998 included the following equipment and labour: 125 hours of Hitachi 200 excavator time, 50 hours of dump truck time, 15 hours of "spider" time, and 260 days of employment for 31 people.

Rehabilitation Work

Restoration activities on the upper Kennedy side channel were designed and planned in 5 component construction phases including: (1) flood protection dykes (Fig. 1-13), (2) intake and flow control structures, (3) excavation of main channel (Fig. 1-14), (4) complexing and function of entire side channel (Fig. 1-15), and (5) site cleanup, revegetation, bank stabilization and signage (Figs. 1-12, 1-16). Construction of the main dyke, intake system, and main channel were initiated in late September 1996 to mid-October 1996, and again in mid-July 1997 to mid-September 1997. The final phases of restoration on the upper Kennedy side channel started on August 12, 1998 and were completed on September 23, 1998.

A second smaller project was undertaken in 1998. Restoration of the Stump Creek side channel started on September 24, 1998 and was completed on September 25, 1998 (Fig. 1-17). Additional restoration of the Stump Creek side channel will be conducted through a number of phases in following years, but construction began in 1998 with a trial which included the excavation of a pool and placement of LWD structures to help support ongoing scour and sediment aggradation in the pool area.

Restoration activities completed in both project sites during 1998 included:

Upper Kennedy Side Channel

- Complexing with the addition of > 200 LWD positioned (in some cases cabled together) instream and on banks as multiple structures or as single deflectors.
- 12 rock/riffle structures to support upstream pools and downstream riffles.
- 10 boulder placements in the channel for cover.
- 7 banks stabilized with rip-rap.
- Banks revegetated with seeding and conifer and willow (*Salix spp.*) plantings.

Stump Creek Side Channel

- Excavation of a 15 m x 7 m x 2.5 m pool.
- Placement of excavated boulder material on right bank.
- Construction of a cabled 8 piece multiple LWD structure with 6 rocks cabled for ballast.

Cost Summary 1998

Engineering and Construction Supervision Project

Labour	$ 45,188
Equipment	$ 22,975
Rentals, misc.	$ 21,794
Total	$ 89,957

Monitoring Results for 1997, 1998, 1999

Surface water flow was opened into the upper Kennedy side channel on September 17th, 1997. Northwest Ecosystem Institute, and Fisheries and Oceans Canada supported monitoring to the channel during 1997 and again a portion in 1998/99. In the upper Kennedy side channel approximately 1250 m of channel was actively restored to functional salmon habitat and an additional 2000 m of wetted channel was created by continuous surface flow opened from the upper channel.

During the spawning period in 1997 and again in 1998, the upper 500 m of the side channel was counted through visual observation. Following the opening of the side channel on September 17th, 1997, approximately 71 coho and 20 sockeye adults were counted in the upper 500 m portion of the side channel. In 1997, approximately 280 coho and 30 sockeye adults were counted throughout the entire 3200 m side channel. In 1998, biological surveys were supported by FRBC and NEI and 38 sockeye and 94 coho adults were counted in the upper 500 m portion of the side channel.

In Stump Creek side channel, approximately 21 coho adults were counted holding under the LWD structure and 8 adults were observed spawning. The habitat restored included: 50 m of main side channel, 20 m of a small tributary; and 0.025 ha of rearing habitat.

Proposed Works Kennedy Watershed 1999

Monitoring and limited maintenance activities are scheduled for 1999 and will include:

- data logger download and maintenance;
- monitoring of bank stability and bank revegetation success;
- monitoring and maintenance of LWD structures and rock riffles; and
- monitoring juvenile and adult salmon habitat use.

Fifteen new restoration project sites are planned in successive years in the Kennedy watershed. FRBC funding will be used in conjunction with other funding sources to support ongoing restoration and monitoring project activities.

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Figure 1-12. Signage developed on the upper Kennedy side channel.

Figure 1-13. Discharge apron and start of the upper Kennedy side channel (looking upstream).

Figure 1-14. LWD structures, pool and riffle structure in the first 100 m of the upper Kennedy side channel.

Figure 1-15. Rip-rap banks, LWD structures in the upper Kennedy side channel at 4+90 m.

Figure 1-16. Lower portion (8+10 m) of the upper Kennedy side channel 1 year post construction.

Figure 1-17. Stump Creek side channel LWD structure and excavated pool following first fall flood. Tla-o-qui-aht First Nation crew chief standing beside jam for scale.

All photographs taken by M. Johannes 1998/99.

1998 Keogh River Instream and Off-channel Restoration Projects

Objectives

The objectives of the Keogh River watershed Restoration Program (KRWRP) are two-fold: 1) restore fish habitat degraded as a result of past forest harvesting practices, and 2) instruct restoration professionals on the proper techniques for assessing and restoring fish habitat. Restoration activities involved the placement of LWD structures, boulder clusters, riffle reconstructions and off-channel habitat development.

Fish habitat assessment and restoration techniques courses continue to be held at the Keogh River. In addition, various research projects investigating salmonid population dynamics, the effectiveness of restoration structure placement and stream fertilization on salmonid growth and survival, and ballasting requirements for structural integrity of LWD complexes continue as well.

FRBC Region/MELP Region/MOF Region

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Proponent

Ministry of Environment, Lands and Parks Western Forest Products Ltd., North Island Division.

Watershed

Keogh River

Location

The Keogh River, a third-order coastal stream, is at the northern end of Vancouver Island. It flows northeast for 33 km from Keogh Lake headwaters and drains into Queen Charlotte Strait (127.4 W, 50.6 N) south of Port Hardy, B.C.

Introduction

The Keogh River is a demonstration training site for both applications of instream and off-channel fish habitat rehabilitation under the Watershed Restoration Program. Several introductory restoration short courses have been given on the North Island, using restored reaches of the Keogh River to illustrate "best practices". Further, it is the only paired watershed site on the entire Coast for intensive effectiveness monitoring, whereby three years of both instream density and smolt output data has been obtained. Restoration of degraded fish habitat along the upper half of the 33 km long stream is near-complete. Key tributary and mid-lower mainstem site restoration remains, as well as riparian reserve treatments to achieve the "future desired riparian condition". The Keogh River lies largely in Tree Farm License 25, of Western Forest Products Ltd. (WFP), who is a partner in restoring the watershed. Over the past five years, Western has supplied restoration materials and undertaken cross ditching, water bar and revegetation work at most unstable road and gully sites. The potential impacts of depressed restoration funding places this key evaluation project at risk, as insufficient restoration has been completed to date to provide an evaluation at a watershed scale.

Instream Rehabilitation Work

Restoration activities were once again concentrated along the upper 13 km of the mainstem Keogh River, with an additional 1.4 km of stream length receiving restoration treatments. A total of 68 instream restoration structures were built during the 1998/1999 restoration season. A majority of instream restoration work involved the creation of new fish habitat (Figs. 1-18 to 1-20). Furthermore, considerable effort was put forth to either reconstruct, or increase the productive capacity of past restoration efforts (Figs. 1-21, 1-22).

Material Requirements

Restoration activities were spread over a lineal river distance of 5.3 km, requiring a total of 172 pieces of large woody debris (LWD), 55 rootwads (RW) and 278 large boulders. Of this total, 111 large trees (174 m^3), ranging from 8 m - 12 m in length and from 0.4 m - 0.8 m in diameter, were purchased from WFP, while 43 logs came from instream and riparian sources and the remaining 18 from structures built during the 1996 or 1997 restoration seasons. In addition, the project required 55 rootwads, 50 of which came from recently harvested cutblocks. Another 4 rootwads came from the stream margin and 1 came from a structure placed in 1996. A total of 205 boulders came from nearby quarries located within the WFP tenure. The remaining boulders were obtained either within the stream margins (48) or were part of structures built over the previous 2 restoration seasons (25). All boulders ranged in size from 0.6 m - 1.3 m in diameter along the b-axis.

Approximately 1000 lineal m of one-half inch galvanized wire rope cable and 188 galvanized steel U-clamps were used to secure the LWD to boulders and/or riparian trees within the structural complex during the 1998 restoration project. Eighty-three tubes of epoxy glue were used to fasten the cables to boulders. Sufficient fixed points are now available to readily trap transported large and small woody debris, adding complexity to summer habitat and overwintering refuges.

Heavy Equipment Requirements
A number of different types of heavy equipment were used to complete the project including 3 excavators, 2 helicopters, 2 self-loading logging trucks, 4 dump trucks and 1 lowbed truck. WFP employees and contractors were given precedence for all jobs requiring heavy equipment.

Employment Figures
The 1998 restoration project created a total of 241.25 person-days of employment to complete, based on an 8-hour work day. This includes 100 days for the Senior Biologist and Project Coordinator, 31.5 days for the Senior Technician, 69.75 days for unionized New Forest Opportunities workers and 40.4 days for unionized and non-unionized equipment operators. Hours required by WFP and the B.C. Conservation Foundation (BCCF) administrative staff to complete tasks associated with the 1998 project are not included in this summary.

Cost Summary

Equipment and operators	$ 75,055
Employment	$ 47,696
Materials	$ 17,971
Misc. expenses	$ 11,538
Administration (BCCF)	$ 4,677
Total	$156,937

As in previous years, project funds were injected back into the local economy, wherever possible, through the use of local contractors and businesses.

Production Estimates
A total of 68 fish habitat structures were either installed or improved, creating an estimated 4534 m^2 of fish habitat. By applying coho fry and steelhead juvenile production information derived by McCubbing and Ward (1997), the 1998/1999 instream restoration component of the KRWRP has produced enough summer habitat to accommodate at least 3127 coho fry and 267 steelhead juveniles, annually. Low escapements of both coho and steelhead, for the 1997 brood year, likely means that the quoted annual production estimates are much lower than what would occur in years of higher coho and steelhead escapements. The high 1998 coho escapement (>8000), which should completely seed the watershed, will likely provide conditions needed to determine the maximum productive capacity of the habitat structures for coho juveniles in the summer of 1999. Recurrent low steelhead escapements leave the system vastly undressed and, therefore, steelhead juveniles production estimates will continue to be lower than capacity.

In addition, relatively high flows during the 1997 sampling period allowed for the fish to spread out more from pool habitats. This was not the case in 1998 when extremely low flows apparently forced salmonid juveniles to deeper water habitats associated with debris jams and other LWD structure configurations.

These assumptions only further reflect on the importance of continuing research on how habitat restoration structures affect salmonid juveniles throughout their freshwater residence.

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Figure 1-18. Lateral debris jam, located along the Wolfe Creek restoration section, placed to scour pool habitat and provide protective cover habitat.

Figure 1-19. Bank protection /debris jam structure placed to protect an eroding bank, scour pool habitat and provide protective cover habitat.

Figure 1-20. Lateral debris jam placed to scour pool, aggrade spawning gravel and provide protective cover habitat.

Figure 1-21. Large rootwad added to double deflector log to increase the efficiency of deflector structure. The same treatment was applied to an adjacent structure in an attempt to form a channel constriction to promote bedload scour.

Figure 1-22. Lateral debris jam structure created by combining 2 double floating log structures, placed in 1996, with a new LWD piece and extra boulders. Structure was placed to provide protective cover element to an existing pool. (Note: structure is built around an existing natural log.)

Off-channel Rehabilitation Work (West-80 Ponds)

The Keogh River has several natural off-channel complexes that are utilized both for summer rearing and overwintering of fish especially in priority juvenile coho salmon, Dolly Varden, steelhead trout and cutthroat trout. Flowing channels favor trout use while ponds favor coho. On the coast, salmonid juveniles search out these refuges in the fall in advance of the onslaught of fall-winter freshets. An assessment of reaches of the river logged to the banks (about 60 %) and the availability of overwintering off-channel refugia for juvenile salmonids indicates a limitation, especially in the lower incised portion of the river from the highway downstream to the mouth. This is the fourth and largest off-channel project, and a larger one is proposed for the lower river for 1999.

In the upper river, some small lakes are available for overwintering of fish, but there are also stream segments with little off-channel habitat. One reach is at the W-80 road crossing (about km 19) where two old river channel sites were identified and surveyed because they were judged as having very high potential as prime overwintering habitats. The site located below the West-80 mainline logging road was selected for use as a paired off-channel pond to use as a demonstration training site. The site has a residual 30 m by 15 m pond at the downstream portion that adjoins the river at a small beaver dam. Back-flooding by the river, a partial old-growth canopy, aquatic vegetation on shoals, and a deep trough with woody cover, ensured this channel remnant was well colonized by juvenile fish. This pond could be readily extended because the old river channel and a side channel had been cut-off and de-watered by construction of the road about thirty years earlier. In addition, a remnant beaver pond existed on the West Side, fed by two very small streams. The plan generated was to restore the original beaver pond, excavate the original river channels as ponds, and then connect the two with a 20-30 m long gravel-boulder lined channel of a gradient that would facilitate access of immigrating fish. A small groundwater channel was also excavated beside the road adjacent to the river to ensure sufficient flow during drought conditions to maintain adequate water circulation and thereby dissolved oxygen levels. The remnant pond was isolated by a plastic curtain, aside from a 70 m^2 semi-vegetated shoal. Fish were removed from the shoal by over-night minnow trapping and added to the main pond. Density of pre-smolts inhabiting the shoal was 1.0 pre-smolts per m^2, which suggested the project should be successful.

The lower pond was excavated to a maximum depth of 2-3 m along two channels, each approximately 50 m by 10 m, separated by an small treed island and a longer island of excavated material. A shallow shoal was created at the upper sections of the pond. River-bed materials were utilized to rebuild the beaver dam, and loamy materials were excavated from the upper pond to seal the upstream side of the upper pond and augment depth. The resulting upper pond after flooding of the old wetland produced a largely vegetated pond varying seasonally in surface area from about 0.2-0.3 ha, and in depth from 2 m near the dam to a 0.3 m at the inflow of two small inlet creeks. Renewed beaver colonization eliminated all cuttings and most planted trees, and thus a floating LWD mat with adjacent log barriers is being installed in the upper pond to prevent further dam construction at the outlet channel. Construction was accomplished by a contractor's Hitachi 400, operated by a WFP employee who took an exceptionally keen interest in the project, completing the project in 44 hours of machine time. Subsequently a four-worker bioengineering crew worked for a week on the project, installing a fishway at the lower pond outlet, constructing a 7 m by 1 m foot-bridge to the main island, and revegetating slopes.

The two resulting ponds have a total area varying from 3000-4000 m^2 (Fig. 1-23). Based on estimates provided in Technical Circular #9 of the Watershed Restoration Program, the additional pond area is predicted to produce 0.5-1.0 coho smolts per m^2 or 1500-3000 coho smolts (area assumed: 3000 m^2), as well as some char and trout migrants. Effectiveness monitoring of migrants from the two separated ponds will assess smolt and parr yields of all species, and is scheduled to commence in the spring of 1999.

The project clearly illustrated to all those involved that flooding a pond site was much more cost effective than excavating ponds for off-channel restoration. In addition, the newly re-flooded old wetland site is expected to rapidly become an “fertile oasis” of complex vegetated habitat as was found by evaluation of smolt yield from the flooded Anderson Pond in the Chilliwack River watershed. The project cost was $20,000 (full accounting) including work required to prevent damming of the upper pond outlet and to permit passage of fish. The project was funded from the Headquarters Investment Plan of FRBC, and it will be used as an instructional site to train restoration planners and workers largely from the North Island communities.

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Figure 1-23. Off-channel ponds at the upper Keogh River. The lower pond (center) was excavated within the old cut-off river flood channel, and the upper “flooded” pond (left edge of photo) was created by constructing a berm with material excavated from the lower pond.

Keogh River Watershed Study - Juvenile Salmonid Density And Growth, 1998

Objectives
To determine the effectiveness of instream and watershed restoration techniques (habitat creation, fertilization, slope stabilization) on the production and growth of salmonids in the Keogh River, B.C.

FRBC Region/MELP Region/MOF Region
Pacific / Vancouver Island / Vancouver

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Proponent
Ministry of Environment, Lands and Parks

Watershed
Keogh and Waukwaas Rivers

Location
The Keogh and Waukwaas Rivers, two third-order coastal streams, are at the northern end of Vancouver Island. The Keogh River flows northeast for 33 km from Keogh Lake head-waters and drains into Queen Charlotte Strait (127.4 W, 50.6 N), south of Port Hardy, B.C. The Waukwaas River, 24 km in length, flows into Rupert Inlet (127 21' W, 50 35' N) near Coal Harbour, B.C. These watersheds of similar climate and geomorphology drain neighbouring hillslopes that have been exposed to comparable forest practices.

Introduction
Under the auspices of Forest Renewal BC (FRBC), considerable resources have and will be used to undertake watershed restoration projects. One component of such rehabilitation work is the restoration of aquatic habitat through in-river treatments. In large programs such as WRP and FRBC, assurance that program goals and benefits have been attained is fundamental.

Key to evaluating the success of WRP projects will be the ability to adequately measure changes in the aquatic environment as a result of the various treatments (Keeley and Walters 1994).

Assessment and Monitoring
This study aims to assess the effectiveness of WRP techniques on one watershed, using population dynamics data gathered from over 20 years of salmonid juvenile abundance instream, smolt enumeration, and adult steelhead and coho salmon run size estimates, compared to the fish abundance in a neighbouring untreated logged watershed.

Within the broad evaluation of salmonid production, a study investigating the relative success of the introduced nutrients and habitat structures will also be conducted, where we will evaluate the durability, species selectivity, densities and survival rates of fish in the various boulder and log designs, under nutrient enhanced and natural conditions. In this summary, we report the fish response to stream rehabilitation from the first two years of summer and early-fall investigations.

Results
Reaches and Juvenile Distribution
Similarities in salmonid production (species, age classes, densities and distribution) were limited both between reaches in a watershed and across watersheds. These differences were the result of a combination of factors including; habitat availability, adult escapement, juvenile mortality and reach location within the watershed.

Steelhead fry densities on the Keogh River have been limited by low adult escapement in recent years (Ward 1999). However, a statistically significant increase in steelhead fry abundance was apparent between 1997 and 1998 (10-fold), in all structure sites sampled, largely due to increased fry densities in treated sub-reaches (Fig. 1-24). Sub-reaches treated with structures also compared favourably to untreated controls in these locations with a mean of 152 steelhead fry per 100 m in the treated areas compared to 37 fry per 100 m in the control section. Similar, although less pronounced differences were found in other treated areas with a mean of 13.5 fry per 100 m compared to 6 fry per 100 m in untreated areas.

Steelhead parr densities showed no overall statistically significant trend by river compared to data recorded in 1997 although overall mean reach densities were slightly elevated in 1998 on the Keogh, (simple reach mean of 22.5 parr per 100 m), compared to 1997 data (17 parr per 100 m bank length). In 1998, steelhead parr were in greatest abundance on the Keogh River in the reaches treated with structures or structures and fertilization, 40 to 64 parr per 100 m of bank length when compared to control and fertilized only reaches in the same river location, (9 to 10 parr per 100 m bank length).

Coho fry abundance was varied in the Keogh and Waukwaas Rivers in 1998, but was reduced compared to 1997 levels (although not statistically significant). None of the 8 paired reaches showed increased coho fry production in 1998 with comparable reaches showing reductions of between 14% and 76% on 1997 densities. Such reductions may reflect poor adult escapement to both rivers and/or unfavourable winter survival of eggs to fry in both watersheds. Current concerns on coho stocks suggest the former may be the case (K. Simpson, DFO, Nanamio pers. comm.). Reaches treated with structures on the Keogh river produced significantly more coho fry than untreated reaches in the Keogh or Waukwaas Rivers.

<u>Structures and Juvenile Production</u>

This year's results from investigations of structure use on the Keogh River differed from those in 1997 and previous studies (Ward and Slaney 1979). Boulder clusters and riffle reconstructions generally favoured by steelhead parr were surpassed in fish abundance by single deflector logs and rootwad complexes (Fig. 1-25). The reason for this shift in preferred habitat appeared a transient one brought about by low flow conditions. Steelhead parr, and to a lesser extent coho fry, were found most abundantly in pool habitat in 1998, probably as a reaction to the severe low flows that prevailed for most of the summer (Fig. 1-26). As boulder clusters were built in run and riffle areas and riffle reconstructions were by their nature shallow, fish may have avoided these structure types simply to seek refuge in deeper water where cooler temperatures from groundwater inflow and increased protection from predators would be available. Thus, fish moved from a preferred habitat under one set of flow conditions to a different habitat type under a second set of flow conditions. In this case the increased availability of pool habitat seen in lower reaches of the river compared to upper (as a result of restoration efforts) may have resulted in an increased parr survival.

Such observations detail the need for varied habitat types and the usefulness of natural and introduced structures in creating such river habitat. It also highlights the risks of assessing structure performance over the short term without investigating the effects of flow, adult escapement, habitat change, and overwinter survivals.

Growth and Fertilization

Data from the Keogh River in 1998, indicated coho fry in fertilized areas had a mean length 5 to 10 mm greater than samples from unfertilized reaches. They also had a 30% increase in mean weight, over their unfertilized controls. Steelhead fry data could only be compared between the fertilized reaches of the Keogh River and the unfertilized upper reaches of the paired Waukwaas watershed due to low success during winter sampling. As with coho fry, significant differences between mean length of fish by the autumn were recorded in fertilized and unfertilized reaches (over 100% increased weight).

Cost Summary

Total budget for monitoring and reporting was $37K. An additional 4 weeks of work was required by MELP staff (not in budget summary).

Conclusions

Initial results suggested significant variations in the distribution and production of juvenile salmonids, particularly coho and steelhead through the two watersheds within and between sample years.

Steelhead and coho juvenile abundance had no relationship to introduced structure type in sampled sites. Reach location and river flow conditions (riffle/pool, etc.) were more important in determining structure performance. However, significant increases in steelhead fry abundance were associated with reaches treated with habitat enhancing structures in 1998.

Steelhead parr densities also were higher in treated areas, with the potential for increased smolt output in subsequent years, (despite low level escapement of adults).

Coho fry densities were generally lower than in 1997, probably due to low escapement of adults in 1996. Structure-treated areas had the highest fry abundance, indicating limited buffering of low seeding levels. Recent escapements of over 8000 adult coho in 1998 should seed the Keogh River to near capacity in 1999. Sampling in the summer of 1999 is thus critical to the determination of habitat restoration and fertilization effectiveness at escapements which exceed estimates of habitat capacity.

The need for continued data collection to determine the outcome of WRP rehabilitation is compelling. It is the key recommendation of this report that the experimental design proposed is followed to completion so that the benefits of watershed restoration can be fully assessed.

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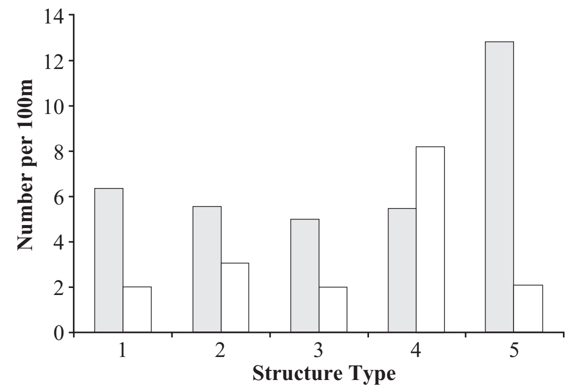

Figure 1-25. Number of steelhead parr (no. · 100m^{-1}) in selected habitat structures installed in the Keogh River; grey bars are averages from 1997, open bars are 1998. 1=boulder cluster, 2=debris jam, 3=riffle reconstruction, 4=single deflector log, 5=A-log structure.

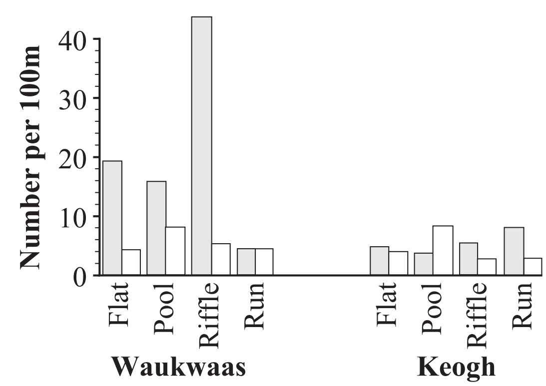

Figure 1-26. Steelhead parr abundance (no. · 100m^{-1}) in stream habitat types in the Keogh River, 1997 (grey bars) and 1998 (open bars).

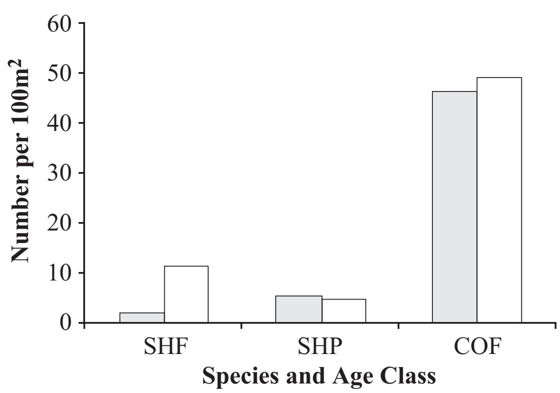

Figure 1-24. Mean densities (no.·100m^{-2}) of steelhead fry (SHF), steelhead parr (SHP) and coho fry (COF) in representative structure sites on the Keogh River in 1997 (grey bars) and 1998 (open bars).

Kootowis, Staghorn, and Lost Shoe Creeks Large Woody Debris Restoration

Objectives
The primary objective of this restoration project is to restore low gradient creeks that have been impacted by deposition of large amounts of historic logging debris. The work plan involved improvements to fish habitat, stream hydrology, and riparian function through woody debris removal, relocation, stabilization, and stream crossing restoration.

FRBC Region / MELP Region /MOF Region
Pacific / Vancouver Island / Vancouver

Authors
Dave Clough, Scott MacDonald and Warren Warttig.

Proponent
International Forest Products Ltd.

Watershed
Kootowis, Staghorn, and Lost Shoe Creeks.

Location
The watershed system is located on the west coast of Vancouver Island between Tofino and Ucluelet.

Introduction
The fish stocks of these systems include coho, chum, steelhead, resident and sea-run cutthroat trout stocks. While logging has been part of the area for over 100 years, the biggest impacts have come in the late 1970's and early 1980's where vast clear-cuts over the tributaries occurred. They left the stream channels of these waterways saturated with both small and large woody debris (SWD and LWD). With the lowland topography of these watersheds (average gradients of less than 0.5% throughout most of the systems), the systems have not been able to effectively flush themselves of the excess debris. Several impacts on the stream and riparian environments have resulted.

Assessments and Prescriptions
Detailed fish habitat condition assessments and hydrology assessments completed in 1995/96 identified the following negative impacts resulting from excess instream woody debris saturation:

- greatly increased floodplain area;
- poor water quality;
- high pool/ low riffle frequencies;
- lack of hydraulic scour on sediments;
- poor spawning habitat availability;
- stunted riparian development;
- fish access restrictions; and
- high incidence of stranded or spawning fish on the floodplain and roads.

Prescription templates were completed on a 150 m representative stream reach and reviewed by the forestry, engineering, hydrology, and biology team. Designs followed basic principles of stream habitat structure. Prescriptions generally were to decrease the SWD and maintain functional LWD in pools, to provide necessary cover, and in riffles, to improve flow for scour, thus restoring historic function. Generally, non-embedded SWD was to be removed extensively while LWD was adjusted to function instream. Some LWD was identified to be relocated, to better serve its hydraulic or habitat function, but embedded LWD was not disturbed. Drainage was improved as the channel was opened to a target of 80% of the cross-sectional area of the active channel at bankfull discharge.

Methodology/Equipment
Stream restoration of this type relies heavily on crew hand labour. The first week the crew were required to undergo Streamkeeper and safety training to obtain an understanding of fish habitat requirements, and work safety. Each crew group consisted of a crew leader and 4 crew persons. They were assigned a truck and all the equipment necessary to work on their own stream section. In 1998 three crews started on August 4 and were augmented by a fourth crew as funding allowed. The project received additional funding through Fisheries Renewal in 1998, which provided one of the crews. Fisheries Renewal Funds were administered by the West Coast Sustainability/Regional Aquatic Management Society (RAMS) in a partnership arrangement.

Chainsaw winches, turfer jacks and helicopters were used to move wood. Where hand bombing of the debris outside of the active floodplain was not achievable, wood was placed in slings (to 1200 lbs.) and a Hughes 530 helicopter was used to lift wood to nearby landings. The helicopter was also used to transport logs to wood deficient reaches. As much of the LWD was already cut in short lengths, most had to be anchored, primarily with 1/2 inch galvanized cable to stumps, other LWD, or if nothing else, to duckbill ground anchors. Cable splices, clamps, and staples where used to secure cable. Three-inch wide nylon webbing was used to eliminate winch tieback damage to trees. Chain saws were used to cut wood into manageable sizes for removal. Hand axes, wedges, peaveys and sledge hammers were used for anchors, jammed saws and wood splitting. Rakes were custom made with 10-12 ft. handles to retrieve floating blocks over deep creek sections.

Rehabilitation Work

Instream work was conducted in the Grice Bay Main of Kootowis Creek (4.2 km) and several tributaries (4.1 km), and an upper reach of West Fork Staghorn (0.95 km). The RAMS Crew completed another 0.6 km on private land. The project completed a total of 9.9 km over 10 weeks and 800 person-days. This was the third year of funding and the crew performed better than expected due to their experience. The following activities were completed:

- training, access clearing and maintenance;
- removal of 3000 m^3 of SWD;
- placement of 3500 pieces of LWD instream anchored with approximately 6000 m of 1/2 inch galvanized cable;
- fry population and water quality surveys at 6 sites in survey area; and
- upgrading of 2 critical creek crossings for fish access (Figs. 1-27 to 1-30).

Wood which ended up on landing sites was trucked away and chipped. The wood was ultimately used as cover for the local landfill waste piles.

Cost Summary: Summer Work

Wages	$150,000
Expenses	$ 87,000
Total	$237,000

Monitoring / Restoration Results

Routine monitoring was completed on the 85 sites representing the 1997 work areas. All scored high in overall performance with excellent structural stability and functions. The 9.9 km length of work area in 1998 sites will be monitored similarly in 1999. The collection of water level and water temperature monitoring data which was initiated in 1997, was also continued in 1999. Fry density measures were taken to compare with 1995 data. Riparian monitoring is planned in March 1999.

Proposed Work

The future work is expected to take place in the following areas:

- complete restoration of high impact areas on Kootowis Creek and move on to areas in Staghorn and Lost Shoe Creeks;
- additional deactivation at road crossings; continued hydrology, riparian assessment and monitoring.

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Figure 1-27. Instream work before at 0+149 Ck 2 (jam #4).

Figure 1-28. Instream work after at 0+149 Ck 2 (jam #4).

Figure 1-29. Instream work before at 2+430 GBM (jam #25).

Figure 1-30. Instream work habitat logs at GBM (upstream jam #25).

Mahatta River Restoration Project

Objectives
The Mahatta River restoration project on northern Vancouver Island has been an ongoing program of Western Forest Products Limited since 1996 as part of its program to preserve undisturbed habitat, control in-channel sediment sources, maintain channel stability, and restore or rehabilitate fish habitat for rearing and overwintering salmonids.

FRBC Region/MELP Region/MOF Region
Pacific / Vancouver Island / Vancouver

Authors
Bruce Walsh, Rob Hanelt and Ken Hall.

Proponent
Western Forest Products Ltd.

Watershed
Mahatta River

Location
The Mahatta River flows from the south into Quatsino Sound on northern Vancouver Island. The site is approximately 1 hour west of Port Alice and can be accessed using the forestry road network.

Introduction
The Mahatta River, located on the north end of Vancouver Island, is renowned for its steelhead fishing. The watershed has a total drainage area of 122 km^2 and features O'Connell Lake mid-way along the mainstem. Two major tributaries enter the river downstream of the lake. The estimated annual precipitation in the watershed is 3500 mm with most of this falling as rain; the maximum daily rainfall is in the order of 150 mm. The 50-year instantaneous discharge was used for design and was estimated at 460 $m^3 \cdot s^{-1}$ for the Mahatta River and 175 $m^3 \cdot s^{-1}$ on the North Tributary. At the project site on the Mahatta River, the bankfull width and depth are 30 m and 1.8 m, respectively, with the corresponding design depth in the order of 2.5 m. The bankfull width and depth on the North Tributary are 16 m and 0.9 m, respectively; the slope is 1 percent and the design depth is 1.7 m.

Historically, all five species of Pacific salmon utilized the Mahatta River. Today, the river supports runs of coho, sockeye and to a lesser extent pink salmon. Steelhead, cutthroat trout and Dolly Varden char are also found within the watershed. Escapement records suggest a decline in the numbers of steelhead and coho salmon returning to the river. Reduced marine survival and a lack of overwintering habitat due to past logging practices have affected salmonid production in the watershed.

Assessments and Prescriptions
Logging in the Mahatta River watershed began in the mid-1950's and by 1995 approximately 60 percent of the watershed had been harvested. By 1980, those blocks harvested in the 1960's had begun hydrological recovery so that the equivalent clearcut area was less than the total percentage harvested.

Harvesting concentrated on the valley bottom and trees were harvested to the riverbanks. Most of the riparian forest harvested in the 1960's and 1970's is now regenerating although recruitment of large woody debris (LWD) to the mainstem and its tributaries has declined.

Coarse sediment supply in the upper watershed increased due to logging-related landslides and reduced bank stability following riverbank harvesting. The river response includes channel avulsions, bank erosion, channel widening, bar enlargement or development, aggradation and deposition of fine gravel over substrate. Fortunately, a natural barrier stops anadromous fish migration to the affected reaches.

O'Connell Lake traps all of the coarse sediment generated in the upper watershed and as a result the main channel is stable downstream of the lake to the first of two main tributaries. Coarse sediment delivery from the north and south tributaries has increased due to channel erosion which has been caused by increased flood peaks, bank instability and sediment released by the removal of large woody debris from the channels; the north tributary was essentially a long glide. The increased sediment loads to the mainstem has lead to channel widening, bar growth and rapid bank erosion, which overall has reduced the channel complexity.

Prescriptions were developed for the entire watershed and were primarily directed at controlling bank erosion, increasing the channel complexity and creating off-channel rearing and overwintering habitat. Work focussed downstream of O'Connell Lake to integrate with the slope and road rehabilitation in the upper watershed.

Rehabilitation Work
Instream rehabilitation work has been ongoing in the watershed since July 1996 and has primarily concentrated on protecting rapidly eroding gravel banks while at the same time increasing the habitat complexity within the channels. A variety of structures have been constructed including small and large multi-log structures, rock riffles and off-channel habitat. Details on selected works are given below.

Small LWD Structures
Prior to construction of the rock riffles, fish salvaged from the North Tributary were found utilizing the few LWD structures in the system. With this in mind, numerous LWD structures were constructed along the North Tributary to protect the banks from erosion while at the same time increasing the amount of wood in the system (Fig. 1-31). Where required, concrete blocks weighing 2200 kg were used to anchor the structures.

Log Jams
Four log jams were constructed on the Mahatta River as part of a design to protect 170 m of a rapidly eroding gravel cutbank. The two largest jams are located along the upper half of a bend and consist of 19 and 15 logs, respectively. The logs are typically 12 m long with a diameter of 0.8 m and are interlocked and cabled together. The log jams are constructed around a base trapezoidal frame onto which other logs are cabled to form triangles that stiffen the structures (Fig. 1-32). Smaller logs and rootwads were used to fill the voids between the main logs. The structures each run 12 m along the bank and extend 12 m into the channel, which is a third of the total channel width (Fig. 1-33). At the bank, the log jams are 2.4 m high reaching to near the top of the gravel cutbank.

Concrete blocks, each weighing 2200 kg, were used to anchor the structures against the bank. Ten anchors were used at the upstream log jam and six anchors at the second log jam. Half of the anchors were located along the toe of the bank and were excavated 1.5 m into the bed; the remaining anchors were attached along the riverside edge. The bank anchors were cabled tightly to the base trapezoidal frame, while the outside anchors were given some slack to allow the anchors to scour into the bed.

The upstream log jam was constructed during the 1997 summer construction program and performed extremely well during the subsequent winter. The log jam has eliminated bank erosion along the upper section of the bend and has formed a 20 m long scour pool off the end of the structure. The pool is 12 m wide and 3.5 m deep, as measured during low flow summer conditions, and provides valuable new habitat in the system. (Prior to construction, the channel cross-section was flat with no well-defined thalweg around the bend.)

The two log jams along the lower half of the bend consist of logs and rootwads that were previously eroded from along the gravel cutbank. These were stabilized by cabling key logs together and anchoring the structure back to large trees on the bank. The four log jams are spaced at 40 m intervals which is equal to four times the distance the jams extend into the channel. (As a rule of thumb, spurs protect the bank for two times the spur length upstream and downstream of the spur.)

Rock Riffles
Seven rock riffles were constructed along the North Tributary using angular rock with a median diameter of 500 mm. The riffles are typically 16 m wide by 10 m long and are keyed up to 1 m into the bed and 2 m into the banks (Fig. 1-34). The crest of each riffle is approximately 0.5 m above the bed at the center of the channel and slopes up to the floodplain at each bank; low flow is concentrated to the middle third of the channel. The upstream face of the riffles is sloped at 4H:1V while the downstream face is sloped at a minimum 20H:1V into the bed. The riffles are spaced 4 to 5 channel widths apart and during low flows create backwater to the upstream riffle.

Careful consideration was required to construct each riffle to account for the influence and condition of the upstream and downstream bends and banks, overbank flow and existing LWD. For instance, at one riffle a pool 8 m by 4 m by 1.2 m deep was constructed along the edge of the riffle and utilizes river behavior to exclude sediment from the pool while at the same time undercutting rootwads and logs along the bank above the pool.

Since construction in 1997, the riffles have performed extremely well. Gravel has deposited upstream of the riffles and scour pools have formed at the downstream edges.

Off-channel Ponds

Five off-channel areas, excavated on the floodplain of the North Tributary, have created over 1670 m^2 of high quality rearing and overwintering habitat. The ponds are groundwater fed, although at two sites small tributaries from upland swamps augment the flows. Berms were constructed around the ponds to protect them during the 50-year design flow. At one site, however, a large log jam was constructed at the head of the pond to provide overbank flow relief while at the same time preventing the main channel from shifting into the excavated side channel. At two sites, a series of notched log weirs were required to maintain an adequate pool depth while reducing the necessary excavation depth.

On the South Tributary, a series of seven small drop structures were constructed to provide fish access to an isolated and abandoned 450 m^2 beaver pond.

Equipment and Labour

The specialized excavator Schaef HS40 (also known locally as a "spider") was used for all instream work. The machine greatly enhanced the end results of the project by minimizing damage to the stream channel while providing an extremely flexible method of construction.

Four crew members were hired through New Forest Opportunities to provide manual labour.

Cost Summary

Construction (hoes)	$ 55,500
Supervision, design, labour and materials (logs/blocks)	$118,500
Total	$174,000

Production Estimates

Production estimates are summarized in the following table for coho salmon and steelhead trout combined. The results are based on the salmonid biostandards in the Watershed Restoration Technical Circular No. 9.

Structures	Area (m^2)	Fry	Smolt	Adult
LWD	1380	1602	859	83
Riffles	1020	737	429	40
Off-channel	2100	2122	1448	142

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Figure 1-31. Downstream view showing four small LWD structures positioned to protect a steep eroding gravel cutbank. The left structure is 2 m high at the bank.

Figure 1-32. Constructing a large log jam on the Mahatta River. Logs are cabled across the structure to stiffen the log jam.

Figure 1-33. Upstream view on the Mahatta River showing two large log jams constructed to protect a gravel cutbank from erosion. A scour pool 20 m long by 12 m wide by 3.5 m deep has formed between the two log jams.

Figure 1-34. Constructing a rock riffle on the North Tributary. The "spider" is excavating a trough across the channel to key the riffle 1 m into the bed.

Malksope River Watershed Restoration Project

Objectives

The primary objectives of the Malksope River Restoration Project (1996 to present) is to accelerate the recovery of anadromous fish populations and fish habitat. More specifically, the objective of instream work to date is to restore juvenile rearing habitat by re-establishing natural channel morphology, stabilizing streambanks, restoring natural pool/riffle frequencies and increasing the frequency of functional large woody debris (LWD). Another objective of the restoration program is to accelerate the recovery of stream productivity by the addition of a low-level nutrient replacement.

By creating more useable habitat for both adult and juvenile salmonids, our intention is to assist the recovery of fish stocks in the Malksope River.

FRBC Region/MELP Region/MOF Region

Pacific / Vancouver Island / Vancouver

Authors

Rupert Wong and Violet Komori.

Proponent

Kyuquot Management Board, consisting of the following:

- Kyuquot/Checleset First Nation;
- International Forest Products;
- Kyuquot Sound Multi-Use Association;
- Ministry of Forests;
- Ministry of Environment, Lands and Parks;
- IWA Canada.

Watershed

Malksope River

Location

The Malksope River, situated immediately south of Brooks Peninsula on Vancouver Island, British Columbia drains into Malksope Inlet and Checleset Bay.

The Malksope River is a fourth-order stream draining an area of 35.6 km^2 with a mean annual flow of 3.4 $m^3 \cdot s^{-1}$ and a mean annual maximum instantaneous flow of approximately 100 $m^3 \cdot s^{-1}$. The mainstem river is 9.7 km in length of which 5.6 km are accessible to anadromous fish species. The Malksope River supports chum, chinook, coho, sockeye and pink salmon as well as summer run and winter run steelhead trout, rainbow trout and cutthroat trout. In general, coho, pink, chum and chinook salmon have shown a decreasing trend in escapement since the 1970's.

Logging was initiated in the Malksope River watershed in 1968. By 1998, 46% of the total watershed area had been harvested and 77 km of road constructed, with logging development continuing to date. The majority of harvesting occurred along valley bottom areas where progressive cutblocks extended into valuable riparian habitat. Approximately 95% of the logging occurred before 1988, prior to implementation of the Coastal Fish-Forestry Guidelines. These guidelines significantly decreased the impacts of forest harvesting on fisheries values by reducing the amount of streamside harvesting and improving road construction procedures.

Assessments and Prescriptions

The resulting impacts of forest harvesting to the mainstem and tributaries in the Malksope drainage include an accelerated rate of coarse sediment loading from slope failures in the upper watershed and increased peak flows during rain on accumulated snow events. Results from 1996 fish habitat assessments suggest that accelerated sediment loading has reduced the natural configuration of pool/riffle ratios and precipitated bank instability in the mainstem. Specific impacts to lower tributaries include increased bedload movement causing the lower reaches to be completely infilled, forcing streamflows down an abandoned road ditch into the adjacent tributary. Additional impacts to the lower tributaries include the loss of channel morphology and complexity due to a reduction in LWD delivery and consequent reduction in pool frequency.

Equipment and Employment

Construction activities since 1996 have included 677 hrs of heavy equipment, 1,552 hrs of employment for 6 professionals, and 2,345 hrs of employment and training for 15 members of the Kyuquot/Checleset First Nation.

Rehabilitation Work

During 1996, 1997 and 1998, restoration works in the Malksope River included rock riffle construction in 3 lower tributaries, channel excavation to restore natural streamflow patterns, excavation of 4 backwater rearing ponds, LWD placements, bank stabilization and stream fertilization. More specifically:

- A 1000 m^2 backwater pond was developed at km 0+500 on the right bank of the mainstem (1996). Construction took 4 days using a Halla 280 backhoe to create the pond features and build a protective berm around the site.
- Thirty meters of eroding bank at left of mainstem km 0+700 was stabilized using a boulder & LWD complex (1996). Using a Halla 280 ten 15 m logs and 25 boulders were embedded in alignment with the streambank.
- Two rock riffles were constructed over the lower 130 m section of a tributary located at kilometer 1+180 left bank. Alluvial deposits were excavated to approximate the original streambed elevation using a Halla 280.
- Five rock riffles were constructed by manual labour over 120 m in the lower reach of a tributary at km 1+220 right bank (1996). Rocks up to 500 mm in diameter were moved instream using a chainsaw winch and pulleys anchored with slings to mature riparian trees.
- Over a length of 425 m, eleven rock riffles were constructed by a Halla 280 in a tributary at km 1+370 left bank to restore natural meander patterns and pool/riffle frequencies (1996). In addition, 100 m^3 of alluvium was removed and a diversion berm constructed to restore flow to the lower 200 m of this tributary.
- Protective cover for holding adults & rearing juveniles was installed over a bedrock pool at km 3+900 in the mainstem (1996). Two 6 m logs and a 1000 mm boulder were maneuvered using manual labour and a chainsaw winch.
- To minimize erosion and improve fish access at 0+500 backwater pond, 11 pieces of LWD were used to hand-build an outlet structure consisting of four wooden weirs (1997). Weirs were also built at two off-channel beaver pond sites at km 1+900 right bank.
- Over 300 m of functional LWD was added to three tributary streams, three off- channel sites and two mainstem sites using a "spider" hoe (1997).
- Riparian revegetation adjacent to 1996 restoration sites (1997).
- Tree revetment of a bank erosion site in tributary 1+370 using a "spider" hoe (1997).
- Repairs to four rock riffles constructed in 1996 using a "spider" hoe (1997).
- Construction of 2800 m^2 of rearing habitat in three off-channel sites located at km 1+370 left bank, 1+400 right bank and 1+900 left bank using a Halla 280 (1998).
- Addition of 47 hand built wood bundles to six 1996/97 restoration sites to increase fish habitat complexity (1998).
- Reconstruction of two rock riffles and two log arc structures using machine and hand labour (1998).
- Implementation of a low-level nutrient replacement program to accelerate the recovery of stream productivity.
- Prior to completion of annual restoration works, exposed excavation sites and tote roads were deactivated, grass-seeded and fertilized.

Construction Cost Summary

1996 Fees	$ 43,320
Expenses	$ 83,937
Subtotal	$127,257
1997 Fees	$ 64,786
Expenses	$ 81,339
Subtotal	$146,125
1998 Fees	$ 45,577
Expenses	$ 41,940
Subtotal	$ 87,517
Total	$360,899

Restoration Results and Monitoring

The Malksope River monitoring program was initiated in February 1997 with Phase 1 and 2 monitoring now completed for 1997 and 1998. The rock riffle structures constructed in three lower tributaries have successfully increased habitat complexity with 12 out of 18 sites having a total biological and physical performance rating of 70% or higher. Due to stream gradients ranging from 2 to 4% in these tributaries, the downstream tail slope of the riffle structure has formed cascading step pools rather than riffle habitat. Due to increased sediment delivery to some sites, the addition of LWD has been necessary to maintain pool habitat upstream of the riffle structure. Both riffle structures and LWD placement sites are providing summer rearing habitat for coho and steelhead juveniles. The 0+500 backwater pond constructed in 1996 is providing good rearing habitat for coho with higher utilization during the winter than summer. Similar results are anticipated at three backwater ponds constructed in 1998. These sites will be monitored through 1999.

Mainstem LWD sites are effectively providing cover for adult and juvenile salmonids but poor bedrock quality at one site has required the addition of a cable anchor to a mature standing conifer. LWD placements are also increasing habitat complexity and aerial photos illustrate the accelerated formation of riffle habitat downstream of scour pools at some sites.

Proposed Work
The following fish habitat restoration activities are proposed for the 1999/2000 fiscal year:

- Continue monitoring of physical and biological performance of restoration sites.
- Continue riparian restoration prescriptions at selected sites, including the placement of bat and bird houses in February 1999.
- Develop 3000 m^2 of off-channel fish habitat at three sites located at km 1+900 left bank, 2+800 right bank, and 4+788 right bank.
- Restore fish access to 2000 m^2 of isolated and abandoned beaver pond habitat.
- Continue LWD placements in lower tributaries adjacent to rock riffle structure sites.
- Continue low-level nutrient replacement program if suitable product is available.

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Davie River Restoration Project

Objectives
The Davie River instream watershed restoration project (the project) is one of a series of projects being undertaken by Canadian Forest Products Ltd. in the Nimpkish River basin, funded by Forest Renewal BC (FRBC). The instream components of the projects have concentrated in the Davie, Lukwa, Kilpala and other smaller watersheds while the upslope and road restoration projects have been completed over much of the Nimpkish watershed.

The Davie River instream restoration project has concentrated on stabilizing banks in the main channel and restoring access to and improving the quality of off-channel habitat. The Level I assessment of the watershed identified the principal limitations to fisheries production as reduced adult escapement and habitat impacts which have reduced the rearing capacity for both anadromous and resident species (Northwest Hydraulic Consultants and Alby 1998a).

FRBC Region/MELP Region/MOF Region
Pacific / Vancouver Island / Vancouver

Authors
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Proponents
Partnership of Canadian Forest Products Ltd., 'Namgis First Nation and International Woodworkers of America (IWA).

Watershed
Davie River, tributary to the Nimpkish River.

Location
The Davie is a major tributary of the Nimpkish River. The Davie River flows west for 41 km from its headwaters above Schoen Lake to enter the Nimpkish River approximately 35 km upstream of the town of Woss. Woss is located 74 km south of Port McNeill on the northern end of Vancouver Island.

Introduction
The Davie River drains 265 km^2 of northern Vancouver Island originating in the steep Sutton Ranges of the Vancouver Island mountains. Approximately half of the watershed lies above Schoen Lake that acts to trap sediment from the upper, steeper watershed. Below Schoen Lake the river flows through a broad valley and is joined by 2 major tributaries and 5 minor tributaries. The major tributaries below Schoen Lake are Klaklakama and Croman Creeks, which flow through lakes in their lower reaches. Like Schoen Lake, these lakes act to trap coarse sediment from the upper watersheds and stop this sediment from entering the lower Davie River. The 5 minor tributaries are Cain, Abel, and Plateau from the north and Unnamed and Boulder from the south. These tributaries are significant sources of coarse sediment to the lower Davie River.

The Davie River and major tributaries (Croman and Klaklakama) have been significant contributors to salmonid production in the Nimpkish River system. The Davie River supports resident rainbow and cutthroat trout, Dolly Varden char, and still supports significant runs of coho salmon. Steelhead, coho and formerly sockeye make the greatest use of the watershed. Although sockeye are reported to have used the Davie River in the past (DFO 1958; R. Scheck, pers. comm.), the only significant sockeye population present today is the kokanee (*O. nerka*) population found in Klaklakama and Schoen Creeks. Woss CDP hatchery releases hatchery steelhead and coho into the Davie as well as other Nimpkish River systems. Chinook, pink and chum salmon have never been reported in the Davie River.

There are no escapement data specific to the Davie River; escapement histories are recorded for the whole of the Nimpkish watershed. In general, escapements of all anadromous salmonid species have declined over the 40 years of record (Shawn Hamilton and Associates 1996a). Coho escapements have declined from a total escapement of 13,600 per year to less than average 1000 per year for the decades 1950 to 1960 and 1985 to 1995, respectively (DFO 1957, R. Lutz, and H. Nelson, pers. comm.). Contrary to this trend, 1998 coho returns to the Nimpkish system were in excess of 8500 spawning adults counted during swim surveys of the mainstem

Nimpkish River (H. Nelson, pers. comm.). Due to the extended spawning period, lack of enumeration effort and a large geographic distribution, the total population of spawning coho is thought to be well in excess of the 8500 counted by the ‘Namgis enhancement crew. Winter run steelhead numbers have declined by up to 30% (R. Lutz, pers. comm.). Steelhead harvest data suggests that the steelhead population of the last 5 years is 50% of what it was in the proceeding 5-year period (Axford 1996).

Assessments and Prescriptions

Forest harvesting in the Davie basin began in the late 1940’s or early 1950’s. To date approximately 30% of the total basin area has been harvested, which likely increased flood peaks in the late 1970’s and early 1980’s. Now, as a result of hydrologic recovery, past harvesting only has a minor effect on flood peaks (nhc and Alby 1998a).

Harvesting has concentrated in the broad valley downstream of Schoen Lake with approximately 50% of this area logged. As a result, much of the riparian and alluvial or colluvial fan vegetation of the lower Davie River and tributaries has been removed. This has increased coarse sediment supply from tributaries and upstream reaches contributing to channel widening in Davie River reaches D2, D3 and D5. Landslides and road failures are not important contributors of coarse sediment because the wide river floodplain prevents them from entering the channel and stores their deposits along the edges of the floodplain. Where landslides and road failures occur in the steeper tributary basins they may act to increase the sediment supply to the Davie River. Reach D3 has 2 large eroding concave banks that are important sediment sources. LWD jams in reaches D5 and D8 also act to increase bank erosion and lead to channel widening.

Rehabilitation Work

Rehabilitation work began in the Davie River watershed with slope rehabilitation and road deactivation. In general, instream work has followed upslope work except along the mainstem and off-channels where roads typically pose little risk in the broad valley. Instream work began in 1995 with biological surveys (Shawn Hamilton and nhc 1996a). This initial work was followed up with further biological assessments in 1996 (nhc and Alby 1998a). Prescription field surveys and site prescriptions were completed in the spring and early summer of 1997. The Level 2 prescription report (nhc and Alby 1997a) was submitted for 1997 Section 9 approval and instream work started that summer. Work continued in spring and early summer of 1998 with field surveys and prescriptions for additional sites. These sites along with the 1997 Level 2 report were submitted for 1998 Section 9 (B.C. Water Act) approval. Instream work continued during the summer of 1998.

The main objectives were to:

- restore access to and improve the quality of off-channel areas;
- rearrange LWD jams to alleviate bank erosion while maintaining their original instream function;
- strengthen eroding banks to reduce further channel widening and sediment inputs; and
- create employment and focus efforts on labour intensive projects when possible.

The following is a summary of the works undertaken to date. For a more detailed discussion see nhc and Alby 1999a.

D2OC1 (Off-channel)

The main habitat objective at this site was to improve the flow and water quality of a 1350 m^2 side channel complex.

- Excavated 55 m long series of ponds and connecting channels to intercept ground flow and provide rearing habitat.
- Built 2 boulder riffles between ponds.
- Added 7 LWD pieces for cover in the channel and ponds.
- Future work at this site includes providing unimpeded juvenile access through the lower, natural channel and monitoring the discharge from the headwater ponds to determine if the inadequate flow intercepted in the summer of 1998 was the result of a very dry summer or poor groundwater resources in the area.

D5DJ1 (Eroding Bank)

The main habitat objective at this site was to strengthen the eroding right bank of the Davie River.

- Built a series of 5 LWD spurs along eroding bank to concentrate flow away from bank at tip of spurs.
- Strengthened natural LWD jam in center of eroding right bank.
- Lined 4 LWD pieces parallel along toe of bank to protect toe of bank.
- Removed small LWD jam and large rootwads from mid-channel bar and incorporated LWD pieces into LWD spurs to prevent them from deflecting flow against bank.

D6OC1 (Off-channel)
The main habitat objective at this site was to improve juvenile access into a 12,250 m^2 series of 11 beaver ponds.

- Built 23 LWD steps to pond water upstream for juvenile access.
- Constructed a 5-step fish ladder at the largest dam.
- Hand-cleaned 400 m of channel to encourage the establishment of a single main channel.

D8OC1 (Off-channel)
The main habitat objective at this site was to improve juvenile access into a 5500 m^2 off-channel pond.

- Built 4 LWD steps to pond water upstream for juvenile access.
- Excavated an 8 m long connecting channel from a natural channel to the Davie River by hand.

D8OC2 (Off-channel)
The main habitat objective at this site was to improve juvenile access into a 300 m^2 off-channel pond and lower reach of small unnamed tributary.

- Removed top portion of LWD jam at entrance to channel for juvenile access.
- Reinforced banks with Davie River cobbles.
- Hand-cleaned 10 m of channel to encourage flow in a single main channel.

Equipment and Labour
A variety of tools were employed in the restoration project including backhoe, helicopter, environmental monitoring equipment, and hand tools. With the emphasis on labour intensive projects hand tools were the most utilized equipment of the project especially chainsaws and attachments.

The only backhoe used in the Davie River projects was the Schaef HS40 Spyder™ in D2OC1. Excavated material was spoiled on-site and no dump truck was needed.

On-site material was used for all projects except rock anchors in D5DJ1 and yellow cedar (*Chamaecyparis nootkatensis*) railroad ties in D6OC1. An Aerospatialle A star 350 BA (max. lifting cap. 1850 lbs) helicopter delivered rock to D5DJ1. The crew carried the yellow cedar railroad ties to D6OC1.

The Davie River projects concentrated on re-establishing access to off-channel areas that had no juvenile usage. Therefore there were no monitoring requirements. The channel excavation at D2OC1 occurred in a damp swale and the channel was not joined to the larger side channel complex until the silt produced settled in the ponds. The LWD rearrangement in D5DJ1 generated little to no suspended sediment. Juvenile salmonids and trout were removed and prevented from re-entering the small connecting channels in D6OC1 by trapping and electrofishing. Fish were left in the larger beaver ponds were they could escape the silt produced.

Hand tools includes all the tools used by the labour crews to secure LWD, move LWD, attach boulders, and replant damaged areas. Chainsaws, chainsaw winches, chainsaw drills, Hilti rotary hammer, geotextile, "belly-grinder" seed applicators, sledge hammers, ratchets and sockets, cable, cable clamps, knobs and wedges, staples, rebar, nailing strips, and nails were all used.

In 1997 the Nimpkish restoration project, which includes the Davie River project, employed 3 labour crews of 5 members in addition to a field coordinator.

In 1998 the Nimpkish restoration project employed 2 crews of 4 members and a field coordinator.

Cost Summary
The costs incurred in the 1997 and 1998 Davie River Level 3 (construction) project only are summarized below. It does not include assessment and prescription costs.

Crew labour (including assessments)	$ 71,675
Consultants (fees and expenses)	$ 14,386
Heavy duty equipment (backhoes and gravel trucks)	$ 0
Helicopter	$ 2,421
Other costs	$ 11,767
Total	$100,249

Production Estimates (Davie River)
The project created or added: 55 m of stable channel including 2 ponds, 2 LWD jams, 11 LWD pieces, 5 LWD spurs, 27 LWD steps, 1 fish ladder, 2 boulder riffles, access into 12,550 m^2 of off-channel area and hand cleaned 420 m of debris choked channel.

Fry density in off-channel areas can range from up to 6 fish·m^{-2} (H. Mundy, pers. comm.) to 0.65 fish·m^{-2} and 1.83 fish·m^{-2} as found in mainstem pools (Shawn Hamilton and Associates 1996a). Using a conservative factor of 1.5 fish·m^{-2} it is estimated that the off-channel areas created will provide rearing for up to 18,825 (1.5 x 12,550 m^2) juvenile coho and resident trout. Because the 1350 m^2 side channel and ponds in D2OC1 requires improved access in 1999 it was not included in the above production estimate. Also the 5500 m^2 D8OC1 off-channel pond dried in the summer of 1998 and despite creating access to it earlier that summer, it was not included in the production estimate. Further work in 1999 will monitor the pond to determine if it dries yearly or if 1998 was an exceptionally dry year.

Scour pools created by mainstem structures will also increase stable rearing areas although total production benefits cannot be quantified without final pool area measurements. These pool measurements will be made during monitoring surveys and we suggest using a conservative multiplication factor of 0.65 fish·m^{-2} to calculate the production benefits.

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Kilpala River Restoration Project

Objectives
The Kilpala River instream watershed restoration project (the project) is one of a series of projects being undertaken by Canadian Forest Products Ltd. in the Nimpkish River basin, funded by Forest Renewal BC (FRBC). The instream components of the projects have concentrated in the Davie, Lukwa, Kilpala and other smaller watersheds while the upslope and road restoration projects have been completed over much of the Nimpkish watershed.

The Kilpala River restoration project has concentrated on restoring the stream channel and restoring access to off-channel habitat. The Level I assessment of the watershed has identified the principal limitations to fisheries production as extremely limited off-channel habitat, poor pool frequency, few holding pools, aggradation of channels from coarse sediment supplied by landslides, and fish passage barriers (Northwest Hydraulic Consultants and Alby 1998b).

FRBC Region/MELP Region/MOF Region
Pacific / Vancouver Island / Vancouver

Authors
Northwest Hydraulic Consultants (nhc), Alby Systems Ltd. and C.J. Forest Engineering/ Canfor.

Proponents
Partnership of Canadian Forest Products Ltd., 'Namgis First Nation and International Woodworkers of America (IWA).

Watershed
Kilpala River, tributary to the Nimpkish River.

Location
The Kilpala River flows northeast for 17 km from its headwaters turning east to enter Nimpkish Lake approximately half way along its western shore, about 15 km south of Port McNeill on the northern end of Vancouver Island.

Introduction
The Kilpala River drains 109 km^2 of the Karmutzen Ranges. The river flows though a steep, confined valley until it forms a distinctive triangular delta in Nimpkish Lake. This steep watershed has 50% of the slopes greater than 60%. Three major tributaries join the river: Little Kilpala River, Meadow Creek and Karmutzen Creek.

Although the Kilpala River and tributaries are not significant contributors of salmonid production to the Nimpkish River system the basin is an important steelhead producing system. It has historically supported coho, steelhead, resident rainbow and cutthroat trout, Dolly Varden char. Sea-run cutthroat trout have been reported (R. Lutz, pers. comm.) as well as sockeye spawning in the lowest reach K1 and on the delta, in 1978 and 1979 (M. Berry, B. Ambers, H. Nelson, pers. comm.). Chinook, pink and chum salmon are not known to utilize the Kilpala River and it's tributaries.

There are no escapement data specific to Kilpala River; escapement histories are recorded for the whole of the Nimpkish watershed. In general, escapements of all anadromous salmonid species have declined over the 40 years of record (Shawn Hamilton and Associates 1996b). Coho escapements have declined from a total escapement of 13,600 per year to less than average 1000 per year for the decades 1950 to 1960 and 1985 to 1995, respectively (DFO 1958; R. Lutz, and H. Nelson, pers. comm.). Contrary to this trend 1998 coho returns to the Nimpkish system were in excess of 8500 spawning adults counted during swim surveys of the mainstem Nimpkish River (H. Nelson, pers. comm.). Due to the extended spawning period, lack of enumeration effort and a large geographic distribution, the total population of spawning coho is thought to be well in excess of the 8500 counted by the 'Namgis enhancement crew. Winter run steelhead numbers have declined by up to 30% (R. Lutz, pers. comm.). Steelhead harvest data suggests that the steelhead population of the last 5 years is 50% of what it was in the proceeding 5-year period (Axford 1996).

Assessments and Prescriptions
Forest harvesting in the Kilpala basin began in the 1950's in a small area in the upper Meadow Creek basin. The rest of the drainage was not

harvested until 1976. To date approximately 22% of the total basin area has been harvested. Now, as a result of hydrologic recovery, past harvesting only has a minor effect on flood peaks and the CWAP prepared by W. M. Resource Consulting in 1996 indicates an overall low peak flow hazard.

Initial harvesting (except the small area in the upper Meadow watershed) proceeded up the main valleys of the Kilpala River and Meadow Creek. As a result both these streams were logged to the bank and have high riparian hazards (W. M. Resource Consulting 1996). The other major tributary streams, due to newer logging practices, were left with riparian buffers or leave strips. Despite the loss of riparian vegetation in Meadow and lower Kilpala the reduced bank strength does not seem to have contributed to channel widening. This is likely due to the incised and confined nature of these stream channels. However, the loss of riparian trees has effected the recruitment of LWD and shading of the affected reaches.

Due to the steep terrain the watershed is prone to landslides. The logging of steep slopes and road building have increased this natural landslide rate as well as destabilizing the steep tributary gullies leading to torrents. Meadow Creek, reach M3 in particular, has been heavily impacted by landslides directly entering the stream channel, whose coarse sediment remains in the stream. The Kilpala River, Little Kilpala River and Karmutzen Creek have also been altered by landslides directly entering the stream channel. Unlike Meadow Creek these channels are steep and have a correspondingly high transport capability, which mitigates the impact of the increased coarse sediment supply.

Rehabilitation Work

Rehabilitation work began in the Kilpala River watershed on slope rehabilitation and road deactivation. After the completion of this upslope work, instream work commenced with biological surveys of the stream habitat in 1995 (Shawn Hamilton and nhc 1996b). This initial work was followed up with further biological assessments in 1996 (nhc and Alby 1998b). Field surveys and prescriptions were completed in the spring and early summer of 1997. The Level 2 prescription report (nhc and Alby 1997b) was submitted for 1997 Section 9 approval and instream work started that summer. Work continued in spring and early summer of 1998 with field surveys and prescriptions for additional sites. These sites along with the 1997 Level 2 report were submitted for 1998 Section 9 approval. Instream work continued during the summer of 1998.

The main objectives were to:
- restore access to off-channel areas;
- rearrange LWD jams to prevent bank erosion and permit transport of angular sediment while maintaining their original instream function;
- excavate gravels from aggraded reaches to restore fish habitat; and
- create employment and focus efforts on labour intensive projects when possible.

The following is a summary of the works undertaken to date. For a more detailed discussion see nhc and Alby 1999b.

M1DJ1 (LWD Jam)

The main habitat objective at this site was to restore the main and low flows to the east fork of reach M1.
- Built a LWD crib across entrance to west fork.
- Realigned LWD pieces in 2 LWD jams to prevent upstream ponding and bank erosion.
- Reinforced 1 LWD jam to promote establishment of single main channel.
- Added or reinforced 2 LWD steps to increase ponded depth during low flows.
- Added 12 LWD pieces for cover in the channel.
- Built 1 LWD spur to protect eroding right bank.

M1DJ2 (LWD Jam)

The main habitat objective at this site was to rearrange 2 large LWD jams to prevent bank erosion and restore unimpeded adult access.

Upper LWD Jam
- Removed the left center portion of the jam.
- Reinforced remaining portion of jam to maintain scour, provide cover and protect banks.

Lower LWD Jam
- Removed the left center portion of the jam.
- Reinforced remaining portion of jam to

maintain scour, provide cover and protect banks.
- Blocked entrance to left channel to establish one main right bank channel.

M3OT1 (Aggraded Mainstem)
The main habitat objective at this site was to restore the habitat of the heavily aggraded reach M3. To accomplish this, two independent objectives were identified: to determine the ongoing sediment delivery to the site (points 1 through 4) and to construct minor improvements to help the channel stabilize through limiting new sediment sources and establishing a single main channel (points 5 through 8).
- Excavated a series of 7 test pits to determine depth below gravel to permanently wetted streambed.
- Excavated 4 pools (1 below and 3 above the torrented right bank tributary) to monitor gravel transport from the upper watershed and tributary.
- Excavated 2 large sediment traps in the lower portion of the torrented tributary's fan to monitor sediment transport from the fan.
- Built a boulder berm at the top of the torrented tributary fan to monitor sediment transport from the upper torrented tributary.
- Rearranged 2 LWD jams to prevent bank erosion, permit transport of angular sediment and restore access and a single main channel.
- Removed an abandoned wood culvert to restore access to the upper watershed.
- Built 3 LWD spurs to encourage local scour and protect eroding banks.
- Placed 1 rootwad and 6 LWD pieces in the channel to promote bed scour and protect the toe of unconsolidated gravel banks.
- Future work at this site will include prescriptions for channel excavation and restoration if ongoing sediment delivery is deemed acceptable.

LK1SD1 (LWD Jam)
The main habitat objective at this site was to rearrange a series of LWD jams to prevent bank erosion and allow transport of angular sediment as well as to create access into a side channel.
- Removed center of LWD jam and reinforced rest of jam.
- Built 7 LWD spurs.
- Hand-cleaned 95 m of upper side channel, creating about 200 m^2 of stable spawning substrate.

K3OC1 (Off-channel)
The main habitat objective at this site was to provide access for juvenile salmonids into 16,400 m^2 of off-channel beaver ponds.
- Replaced the mainline culvert with a fish passable baffled arch culvert.
- Built 2 LWD steps.
- Hand-cleaned a 103 m side channel to permit access around 3 beaver dams.
- Removed a collapsed LWD culvert on an abandoned spur.
- Built a 5-step fish ladder for juvenile access over a beaver dam.

Equipment and Labour
A variety of tools were employed in the restoration project including backhoes, helicopters, environmental monitoring equipment, and hand tools. With the emphasis on labour intensive projects hand tools were the most utilized equipment of the project especially chainsaws and attachments.

The Schaef HS40 Spyder™ backhoe was used for the excavations and wood culvert removal in M3OT1 as well as the abandoned spur culvert removal in K3OC1. A John Deere JD892 backhoe was employed for the installation of the mainline arch culvert at K3OC1.

On-site material was used for all projects except rock anchors in M1DJ1 and yellow cedar railroad ties in K3OC1. An Aerospatialle A star 350 BA (max. lifting cap. 1850 lbs) helicopter delivered rock to M1DJ1. The crew carried the yellow cedar railroad ties to K3OC1.

Flow diversion around or away from the work site was used whenever possible to control the silt produced by instream work. Silt fences, hay bales, gravel bermed settling ponds and pumps were utilized when diversion was not possible. Fry were removed by electrofisher and blocked from re-entering all channel excavation sites using exclusion netting.

Hand tools includes all the tools used by the labour crews to secure LWD, move LWD, attach boulders, and replant damaged areas. Chainsaws, chainsaw winches, chainsaw drills, Hilti rotary hammer, geotextile, "belly-grinder" seed applicators, sledge hammers, ratchets and sockets, cable, cable clamps, knobs and wedges, staples, rebar, nailing strips, and nails were all used.

In 1997 the Nimpkish restoration project, which includes the Kilpala River project, employed 3 labour crews of 5 members in addition to a field coordinator.

In 1998 the Nimpkish restoration project employed 2 crews of 4 members and a field coordinator.

Cost Summary

The costs incurred in the 1997 and 1998 Kilpala River Level 3 (construction) project only are summarized below. It does not include assessment and prescription costs.

Crew labour (including assessments)	$ 60,466
Consultants (fees and expenses)	$ 11,419
Heavy duty equipment (backhoes and gravel trucks)	$ 17,866
Helicopter	$ 1,756
Other costs	$ 20,418
Total	$111,925

Production Estimates

The project created or added: 4 monitoring pools, 9 monitoring pits, 1 boulder berm, 3 culverts, 1 fish ladder, 15 m of LWD crib, 7 LWD jams, 30 m of rootwad crib, 18 LWD pieces, 1 rootwad, 11 LWD spurs, 4 LWD steps, access into 16,600 m^2 of off-channel area and hand cleaned 300 m^2 of debris choked channel.

The anticipated improvements to substrate could increase viable spawning capacity by up to 20 pairs of adult coho based on 1 pair for every 10 m^2 of stable channel created.

Fry density in off-channel areas can range from up to 6 $fish{\cdot}m^{-2}$ (H. Mundy, pers. comm.) to 0.65 $fish{\cdot}m^{-2}$ and 1.83 $fish{\cdot}m^{-2}$ as found in mainstem pools (Shawn Hamilton and Associates 1996b). Using a conservative factor of 1.5 $fish{\cdot}m^{-2}$ it is estimated that the off-channel areas created will provide rearing for up to 24,900 (1.5 x 16,600 m^2) juvenile coho and resident trout. Further work in 1999 will attempt to restore access to the lower side channel at site LK1DJ1 and is expected to provide an additional 200 m^2 of stable spawning and rearing channel.

Scour pools created by mainstem structures will also increase stable rearing areas although total production benefits cannot be quantified without final pool area measurements. These pool measurements will be made during monitoring surveys and we suggest using a conservative multiplication factor of 0.65 $fish{\cdot}m^{-2}$ to calculate the production benefits.

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KO51 (Lutz) and WB9 (Unnamed) Creeks Restoration Projects

Objectives
The KO51 (Lutz) Creek and WB9 (Unnamed) Creek instream watershed restoration projects (the projects) are part of a series of projects being undertaken by Canadian Forest Products Ltd. in the Nimpkish River basin, funded by Forest Renewal BC (FRBC). The instream components of the projects have concentrated in the Davie, Lukwa, Kilpala and other smaller watersheds while the upslope and road restoration projects have been completed over much of the Nimpkish watershed.

The restoration project in KO51 creek has concentrated on restoring the stream channel and restoring access to the upper watershed. The WB9 project has concentrated on restoring access to the upper watershed and rearing habitat. There have been no Level 1 assessments of either watershed to date. KO51 Creek has poor pool frequency, restricted access to the upper watershed by a large beaver dam, channel widening and aggradation and lack of riparian vegetation. WB9 has abundant beaver activity that is limiting juvenile and adult migration to the upper watershed and loss of off-channel habitat.

FRBC Region/MELP Region/MOF Region
Pacific / Vancouver Island / Vancouver

Authors
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Proponents
Partnership of Canadian Forest Products Ltd., 'Namgis First Nation and International Woodworkers of America (IWA).

Watersheds
KO51 (Lutz) Creek, tributary to Vernon Lake and the Nimpkish River.
WB9 (Unnamed) Creek, tributary to the Woss River and the Nimpkish River.

Location
KO51 Creek flows west from its marshy headwaters to enter Vernon Lake approximately three-quarters of the way along its eastern shore. Vernon Lake lies 20 km southeast of the town of Woss. Woss is located 74 km south of Port McNeill on the northern end of Vancouver Island.

WB9 Creek flows northwest entering the Woss River in reach W1 as it flows onto the Nimpkish River floodplain. The Woss River joins the Nimpkish River about 4 km downstream of the town of Woss.

Introduction
KO51 Creek drains 5.3 km^2 and has a mainstem length of 4.2 km. The basin has maximum elevations of about 1100 m along the south side of the valley. The main valley is broad with abundant marshy areas. The creek has one large tributary that joins the mainstem in reach KO2 from the south.

WB9 Creek is a small 4.3 km^2 basin with a mainstem length of 4.4 km. The basin has very little relief and maximum elevations are about 800 m in the southeast corner of the basin. There are no major tributaries and the mainstem flows through a series of marshes and beaver ponds.

KO51 and WB9 are too small to be significant contributors of salmonid production to the Nimpkish River system but both have supported healthy coho, cutthroat trout and Dolly Varden char populations in the past. KO51 has historically been a source of brood stock for the Woss Community Hatchery while WB9 has been stocked with juvenile coho for the past 2 years. Sockeye spawn in the lowest reach of KO51 and its fan. Steelhead, rainbow trout, chinook, pink and chum salmon are not known to utilize either of the creeks (R. Lutz, pers. comm.).

There are no escapement data specific to KO51 or WB9 creeks; escapement histories are recorded for the whole of the Nimpkish watershed. In general, escapements of all anadromous salmonid species have declined over the 40 years of record (Shawn Hamilton and Associates 1996b). Coho escapements have declined from a total escapement of 13,600 per year to less than average 1000 per year for the decades 1950 to 1960 and 1985 to 1995, respectively (DFO 1958; R. Lutz, and H. Nelson, pers. comm.). Contrary to this trend 1998 coho returns to the Nimpkish system were in excess of 8500 spawning adults counted during swim surveys of the mainstem Nimpkish River (H. Nelson, pers. comm.). Due to the extended spawning period, lack of enumeration effort and a large geographic distribution, the total population of spawning coho is thought to be well in excess of the 8500 counted by the 'Namgis enhancement crew.

Assessments and Prescriptions

The KO51 Creek basin has been heavily harvested. Logging proceeded up the broad valley often cutting to the streambank. Reaches KO2 and KO3 have been left with little or no riparian buffer. The left bank tributary that enters reach KO2 from the south has also been logged to the bank in its lower reaches. The basin is not prone to landsliding due to the low relief and slides are not significant contributors of coarse sediment to the stream channels.

As a result of the riparian removal both the mainstem and tributary channels have experienced increased bank erosion rates which has lead to a widening of the channels and an increase in coarse, angular sediment stored in the channel. As the channels have widened the pools have filled with gravel. Wind-throw of the small riparian fringe along both streams has created large LWD jams that pond water upstream causing bank erosion. KO51 tributary was spanned by an underfit wood culvert in the lower reach which ponded water upstream. This ponding has slowed sediment transport leading to a large gravel wedge filling the channel. As well numerous skid trails cross the upper reaches and threaten bank integrity.

WB9 has had moderate forest harvesting of its basin. Above the mainline the basin is marshy and remains forested. Below the mainline much of the basin has been logged leaving a thin riparian buffer along the creek.

Beavers have had a significant impact on the WB9 channel. Beavers built a large dam upstream of the mainline and historic railroad grade providing a large beaver pond for resident trout species. Removal of the railroad grade destroyed the dam and drained the pond. The lower reaches of the creek have several dams along them which are thought to impede adult and juvenile migration in the channel.

Rehabilitation Work

Instream rehabilitation work started in the 2 basins in the spring and early summer of 1998 with field surveys and site prescriptions. Two sites in WB9 and five sites in KO51 were submitted for 1998 Section 9 approval (nhc and Alby 1998c). Instream work commenced during the summer of 1998. Road deactivation of the spur road crossing the KO51 mainstem in reach KO1 and KO51 tributary in reach KOT1 was carried out at the end of the field season in 1998.

Rehabilitation Work in KO51 Creek

The main objectives in KO51 Creek were to:

- create pools in the aggraded main channel;
- rearrange LWD jams to prevent bank erosion and permit transport of sediment while maintaining their original instream function;
- ensure juvenile and adult access over the large beaver dam at the top of reach KO1;
- excavate aggraded gravels from the south tributary to restore year-round flow, fish habitat and prevent the transport of these gravels to other fisheries sensitive areas downstream; and
- create employment and focus efforts on labour intensive projects when possible.

The following is a summary of the works undertaken to date. For a more detailed discussion see nhc and Alby 1999c.

KO51 Lower Mainstem (LWD Jams)

The main habitat objective at this site was to create pools and rearrange LWD jams to prevent bank erosion and allow transport of angular coarse sediment.

- Constructed 12 LWD spurs.
- Realigned LWD pieces in 6 LWD jams to prevent upstream ponding and bank erosion.
- Added 5 LWD pieces for cover in the channel.

KO51 Beaver Dam (Beaver Dam)

The main habitat objective at this site was to provide year-round juvenile and adult access over the 1.5 m tall beaver dam.

- Excavated an existing left bank overflow channel for 20 m to connect the beaver pond to the lower mainstem, including a road crossing.
- Hand placed boulders to form 6 rock riffles

in the channel downstream and across the deactivated road.
- Lined the channel with rip-rap across the deactivated road.
- Built 1 LWD step at the head of the channel to control the level of water in the beaver pond.
- Placed 6 LWD pieces across the channel for cover.

KO51 Upper Mainstem (LWD Jam)
The main habitat objective at this site was to create pools and rearrange LWD jams to prevent bank erosion and allow transport of angular coarse sediment.
- Constructed 9 LWD spurs.
- Realigned LWD pieces in 9 LWD jams to prevent upstream ponding and bank erosion.
- Added 7 LWD pieces for cover and to protect the toes of eroding banks in the channel.
- Realigned 8 rootwads to protect eroding banks and to provide cover.

KO51 Lower Tributary (Aggraded Channel)
This site consists of 2 sections: the upper aggraded portion of the site and lower LWD-poor portion of the site. The main habitat objective in the upper portion of the site was to excavate the aggraded gravels to: restore year-round flow, construct fish habitat and prevent transport of angular coarse sediment to other fisheries sensitive reaches downstream. The main habitat objective in the lower portion of the site was to improve the quality of the habitat by deepening summer rearing pools and adding LWD pieces for cover.

<u>Upper Aggraded Portion of the Site</u>
- Excavated 150 m of aggraded channel by backhoe and end-hauled or spoiled sediment on-site.
- Constructed 7 LWD steps for grade control and pool habitat.
- Added 20 LWD pieces for cover and to protect the toes of eroding banks in the channel.
- Realigned 4 rootwads to protect eroding banks and to provide cover.
- Constructed 1 rock riffle.
- Constructed 3 LWD spurs.
- Realigned LWD pieces in 6 LWD jams to prevent upstream ponding and bank erosion.

<u>Lower LWD Poor Portion of the Site</u>
- Excavated 8 naturally formed pools to increase summer low flow depth.
- Added rip-rap to 6 natural riffles between pools to reconstruct them with larger pieces of rock.
- Added 11 LWD pieces and 2 rootwads to the channel and excavated pools for cover.
- Realigned and strengthened 2 LWD jams.

KO51 Upper Tributary (LWD Jams)
The main habitat objective at this site was to create pools and rearrange LWD jams to prevent bank erosion and allow transport of angular coarse sediment.
- Realigned LWD pieces in 4 LWD jams.
- Constructed 3 LWD spurs.
- Realigned 5 rootwads to add cover to the channel.

Rehabilitation Work in WB9 Creek
The main objectives in WB9 Creek were to:
- rebuild the large pond upstream of the mainline;
- ensure juvenile and adult access over the largest of the downstream beaver dams; and
- create employment and focus efforts on labour intensive projects when possible.

The following is a summary of the works undertaken to date. For a more detailed discussion see nhc and Alby 1999c.

WB9 Lower (Beaver Dam)
The main habitat objective at this site was to ensure access over the largest of the downstream beaver dams.
- Constructed a 5-step fish ladder in the main channel downstream of the beaver dam.
- Constructed a LWD step in the right bank channel to allow access through this channel over the dam.
- Constructed a small LWD jam along the edge of the abandoned spur to prevent the pond from spilling across the road.

WB9 Upper (Historic Beaver Pond)
The main habitat objective at this site was to recreate the historic beaver pond by ponding water upstream of a large LWD step.
- Constructed 4 LWD steps to pond water upstream and create access into a newly constructed 360 m^2 pond.

- Excavated gravels from center of pond to increase pond depth.
- Added 3 LWD pieces to downstream channel for cover.
- Realigned natural cobbles by hand to back water downstream of the LWD step.

Equipment and Labour

A variety of tools were employed in these restoration projects including backhoes, dump trucks, logging trucks, helicopters, environmental monitoring equipment, and hand tools. With the emphasis on labour intensive projects hand tools were the most utilized equipment of the project especially chainsaws and attachments.

The Schaef HS40 Spyder™ backhoe was used for the excavations and wood culvert removal of the lower wood culvert of the KO51 tributary. The upper culvert and bridge over reach KO1 were removed by a road deactivation backhoe (Hitachi EX 300).

Two types of dump trucks were used to end-haul gravels removed from the aggraded KO51 tributary as well as to deliver rip-rap to this site. Conventional dump trucks delivered rip-rap to the spur road that crossed the site while an articulated Cat dump truck was used to end-haul as well as to deliver rip-rap.

Except for the rip-rap in the KO51 tributary, yellow cedar railroad ties for the fish ladder and the LWD pieces required for the 4 LWD steps in WB9 on-site materials were used for all projects. A self-loading logging truck delivered the LWD pieces to the mainline at WB9 Upper and the crew carried in the yellow cedar railroad ties to WB9 Lower.

An Aerospatialle A star 350 BA (max. lifting cap. 1850 lbs) helicopter was employed in KO51.

The channel excavation of the upper section of the KO51 Lower Tributary site was carried out while the channel was completely dry and no silt control measures were required. In the lower section of KO51 Tributary and WB9 Upper sites fry were removed by electrofisher and Gee minnow traps and blocked from re-entering the sites using exclusion netting. There was no flow over the riffles in the KO51 Tributary and no silt control measures were required. If precipitation were to have occurred all work would have stopped and appropriate measures taken. At all LWD jam rearrangement sites care was taken to produce as little silt as possible.

Hand tools includes all the tools used by the labour crews to secure LWD, move LWD, attach boulders, and replant damaged areas. Chainsaws, chainsaw winches, chainsaw drills, Hilti rotary hammer, geotextile, "belly-grinder" seed applicators, sledge hammers, ratchets and sockets, cable, cable clamps, knobs and wedges, staples, rebar, nailing strips, and nails were all used.

In 1998 the Nimpkish restoration project employed 2 crews of 4 members and a field coordinator.

Cost Summary

The costs incurred in the 1998 KO51 and WB9 Level 3 (construction) projects only are summarized below. It does not include assessment and prescription costs.

KO51

Crew labour (including assessments)	$ 66,841
Consultants (fees and expenses)	$ 12,155
Heavy duty equipment (backhoes and gravel trucks)	$ 21,929
Helicopter	$ 1,496
Other costs	$ 11,646
Total	$114,067

WB9

Crew labour (including assessments)	$ 10,997
Consultants (fees and expenses)	$ 1,000
Heavy duty equipment (backhoes and gravel trucks)	$ 2,000
Helicopter	$ 0
Other costs	$ 833
Total	$ 14,830

Production Estimates for KO51 Creek

These projects created or added: 800 m^2 of stable channel, 8 deepened pools, 3 culverts, 27 LWD jams, 49 LWD pieces, 21 rootwads, 27 LWD spurs, 8 LWD steps, 6 stable riffles with rip-rap, 7 rock riffles (6 built by hand), ensured access into approximately 4.8 km of fish bearing headwater stream length.

The anticipated improvements to substrate could increase viable spawning capacity by up to 80 pairs of adult coho and/or sockeye based on 1 pair for every 10 m^2 of stable channel created.

Fry density in off-channel areas can range from up to 6 fish·m^{-2} (H. Mundy, pers. comm.) to 0.65 fish·m^{-2} and 1.83 fish·m^{-2} as found in mainstem pools (Shawn Hamilton and Associates 1996b). Using a conservative factor of 1.5 fish·m^{-2} it is estimated that the increased pool depth and size in the KO51 tributary channel will provide rearing for up to 300 (1.5 x 200 m^2) juvenile coho and resident trout. The above estimate does not include the ensured access into the 4.8 km of fish bearing channel.

Scour pools created by mainstem structures will also increase stable rearing areas although total production benefits cannot be quantified without final pool area measurements. These pool measurements will be made during monitoring surveys and we suggest using a conservative multiplication factor of 0.65 fish·m^{-2} to calculate the production benefits.

Production Estimates for WB9 Creek

These projects created or added: 360 m^2 pond, 1 fish ladder, 1 LWD jam, 3 LWD pieces, 5 LWD steps, 1 hand built rock riffle, ensured access into approximately 3.4 km of fish bearing headwater stream length including the 200 m^2 beaver pond.

Fry density in off-channel areas can range from up to 6 fish·m^{-2} (H. Mundy, pers. comm.) to 0.65 fish·m^{-2} and 1.83 fish·m^{-2} as found in mainstem pools (Shawn Hamilton and Associates 1996b). Using a conservative factor of 1.5 fish·m^{-2} it is estimated that the increased pool depth and size in the KO51 tributary channel will provide rearing for up to 840 (1.5 x 560 m^2) juvenile coho and resident trout. The above estimate does not include the ensured access to 3.4 km of fish bearing channel.

Scour pools created by mainstem structures will also increase stable rearing areas although total production benefits cannot be quantified without final pool area measurements. These pool measurements will be made during monitoring surveys and we suggest using a conservative multiplication factor of 0.65 fish·m^{-2} to calculate the production benefits.

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Lukwa Creek Restoration Project

Objectives
The Lukwa Creek instream watershed restoration project (the project) is one of a series of projects being undertaken by Canadian Forest Products Ltd. in the Nimpkish River basin, funded by Forest Renewal BC (FRBC). The instream components of the projects have concentrated in the Davie, Lukwa, Kilpala and other smaller watersheds while the upslope and road restoration projects have been completed over much of the Nimpkish watershed.

The Lukwa Creek instream restoration project has concentrated on restoring the stream channel and restoring access to off-channel habitat. The Level I assessment of the watershed identified the principal limitations to fisheries production as reduced adult escapement, sediment deposition that has altered streams and limited spawning success, and reduced rearing capacity for both anadromous and resident species (Northwest Hydraulic Consultants and Alby 1998d).

FRBC Region/MELP Region/MOF Region
Pacific / Vancouver Island / Vancouver

Authors
Northwest Hydraulic Consultants (nhc), Alby Systems Ltd. and C.J. Forest Engineering/ Canfor.

Proponents
Partnership of Canadian Forest Products Ltd., ‘Namgis First Nation and International Woodworkers of America (IWA).

Watershed
Lukwa Creek, tributary to the Nimpkish River.

Location
Lukwa Creek flows south from its headwaters to the Island Highway where it turns west, entering the Nimpkish River approximately 1 km upstream of the town of Woss. Woss is located 74 km south of Port McNeill on the northern end of Vancouver Island.

Introduction
Lukwa Creek is 13 km long and drains an area of 54.4 km^2. Lukwa Creek originates in 2 branches. One branch originates in a steep gully that joins the second branch of flow when it enters the main valley. The second branch of Lukwa Creek originates in a marsh that flows from its Lukwa Creek’s drainage divide with Claude Elliot Creek. Lukwa Creek then flows through a moderately broad valley with few large tributaries to the Nimpkish River. As you move away from the main channel the valley quickly steepens. As a result most of the fish producing areas are in the mainstem of Lukwa Creek. Lukwa Creek’s only major tributary, Hoomak Creek, enters the stream in Reach LU3 where the Lukwa valley opens to the main Nimpkish valley.

Lukwa Creek has been a significant contributor of salmonid production to the Nimpkish River system. It supports resident rainbow (may actually be juvenile steelhead) and cutthroat trout, Dolly Varden char, and in the past has had significant runs of coho salmon. Adult steelhead have not been reported in the basin despite the recent Woss CDP hatchery releases of hatchery steelhead and coho into the lower reaches. Sockeye, chinook, pink and chum salmon have never been reported in the Lukwa.

There are no escapement data specific to Lukwa Creek; escapement histories are recorded for the whole of the Nimpkish watershed. In general, escapements of all anadromous salmonid species have declined over the 40 years of record (Shawn Hamilton and Associates 1996a). Coho escapements have declined from a total escapement of 13,600 per year to less than average 1000 per year for the decades 1950 to 1960 and 1985 to 1995, respectively (DFO 1958, R. Lutz, and H. Nelson, pers. comm.). Contrary to this trend 1998 coho returns to the Nimpkish system were in excess of 8500 spawning adults counted during swim surveys of the mainstem Nimpkish River (H. Nelson, pers. comm.). Due to the extended spawning period, lack of enumeration effort and a large geographic distribution, the total population of spawning coho is thought to be well in excess of the 8500 counted by the ‘Namgis enhancement crew.

Assessments and Prescriptions

Forest harvesting in the Lukwa basin began in the 1960's. To date approximately 42% of the total basin area has been harvested, which likely increased flood peaks in the late 1970's and early 1980's. Now, as a result of hydrologic recovery, past harvesting only has a minor effect on flood peaks (nhc and Alby 1998d).

Lukwa Creek also experienced an increase in coarse sediment supply, both from road failures and torrented creeks. Much of the sediment entered reaches LU5, LU6 and LU8. Reaches LU4, LU5, LU6 and LU7 are aggraded by coarse, angular material that fills pools, and has deposited over the substrate reducing spawning success and blocking access to off-channel habitat. LWD (large woody debris) jams block sections of the channel resulting in bank erosion and sediment accumulation. Stable rearing and spawning areas are limited in these reaches. A debris torrent from the upper watershed deposited most of its load in Reach LU8 (since carried to Reach LU7) which has filled the channel causing avulsions into the marsh in the upper watershed.

Reaches LU1 through LU3 with their steeper gradient and correspondingly increased sediment transport capability have not been as significantly impacted.

Rehabilitation Work

Rehabilitation work began in the Lukwa Creek watershed with slope rehabilitation and road deactivation. Instream work, following the upslope work, began in 1995 with biological surveys (Shawn Hamilton and nhc 1996c). This initial work was followed up with further biological assessments in 1996 (nhc and Alby 1998d). Prescription field surveys and site prescriptions were completed in the spring and early summer of 1997. The Level 2 prescription report (nhc and Alby 1997c) was submitted for 1997 Section 9 approval and instream work started that summer. Work continued in spring and early summer of 1998 with field surveys and prescriptions for additional sites. These sites along with the 1997 Level 2 report were submitted for 1998 Section 9 approval. Instream work continued during the summer of 1998.

The main objectives were to:

- create pools in the main channel;
- restore access to off-channel areas;
- re-arrange LWD jams to prevent bank erosion and permit transport of angular sediment while maintaining their original instream function;
- excavate aggraded gravels from torrented tributaries to restore habitat and prevent the transport of these gravels to more fisheries sensitive areas downstream; and
- create employment and focus efforts on labour intensive projects when possible.

The following is a summary of the works undertaken to date. For a more detailed discussion see nhc and Alby 1999d.

LU4OC1 (Off-channel)

The main habitat objective at this site was to provide access for juvenile salmonids into a 2600 m^2 off-channel marsh.

- Installed 11 LWD steps to provide juvenile access to the off-channel marsh.
- Increased pond depth during low flows.
- Added LWD pieces for cover in the channel.
- Rebuilt channel through abandoned road crossing.

LU4DJ1 (LWD Jam)

The main habitat objective at this site was to produce local bed scour and create pool habitat.

- Rearranged spanning LWD pieces into a LWD spur to produce a scour pool.
- Rearranged LWD pieces along bank to narrow channel.

LU4DJ2 (LWD Jam)

The main habitat objective at this site was to rearrange a large LWD jam to prevent bank erosion and permit transport of angular sediment while maintaining the LWD jam's original instream function.

- Rearranged LWD jam at downstream end of site which was ponding water upstream and causing bank erosion.
- Excavated gravels from high mid-channel bar to prevent downstream transport.
- Built right bank rootwad crib to protect small alder island.
- Built 1 LWD spur and placed 3 LWD pieces

in channel to encourage flow through center of channel and produce scour.
- Built 2 LWD spurs and placed 2 rootwads and 2 LWD pieces in right bank channel to slow erosion of right bank.
- Reinforced LWD jam at top of left bank channel and added 3 rootwads and built 2 LWD spurs in channel to scour pools and provide cover.

LU4DJ3 (LWD Jam)
The main habitat objective at this site was to re-arrange a large LWD jam to prevent bank erosion and permit transport of angular sediment while maintaining the LWD jam's original instream function.
- Removed center 8 m from LWD jam to prevent flow from being diverted through the left bank riparian reserve.
- Built left bank LWD crib at entrance to side channel to prevent flows from entering channel and eroding bank.
- Built 8 LWD spurs to produce scour pools, above and below the LWD jam on both banks.
- Realigned LWD pieces from jam perpendicular to banks to prevent subsequent bank erosion.

LU5DJ1 (LWD Jams)
The main habitat objective at this site was to re-arrange a series of large LWD jams at the toe of a valley wall slide to prevent bank erosion and permit transport of angular sediment while maintaining the LWD jams' original instream functions.
- Removed the center portion of 4 LWD jams to reduce bank erosion, permit scour, and restore flow through the main channel.
- Removed center of jams only and left outside portions of all jams intact to produce scour, provide cover and prevent bank erosion.

Habitat structures built by LWD jam are listed below. Distances refer to the distance downstream from the mouth of the torrented tributary LU5OT1.

<u>LWD Jam 1 (0+057 m)</u>
- Removed right center portion of jam.
- Built 2 LWD spurs upstream.
- Lined right bank with LWD pieces to prevent bank erosion.
- Strengthened left bank portion of jam by cabling large stable pieces together.
- Placed rootwad with roots upstream at base of eroding left bank to protect toe of bank.

<u>LWD Jam 2 (0+101 m)</u>
- Removed left center portion of jam.
- Strengthened right bank portion of jam by cabling large stable pieces together.
- Built LWD jam on left bank to prevent further bank erosion and narrow channel to encourage scour.
- Built large left bank spur to protect left bank from erosion.
- Added LWD pieces to upstream side of bank slump to protect bank from further erosion.

<u>LWD Jam 3 (0+170 m)</u>
- Removed left center portion of jam.
- Hand cleaned small right bank channels to encourage flow away from the eroding left bank.
- Built 3 LWD spurs on undercut left bank.
- Placed LWD pieces along right bank to add cover in natural pool downstream of jam location.

<u>LWD Jam 4 (0+270 m)</u>
- Removed start of LWD jam and realigned LWD pieces along banks to narrow channel and protect banks.
- Added LWD pieces for cover to natural pools upstream of small island.
- Added LWD pieces to entrance to right bank channel to encourage main flow in left bank channel.
- Built and augmented natural LWD spurs on left bank to protect bank and create pools.
- Left LWD pieces along left bank for cover.

LU5OC1 (Off-channel)
The main habitat objective at this site was to establish juvenile access into a 2800 m^2 beaver pond and surrounding 8100 m^2 marsh as well as the upstream low gradient tributary channel.
- Hand cleaned small wood choked channel through a series of beaver ponds and marsh to allow fish access.
- Built a series of LWD steps over abandoned beaver dam for fish access.
- Added LWD pieces to upper tributary for cover.

LU5OT1 (Torrented Tributary)
The main habitat objective at this site was to

excavate aggraded gravels from a torrented tributary to restore habitat and prevent the transport of these gravels to more fisheries sensitive areas downstream.

- Excavated aggraded gravels from 200 m of torrented tributary channel.
- Placed 8 LWD steps approximately every 25 m for grade control and to produce scour pools downstream.
- Built 25 m long rootwad crib on right bank to restore bank and prevent channel migration through Lukwa Creek riparian area.
- Excavated 50 m long side channel for refuge during high flows.
- Excavated off-channel pond for refuge during high flows.
- Placed 2 sill LWD along base of unconsolidated gravel banks to protect toe of banks.
- Placed 3 rootwads, 3 LWD spurs and 2 boulders for cover and to encourage pool development.
- Built LWD jam at entrance to side channel to prevent main flow from entering channel and narrow channel to produce a scour pool to maintain low flows in the side channel.
- Lined 70 m of bank in 2 areas with rip-rap to prevent erosion and channel avulsion.

LU7SD1 (Aggraded Mainstem Lukwa Creek)

The main habitat objective at this site was to excavate aggraded gravels of Lukwa Creek to restore habitat and prevent the transport of these gravels to other fisheries sensitive areas downstream.

- Excavated aggraded angular gravels from 80 m of Lukwa Creek, storing on floodplain.
- Rebuilt right bank with 25 m long rootwad crib.
- Placed 1 LWD step downstream of bridge for grade control and to produce a scour pool downstream.
- Added 2 LWD pieces to left bank to provide cover and scour pools.
- Placed sill LWD along toe of unconsolidated gravel bank to protect toe.
- Lined both banks with rip-rap for 5 m downstream of bridge to prevent bank erosion.
- Placed 1 LWD step and hand-cleaned small channel to restore juvenile access to the 32,000 m^2 headwater swamp.

LU8SD1 (Torrented Headwaters)

The main habitat objective at this site was to excavate aggraded gravels from the torrented headwaters of Lukwa Creek to restore habitat and prevent the transport of these gravels to more fisheries sensitive areas downstream.

- Excavated aggraded gravels from 260 m of torrented channel.
- Placed 13 LWD steps approximately every 20 m for grade control and to produce scour pools downstream.
- Built 3 rootwad cribs along 50 m of bank to prevent channel avulsion.
- Placed 3 rootwads, 5 LWD pieces and 5 boulder clusters for cover and to encourage pool development.
- Lined bank in 8 areas with rip-rap to prevent channel avulsion and bank erosion.

Equipment and Labour

A variety of tools were employed in the restoration project including backhoes, dump trucks, helicopters, logging trucks, environmental monitoring equipment, skyline, and hand tools. With the emphasis on labour intensive projects hand tools were the most utilized equipment of the project especially chainsaws and attachments.

Different backhoes were used depending on the size of the excavation, the proposed channel width, swinging room within the riparian vegetation, and the type of machines available in the TFL. The backhoes, from smallest to largest, were the Schaef HS40 Spyder™, Hitachi EX 200 and EX 300.

Two types of dump trucks were used to end-haul gravels removed from the aggraded channels as well as to deliver LWD pieces and rip-rap to the construction site. Conventional “Euclid” trucks were used when access did not include tight bends and uneven streambed. For all other purposes Volvo articulated dump trucks were used.

Helicopters delivered rock anchors and small rootwads to remote sites. The two types of helicopters employed were the Aerospatialle A star 350 B2 (max. lifting cap. 2400 lbs) and the Aerospatialle A star 350 BA (max. lifting cap. 1850 lbs). The “B2” was employed to lift rock anchors and rootwads while the “BA” was used for reconnaissance and smaller lifting duties.

Self-loading logging trucks delivered LWD pieces and rootwads to sites along roads where they could be reloaded onto dump trucks or helicopters and delivered to the work sites. On-site material was used whenever possible and as a result logging truck use was kept to a minimum. Flow diversion around or away from the work site or work during extreme low flow period was practiced whenever possible to control the silt produced by instream work. In particular LU7SD1 employed a 100 m long 700 mm corrugated metal pipe (cmp) to divert flow around the excavation site. Silt fences, hay bales, gravel bermed settling ponds and pumps were utilized when diversion was not possible. Fry were removed by electrofisher and blocked from re-entering all channel excavation sites using exclusion netting.

A mini-skyline was used in 1997 by the labour crews to winch LWD pieces out of the channel or to other locations in the channel. It was found to be slow and lacked enough power to successfully pull larger LWD pieces out of LWD jams. The skyline was not used in 1998.

Hand tools includes all the tools used by the labour crews to secure LWD, move LWD, attach boulders, and replant damaged areas. Chainsaws, chainsaw winches, chainsaw drills, Hilti rotary hammer, geotextile, "belly-grinder" seed applicators, sledge hammers, ratchets and sockets, cable, cable clamps, knobs and wedges, staples, rebar, nailing strips, and nails were all used.

In 1997 the Nimpkish restoration project, which includes the Lukwa Creek project, employed 3 labour crews of 5 members in addition to a field coordinator.

In 1998 the project employed 2 crews of 4 members and a field coordinator.

Cost Summary

The costs incurred in the 1997 and 1998 Lukwa Creek Level 3 (construction) project only are summarized below. It does not include assessment and prescription costs.

Crew labour (including assessments)	$ 285,415
Consultants (fees and expenses)	$ 54,459
Heavy duty equipment (backhoes and gravel trucks)	$ 70,131
Helicopter	$ 25,987
Other costs	$ 78,975
Total	$ 514,967

Production Estimates

The project created or added: 2800 m^2 of stable channel, 7 LWD jams, 111 m of rootwad crib, 145 m of rip-rap bank, 50 LWD pieces, 12 rootwads, 26 LWD spurs, 38 LWD steps, 8 boulder clusters, access into 42,900 m^2 of off-channel area and hand cleaned 240 m^2 of debris choked channel.

The anticipated improvements to substrate could increase viable spawning capacity by up to 250 pairs of adult coho.

Fry density in off-channel areas can range from up to 6 fish$\cdot$m^{-2} (H. Mundy, pers. comm.) to 0.65 fish$\cdot$m^{-2} and 1.83 fish$\cdot$m^{-2} as found in mainstem pools (Shawn Hamilton and Associates 1996a). Using a conservative factor of 1.5 fish$\cdot$m^{-2} it is estimated that the off-channel areas created will provide rearing for up to 64,350 (1.5 x 42,900 m^2) juvenile coho and resident trout. An additional 2600 m^2 marsh in LU4OC1 dried in the summer of 1998 and despite creating access to it in 1997 this marsh was not included in the above production estimate. Further work in 1999 will attempt to determine the source area for this marsh and determine where, if any, flow diversion out of the basin is occurring.

Scour pools created by mainstem structures will also increase stable rearing areas although total production benefits cannot be quantified without final pool area measurements. These pool measurements will be made during monitoring surveys and we suggest using a conservative multiplication factor of 0.65 fish$\cdot$m^{-2} to calculate the production benefits.

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Spirit Creek and Montague Creek Habitat Complexing

Objectives
In old-growth forests abundant LWD is responsible for stream structure including development of pools, storage of sediments and hydraulic "tailouts" of gravel (Cederholm et al. 1997). Harvesting of trees to the banks of Spirit and Montague Creeks has resulted in a reduction of LWD within the channel and associated loss of channel complexity. The focus of restoration has been on increasing habitat complexity in the main channel of Spirit and Montague Creeks through the introduction of LWD and boulders.

FRBC Region/MELP Region/MOF Region
Pacific / Vancouver Island / Vancouver

Author
Dave Duff

Proponent
Steelhead Society Habitat Restoration Corporation (SSHRC).

Watershed
Salmon and Eve Rivers.

Location
Spirit Creek is a tributary of Big Tree Creek which in turn flows into the Salmon River. Montague Creek is a tributary of the Eve River. Both the Salmon and the Eve Rivers flow into Johnstone Strait. The Spirit Creek site is located on Spirit Creek for 1.2 km downstream and 2.4 km upstream of the bridge on the Big Tree mainline road. The Montague Creek project is located on Montague Creek for 0.4 km downstream of the bridge on the Eve River mainline road.

Introduction
Both the Salmon and the Eve Rivers have historically supported eight species of salmonids including chinook, coho, pink, chum, sockeye, rainbow trout/steelhead, cutthroat trout and Dolly Varden char. Escapement numbers have steadily declined for most species since the 1960's.

The Salmon and the Eve watersheds have been subjected to heavy logging pressure. Much of the fish habitat has been impacted through these activities. The major impacts include loss of riparian function, bank instability, widening of the channel, aggradation and degradation of the channel and loss of habitat complexity.

The Steelhead Society Habitat Restoration Corporation initiated restoration on Spirit Creek and Montague Creek during 1996 and 1997, respectively. Restoration of these two creeks continued during 1998/99.

Assessments and Prescriptions
In Spirit Creek, fish habitat assessments in 1995 by Raven River Habitat Services showed a lack of LWD and pools within the channel. During 1996 and 1997, LWD was added to 43 sites in the lower 3.7 km of Spirit Creek. Post-construction field visits to Spirit Creek revealed that further benefits could be attained by adding additional LWD sites and modifying existing sites. Twenty-six sites were selected for addition of LWD and/or modification during 1998.

In Montague Creek, the Summit (1997) prescription reported little hydraulic diversity due to a lack of LWD and boulders. During 1997 LWD was added to 5 sites and boulders added to 3 sites in the lower 0.3 km of Montague Creek. Post-construction field visits to Montague Creek revealed that adding additional boulders to the creek and modifying some of the LWD placements could attain further benefits. Three sites were selected for addition of boulders and modification of 4 LWD structures during 1998.

Karl Wilson (SSHRC) and Allan Thompson developed prescriptions for both projects. Water Management prior to the commencement of work granted Section 9 (B.C. Water Act) approvals.

Rehabilitation Work
Construction was undertaken on the project between August 24 and September 10, 1998. Some additional cabling and small adjustments to the structures were made on October 30 and December 11, 1998.

Prior to construction in Spirit Creek LWD was identified for project use. The source of LWD was isolated pieces of wood, with no biological or physical function, from gravel bars on the Salmon River near the confluence of the

Memekay River. LWD used was coniferous species mostly with the rootwad still attached. Each piece of LWD was marked with an orange spray painted dot for easy identification from the air by the helicopter pilots.

Boulders for the project came from a nearby quarry near the Memekay River. Boulders were then trucked to a staging area in an old gravel pit adjacent to Spirit Creek. Cable tags with choker knobs were installed using the Hilti epoxy method (Melville 1997). This allowed the helicopter to lift two boulders at a time using their choker hooks.

Each site had alders (*Alnus rubra*) removed that may have interfered with the wood placement. The site was then flagged and marked using sheets of house wrap with the site number painted on it for easy identification from the air. The helicopter pilots were given a diagram of each site to help in LWD placement.

Material was placed in the creek by use of a Sikorsky 61 helicopter (Fig. 1-35). LWD and boulders were then repositioned according to the design prescription (SSHRC 1998) by a ground crew using a chainsaw winch. LWD was cabled to live trees on the bank and to the boulders. Some sites were modified in the field due to differences in wood size at the site compared to the wood in the design plan, ease of installation, or to achieve a different physical and biological effect as determined appropriate by the project biologist. Eighty-four pieces of LWD along with 26 boulders for ballast were added to 19 sites (Figs. 1-36 to 1-40). Another 5 sites were modified.

Boulders added to Montague Creek had been transported to the site during 1997 restoration.

Boulder placement and LWD repositioning was done using a track excavator. Some sites were added and modified in the field to achieve a different physical and biological effect as determined appropriate by the project biologist. Four LWD structures were modified and 35 boulders were added to 3 sites.

Equipment and Labour

For Spirit Creek equipment and time included: Sikorsky 61 helicopter for 12 hours, Jet Ranger helicopter for 4 hours, chainsaw winch, chainsaw drill, cutoff saw, rotary hammer drill and generator, and Hilti HIT-MD2000 kit with HYISO epoxy. One hundred days of employment were created.

For Montague Creek equipment and time included: Hitachi 200 EX excavator for 4 hours. Four days of employment were created.

Cost Summary

Labour	$ 34,300
Equipment, rentals, materials, misc.	$ 83,700
Total	$118,000

Restoration Results

Fish sampling using minnow traps was conducted during February and March of 1998 for Spirit Creek LWD structures installed in 1997. Juvenile coho and Dolly Varden were found to be utilizing the LWD structures at the time of sampling.

Since construction adult and juvenile salmonids have been seen using the LWD structures. Juvenile sampling will be conducted during February and March of 1999. All structures appear to stable and functioning as designed.

Proposed Works

The following works are planned for the 1999/2000 fiscal year:

- Level 1 and 2 monitoring of sites installed form 1996 to 1998.
- Riparian restoration based on a riparian assessment currently being conducted by the Ministry of Environment, Lands and Parks.
- Possible addition of LWD structures on untreated areas of Spirit Creek.
- Development of off-channel habitat in other areas of the Salmon and Eve Rivers.

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Figure 1-35. Helicopter placing LWD into Spirit Creek.

Figure 1-36. Site 20, upper Spirit Creek prior to LWD placement.

Figure 1-37. Site 20, upper Spirit Creek after LWD placement.

Figure 1-38. Site 6, lower Spirit Creek after LWD placement.

Figure 1-39. Site 8, lower Spirit Creek after LWD placement.

Figure 1-40. Site 13A, upper Spirit Creek after LWD placement.

San Juan River Restoration Project

Objectives

- To restore side channel habitat at the historic Tremblay Creek site.
- To provide cover for coho in Crompton Slough, through the placement of spruce sapling bundles.
- To prepare for 1999 instream activities through the placement of construction materials adjacent to the stream, at respective priority locations.
- To complete Level 1 and Level 2 assessments and conduct routine and effectiveness monitoring of 1997 stream restoration works.

FRBC Region / MELP Region / MOF Region
Pacific / Vancouver Island / Vancouver

Authors
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Proponent
TFL Forest Ltd.

Partners
Pacheedaht Band, Sooke Renfrew Forestry Society, San Juan Enhancement Society, Cowichan Lake Forest Coop, Renfrew Community Association and IWA.

Watershed
San Juan River

Location
The San Juan River drainage is located on the southwest side of Vancouver Island, approximately 60 km west of Victoria.

Introduction
The San Juan River drainage is one of the larger systems on Vancouver Island. It supports a variety of important fish stocks and wildlife. The San Juan River is known for its high production of salmon for the commercial fishery, and for its sport fishing opportunities.

For many decades, the San Juan River watershed has undergone intensive forest harvesting. Earliest logging probably started before the turn of the century and centered initially around the lower delta. By the mid-1990's, large areas of many of its sub-basins had been logged and were in various stages of regeneration.

Assessments and Prescriptions
Instream assessments in the San Juan indicated that the watershed suffers from classic impacts of logging. These range from loss in habitat complexity to widening and infilling of stream channels. These impacts affect all species of salmonids in one way or another throughout their freshwater lifestages. Assessment summaries for sites which had construction completed in 1998 are as follows:

<u>Tremblay Creek</u>
Historic road and bridge building activities saw the bottom 250 m of Tremblay Creek diverted through a 50 m long man-made channel and connected back to Harris Creek further upstream. During large flood events, Harris Creek rises and flows up the 50 m long man-made section of Tremblay. The combined flow from Tremblay and Harris then flows through the original 250 m cut off reach and back into Harris. Fine sediments have been settling and filling the isolated reach. Prescriptions developed were focused at improving the side channel's hydraulic depth, fish access and habitat complexity.

<u>Crompton Slough</u>
The slough was assessed in October of 1998 for the presence of overwintering coho fry. Despite habitat conditions generally appearing to be favorable, no coho were found. Placement of cover to improve habitat was recommended.

<u>Assessments</u>
Level 2 assessments were carried out in Pixie Creek, sections of Hemmingsen Creek and Harris Creek. A Level 1 assessment was carried out on side channels located on the south side of the San Juan, about 8 km up the mainstem.

Rehabilitation Works
Due to administrative conflicts between the implementing partners and delivery corporations, much of the planned instream construction activities could not proceed this year. An emphasis was placed on completing activities

which were not implicated by the administrative setbacks. These activities are as follows:

Tremblay Creek

The work done in this project focused on increasing water depth, lowering the control invert into the isolated reach so that fish would have better access and increasing habitat complexity by adding some woody debris. The outlet of this channel was also stabilized to prevent further erosion of the channel bed.

A Samsung 130 track excavator was used to side-cast about 600m^3 of fine sediments from the side channel area of Tremblay Creek. This project deepened existing ponds and removed several high spots where sediment had settled. Material from the inlet area to the ponds was removed to facilitate better seasonal salmonid access. Rip-rap armoring (0.45 m minus) was used in the intake area to prevent erosion. A natural flood overflow outlet at the end of the ponds was also armored.

About 20 stumps (LWD) were placed in the channel. Some cabling was used to ensure that the stumps did not float away during floods. Duck-bill anchors were used to hold the stumps in place. All of the disturbed banks were planted with a bank stabilization seed mixture immediately following construction. Approximately 100 pieces of LWD still has to be added to the side channel.

Crompton Slough

Spruce saplings were bundled together and placed in the Crompton slough backwater area to provide cover. Three bundles in total were made. Bundles were constructed by using a cable to harness together five to six 25 foot long trees. Tree limbs were kept intact. Rock anchors were attached at both the ends of the bundles to provide ballast.

Preparation for 1999 Activities

Rootwads, logs, and boulders were placed adjacent to streams in preparation for 1999 construction activities. These complexing materials were placed at the following locations:

- Tremblay Creek;
- Halliday Creek;
- Mosquito Creek; and
- Four Mile Creek.

Monitoring

Effectiveness monitoring was conducted by Babakaiff and Henalt, in the winter of 1998, on the three main instream locations restored in 1997 through WRP. Both biological and geomorphic parameters were monitored and results were given a 1 to 4 class ranking. Class descriptions are as follows:

- Class 4: fully meeting or exceeding effectiveness standards.
- Class 3: adequately meeting effectiveness standards.
- Class 2: poorly meeting effectiveness standards.
- Class 1: is defined as not meeting effectiveness standards.

The draft report summary of the mean biological and geomorphic effectiveness ranking for the study reaches are detailed in the following table (Babakaiff et al. 1999).

Project	Reach/ Project Type	Mean Effectiveness Rating	
		Biological	Geomorphic
Halliday	1/ Riffle Pool	1.7	4.0
Five Mile	2 / LWD	4.0	2.8
Renfrew	5 / LWD	3.3	3.0

Overall, results are quite positive. The report stated that over time, fish production should see further increases, as a result of natural improvements to habitat conditions (i.e., as residual pool depth increases with scour, and as LWD structures catch more woody debris).

At Halliday Creek, the report concluded that low fish densities within the pool habitat may be the result of lack of LWD cover and fish may require more time for access. LWD and spawning gravel placement is scheduled as a phase 2 activity, planned for the 1999 work window.

At Five Mile Creek, all structures tested were given a class 4 biological ranking. Although the geomorphic ranking was not as high, the reach was said to provide good LWD cover and a good ratio of pools to riffles. This creek had the highest catch per unit effort of the Vancouver Island watersheds monitored. Coho salmon accounted for 214 (96%) of the 223 fish sampled.

Renfrew Creek was reported to contain good LWD cover in the scour pools throughout, and good natural accumulations of LWD were evident.

Cost Summary

Labour (estimate)	$ 40,000
Materials and equipment (estimate)	$ 38,000
Total	$ 78,000

Production Estimates

In total, approximately 1250 m^2 of coho rearing area was created (250 m length). Estimated production is 1250 coho smolts (i.e., 1 smolt per m^2). See Figures 1-41 and 1-42 for before and after representations of the site.

Proposed Work

The following identifies works proposed for 1999:

- George's channel - improve habitat and complex.
- Green Heron- dig overwintering channel and complex.
- Tremblay, Halliday, Mosquito- complex with assembled materials.
- 4-Mile- construct new overwintering channel and complex.
- Fertilizer placement- place fertilizer in stream.
- Continue with assessments and prescription development.

Figure 1-41. Before excavation, the side channel was over grown and filled with sediment.

Figure 1-42. After construction, the wetted area of the side channel was greatly increased. Additional LWD still has to be added.

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The Sarita River Watershed: Groundwater Channel and Large Woody Debris Placement

Objectives
The objectives of this project were to:
- Construct a groundwater-fed, side channel to provide off-channel rearing habitat for juvenile salmonids.
- Construct LWD structures, in four separate pools designed to promote scour and slow sediment infilling in the pools.
- Provide protective cover for holding adults and juveniles.

Although these works were built, primarily, to enhance chinook, coho and steelhead stocks, all salmonid species are expected to derive benefits especially, during periods of low flow.

FRBC Region / MELP Region / MOF Region
Pacific / Vancouver Island / Vancouver

Author
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Proponents
The Huu-ay-aht First Nation and MacMillan Bloedel Limited.

Watershed
Sarita River

Location
The Sarita River enters Numukamis Bay in Barkley Sound (on the central west coast of Vancouver Island), approximately 12 km northeast of Bamfield. Its drainage area is 190 km^2. The basin is comprised primarily of provincial Crown lands, with scattered, small areas of private parcels and Indian Reserves.

Introduction
Historically, the Sarita River watershed supported a diverse salmonid population: chum, coho, chinook, sockeye, and pink salmon; steelhead, rainbow and cutthroat trout; and Dolly Varden char. Forest development, beginning in the 1920's, has impacted stream and riparian areas throughout the watershed, resulting in channel widening, channel and bank instability, pool infilling, reduced surface flows, and loss of instream woody debris. The 1997 CWAP determined that 62% of the watershed had been logged.

Assessments and Prescriptions
The Level 1 Fish Habitat Assessment for this watershed concluded that chinook, coho and steelhead production was restricted by available rearing and holding habitat during low flow conditions, exacerbated by insufficient pool habitat and pool cover. To address this, the Level 1 and Level 2 assessments recommended the maintenance and expansion of deep pool habitat, with adequate instream and overstream cover, in the lower reaches of the Sarita and South Sarita Rivers. Such habitat elements are critical for chinook as holding areas for spawning adults, and as rearing areas for young-of-the-year fry migrating to salt water.

The assessments prescribed LWD placements in four pools and recommended designs to encourage scour thereby, maintaining the pools at their present depths (by discouraging sediment infilling) and possibly, enlarging the pools. Also, these structures would provide instream cover. In addition to the benefits to chinook, these elements would be expected to improve summer habitat conditions for coho and steelhead fry. Pools in reaches 3 and 4 were assigned the highest priorities for LWD placement.

The Level 1 assessment also noted that off-channel habitat for rearing and spawning was poor throughout the watershed and was inaccessible during low flow conditions. To address this, the development of a groundwater-fed, side channel was prescribed, using the alignment of a relic channel adjacent to Reach 20. Off-channel habitat was expected to provide spawning and juvenile rearing opportunities for coho.

Rehabilitation Work
All work sites during 1998 were located within close proximity to each other, enabling the construction crew to work on several structures 'simultaneously'. Construction began in early July, and ended in mid-September.

Works consisted of the following:
- Construction of a 150 m side channel in Reach 20, the South Sarita River (Fig. 1-43). Test pits were dug during the spring along a

relic channel, to determine whether there was a sufficient supply of groundwater to maintain flow during summer months. Groundwater was found at very shallow depths in the test pits, therefore excavation was discontinued before determining whether spawning gravel occurred at the proposed grade for the side channel. During excavation of the side channel, very little gravel was found at the final grade, and small amounts were found in a deep pool constructed at the end of the channel. A decision was made not to import gravel, because of the cost, and because the primary objective for the side channel was to provide off-channel rearing habitat. Some habitat complexity was created in the channel by adding LWD pieces and large rocks.

- Construction of four LWD structures. Each was designed and oriented differently to enable future comparison of effectiveness. At Site 7, in Reach 3 of the Sarita River, six large logs with roots attached, were individually placed (roughly parallel to each other) so that the roots extended into a large pool, and the 'cut' ends could be anchored to the bank (Fig. 1-44). Anchoring was accomplished by epoxying each log to a bedrock outcrop along this bank, and by cabling anchor rocks to the instream end and the nearshore end of each piece.
- At Site 8, in Reach 3, immediately downstream from the confluence of the Sarita and the South Sarita Rivers, 12 large logs some with roots attached, were cabled in a criss-cross fashion, to each other and to two large rootwads, to create a large crib (Fig. 1-45). This was anchored to the streambank and extended into a large pool, with additional anchoring provided by ballast rocks.
- At Site 9, a modified crib was constructed in Reach 3 of the Sarita River, immediately downstream from the Blenheim mainline bridge (Fig. 1-46). Four large logs with roots, and two logs without roots, were arranged and cabled into a loose crib structure to provide stability during high flows. The rooted ends were extended into the adjacent pool, where they could promote scour. The structure was anchored by cabling the logs to large ballast rocks on both the streambank and instream ends.
- At Site 13, in Reach 12 of the South Sarita River (immediately upstream of Reach 3 in the Sarita River), three triangular log structures were placed approximately 15 m apart, extending into a pool downstream from the Bamfield mainline bridge (Fig. 1-47). Each structure consisted of two logs, one with roots attached; and, was anchored to bedrock on shore, as well as with anchor rocks at the instream end.

A fabric weave, composed of willow material, was installed after construction, on access routes at all sites and on the side channel berm and banks, to control erosion. Revegetation was delayed until mid-autumn due to extremely dry conditions.

In 1999, the above structures will be evaluated to determine the need for further work, LWD structures will be constructed at other pool locations, and a riffle-pool sequence is planned for a 500 m section of Sabrina Creek. Using LWD to stabilize banks of the South Sarita River is also under consideration.

Cost Summary

Final costs for construction of the side channel and the four LWD structures have not been determined. The total approximate cost for all works was $110,000.

Production Estimates

Heavy salmonid fry use of constructed LWD structures was observed immediately following placement at Sites 7 and 8. Visual observations of fry and returning adults, plus the use of minnow traps, confirmed heavy use of pool areas adjacent to all four LWD structures during October and early November 1998. Heavy river flows during late November caused the structure at Site 9 to be lifted a short distance up the bank, further away from the pool. The structures at Site 13 capture large and small woody debris during every storm event, and initial visual observations suggest that they have caused increased scour and enlarged the adjacent pool.

High river levels backwatering into the side channel have dislodged most LWD pieces. This will be assessed during 1999, and the pieces will be repositioned, and augmented. Initial sampling with minnow traps has indicated limited fry use thus far, but the summer low flow period was thought to be more critical.

Monitoring and assessment of all structures will continue throughout the year, with special attention during summer low flow periods.

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Figure 1-43. Photograph showing the mouth of the side channel constructed at Site 12, Reach 20, South Sarita River. Photo was taken during high river flows. A willow weave was installed on the sides of the set-back dyke to control erosion.

Figure 1-44 . LWD structure at Site 7, Reach 3, Sarita River. Photo shows rooted ends extending into a deep pool.

Figure 1-45. LWD crib structure at Site 8, Reach 3, Sarita River. Photo taken at extreme low flows.

Figure 1-46. Modified crib structure at Site 9, Reach 3, Sarita River. Photo taken at extreme low flows.

Figure 1-47. Three LWD triangles at Site 13, Reach 20, South Sarita River. Photo taken at extreme low flows.

Taylor River Borrow Pit #2 Construction

Objectives
The primary objective of the project is to develop an existing borrow pit to increase the productive capacity of this off-channel habitat. In its present state the borrow pit has a good groundwater supply, but lacks depth and complexity for rearing habitat (Figs. 1-48 to 1-56).

FRBC Region / MELP Region / MOF Region
Pacific / Vancouver Island / Vancouver

Authors
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Proponents
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Hupacasath First Nation.

Watershed
Taylor Watershed

Location
The Taylor River basin is the headwater of the Sproat Lake watershed. The construction site is approximately 53.2 km west of Port Alberni. The site can be accessed by driving 11.2 km along the MacMillan Bloedel Taylor Mainline (505).

Introduction
The streams of the Taylor watershed have historically supported spawning and rearing areas for sockeye, coho, chinook, steelhead, and cutthroat trout. Utilization by chinook was confirmed in 1997 by the Department of Fisheries and Oceans. Sockeye and coho are numerically the most abundant species in the Taylor River watershed. Escapement data is very limited, the most detailed information on fish abundance and distribution of adult salmon was collected in 1997 and 1998. Escapement counts were limited to the lower 7.5 km in 1997 and the lower 12 km in 1998. Information on spawner distribution above 12 km is limited. There is little information available on juvenile fish distribution and habitat condition within the Taylor River watershed. Pollard and Lindsey (1977), provide the most detailed information on fish distribution and habitat condition. Although minor logging activities occurred just above the outlet at Sproat Lake between 1905 and 1911, the Taylor watershed has only really been subjected to logging activities since the 1960's, with the most extensive logging occurring during the 1970's (Horel 1996). The logging activities on the low-gradient alluvial reaches of the lower Taylor River during the 1970's have had the greatest impacts on mainstem and off-channel fish habitat. In addition to the impacts of logging, the Taylor watershed has suffered negative impacts from the construction of Highway 4 and recreation activities throughout the lower 7.5 km. These impacts include; failing or unstable stream banks, lost connections of tributaries to the mainstem, stream aggradation and degradation, and decreased stream complexity due to the loss of LWD recruitment into the system. Gravel bar stability has been impacted by heavy use of recreational vehicles utilizing these areas for campgrounds. The impacts to gravel bars have been impeded natural revegetation of bars, and discharge of gray water into the Taylor River and removal of LWD for firewood.

This project is co-funded by Fisheries Renewal BC and Forest Renewal BC.

Assessments and Prescriptions
The construction of logging roads during the 1970's created what are commonly referred to as "borrow pits" (an area from which gravel is removed to be used for road construction).

Borrow Pit #2, the largest in the watershed, was excavated in the mid-1970's. This pond was excavated down to the groundwater table. To drain water away from Borrow Pit #2 the outlet of the pit was connected to a groundwater stream that supported juvenile coho. Over time this area became fish habitat. In its present state the borrow pit has good groundwater supply, but lacks depth and complexity for rearing habitat. This site was recommended by Bill Pollard, MacMillan Bloedel, as a good enhancement opportunity to increase the productive capacity of this existing off-channel habitat. By enhancing this off-channel rearing habitat and other areas like it within the Taylor watershed, coho production throughout the watershed can be increased. After consultation with representatives of the Department of Fisheries and Oceans, Ministry of the Environment, Lands and Parks, Nuuchalnuth Tribal council, Hupacasath First Nation and MacMillan Bloedel a prescription was developed to increase the productive capacity of this off-channel habitat. The prescription was developed by M.C.Wright and Associates and the Department of Fisheries and Oceans, Resource Restoration Division during the summer of 1998.

Assessment of Borrow Pit #2 showed that the existing rearing habitat could be enhanced by lowering the bed elevation by an average of 1.5 m (range: <0.5 to max 2.0 m). During excavation 2 small islands and a peninsula will be created with some of the excavated materials. The islands and peninsula will increase the shore line margins which will provide extensive shallow areas where food production is high. The deep areas of the pond will provide refuge from predators. The pond will be complexed with LWD and large boulders to provide further cover for juvenile salmonids. On completion of construction, the areas that have been disturbed (the shoreline, both islands and the peninsula) will be revegetated with cottonwood whips (*Populus balsamifera spp. trichocarpa*), willow whips (*Salix spp.*), hemlock (*Tsuga heterophylla*), spruce (*Picea sitchensis*) and western red cedar (*Thuja plicata*) seedlings and seeded with West Coast Hemlock Mix and Fall Rye. Vegetation of the islands will eventually provide shade to the middle area of the pond. Enhancement of "Borrow Pit #2" will provide 0.24 ha of rearing habitat. Surveys prior to construction identified that there is low risk to this channel from mainstem flooding and shifting. An existing berm along the right bank of the borrow pit is sufficient to protect the pond from the Taylor River during flood events. Designs were approved through the Ministry of Environment, Lands and Parks and a Section 9 (B.C. Water Act) was filed.

Rehabilitation Work

Enhancement of Borrow Pit #2 was completed between September 17 - 23, 1998. As-built surveys (GPS and Rod and Level) were completed on September 24 and 28, 1998. The excavated pond has a mean depth of 0.97 m (range: 0.001 to 1.7 m). The completed pond will provide 0.20 ha of summer and overwinter rearing habitat. Revegetation of the area was done September 21-23 and November 2 1998. The area was revegetated with willow and cottonwood whips, conifers (cedar, hemlock and spruce seedlings) and seeded with West Coast Hemlock Mix and Fall Rye.

To provide better access to Borrow Pit #2, MacMillan Bloedel, Sproat Lake Division replaced the existing 800 mm pipe culvert at the downstream end of the pond with a wooden culvert (0.9 m high x 2.0 m wide).

Equipment and Labour

Construction during September 1998 included the following: 47.0 hours of an EX 200 excavator; 41 hours of dump trucks, and 45.5 days of employment for 7 people.

Cost Summary

Biological monitors and project labour	$ 9,415
Equipment, rentals, misc.	$ 13,405
Total	$ 22,820

Restoration Results

Fish access to the pond was restored September 25, 1998. During a snorkel survey of the pond on October 14, 1998 observers counted 150 coho fry in the pond. The majority of the coho were observed along the shoreline of the pond perimeter and the shoreline margins of the islands. Most of the fish were observed under LWD placed in the pond during construction. Approximately 20% of the fish were observed in offshore areas of the pond. Baited minnow traps were set to verify species of fish observed through visual observations. All fish (66) were identified as coho. The site was inspected on November 17, 1998 after a major storm event passed through the area. The pond was found to be as constructed. Minor amounts of small woody debris from the islands and pond perimeter shifted.

This project will provide 0.2 ha of rearing habitat. Based on biostandards set out in Circular No. 9, the estimated capacity of the pond with a density of 1.01 coho fry per m^2 will be 2424 coho fry. With a survival rate of 0.68 a total of 1648 coho smolts will be produced.

Proposed Work

The following activities are proposed for the borrow pit during the 1999/00 fiscal year:

- Monitor the physical and biological results of construction works. This will include conducting inspections of structural stability of the islands and complexing materials, surveying juvenile coho and cutthroat trout abundance.
- Develop prescriptions during the winter of 1999 for the upper and lower Taylor River. These will be initiated as funding allows.
- Evaluate the success of the planting and seeding during the fall of 1998. Plant and seed where it is necessary in the spring of 1999.

Figure 1-48. Pre-construction view of one of the groundwater sources at Borrow Pit #2, 1998.

Figure 1-49. Pre-construction view (looking downstream) of Borrow Pit #2, 1998.

Figure 1-50. Post-construction view (looking downstream) of Borrow Pit #2, 1998.

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Figure 1-51. Pre-construction view (looking upstream) of Borrow Pit #2, 1998.

Figure 1-52. Post-construction view (looking upstream) of Borrow Pit #2, 1998.

Figure 1-53. Construction of Island #2, Borrow Pit #2, 1998.

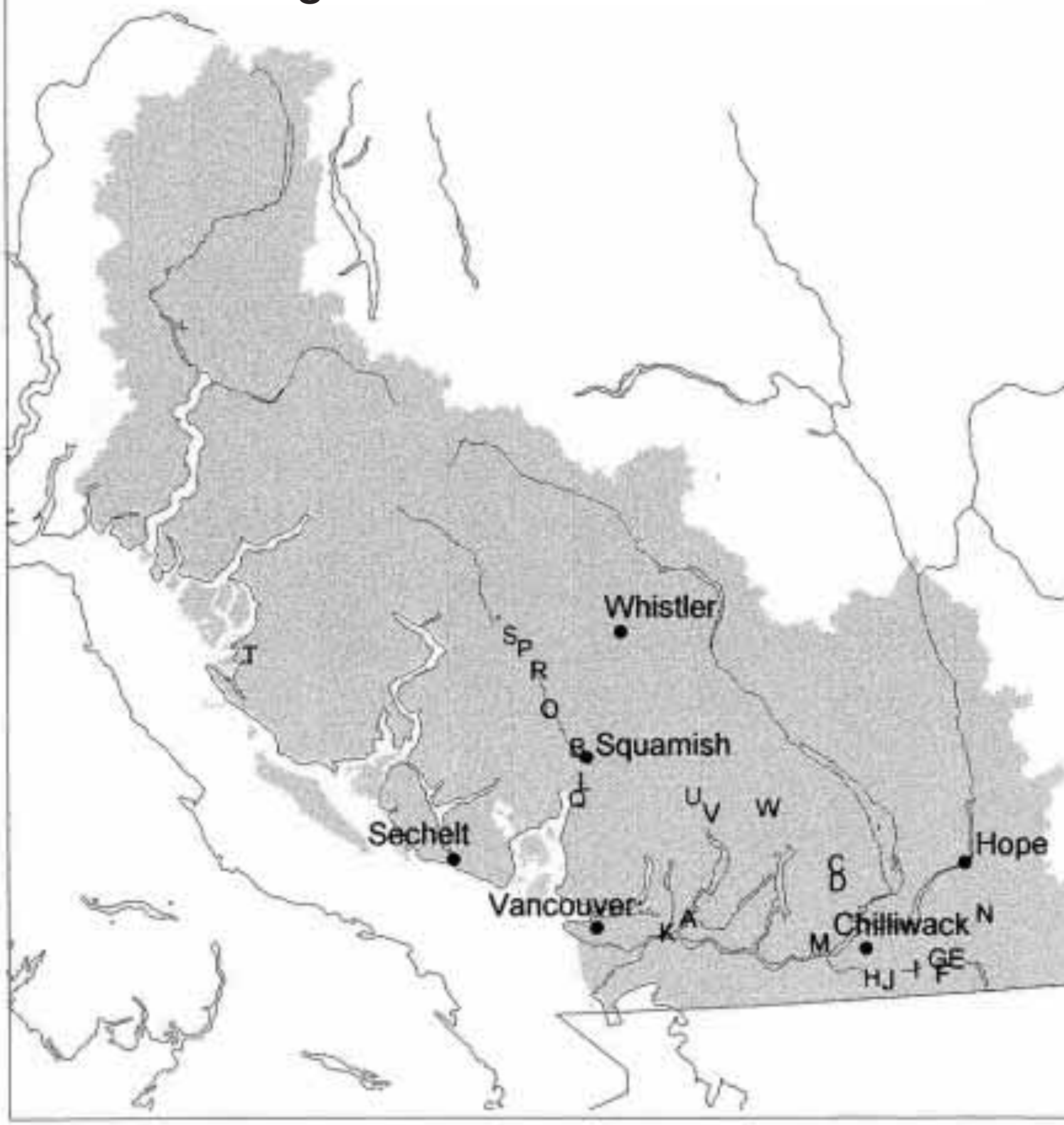
Figure 1-54. Construction of Borrow Pit #2, showing environmental protection measures, 1998.

Figure 1-55. Post-construction of Borrow Pit #2, showing complexing of Island #1 and peninsula, 1998.

Figure 1-56. Post-construction of Borrow Pit #2, showing complexing, 1998.

Lower Mainland Region

Region 2. Lower Mainland



WRP Projects

A South Alouette River
B Far Point Channel
C Chehalis Lake
D Statlu Creek
E Anglewing Creek
F Bulbeard Creek
G Foley Creek
H Little Tamihi Creek
I Slesse Creek (Bar/Ponds)
J Young Creek
K Coquitlam River
L Mamquam River (Ponds)
M Norrish Creek
N Yola Creek
O Ashlu Creek
P Shovelnose Creek
Q Squamish River Estuary
R 36 Mile Creek
S 28.5 Mile Creek
T Theodosia Creek
U Fish Hatchery Creek
V Homestead Creek
W Rocky Creek

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 2, Lower Mainland.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
A	**Lower Mainland**	Alouette River	South Alouette River	10	5456901	521242	100-026700-06000	00000LFRA
B		Cheakamus River	Far Point Channel	10	5514176	487148	900-097600-12900	00000SQAM
C		Chehalis River	Chehalis Lake	10	5472338	570290	110-090200	00197HARR
D		Chehalis River	Statlu Creek	10	5466500	570300	110-090200-29300	00000HARR
E		Chilliwack River	Angelwing Creek	10	5440155	599559	100-065700-09700-45800	00000CHWK
F		Chilliwack River	Bulbeard Creek	10	5438750	604500	100-065700-09700-52550	00000CHWK
G		Chilliwack River	Foley Creek	10	5440155	599559	100-065700-09700-45800	00000CHWK
H		Chilliwack River	Little Tamihi Creek	10	5436313	584076	100-065700-09700-24000	00000CHWK
I		Chilliwack River	Slesse Creek (Bar Stabilization and Ponds)	10	5436974	594273	100-065700-09700	00000CHWK
J		Chilliwack River	Young Creek	10	5436331	584579	100-065007-09700-24500	00000CHWK
K		Coquitlam River	Coquitlam River	10	5452610	514183	100-024500	00000LFRA
L		Mamquam River	Mamquam River (Ponds)	10	5508906	489307	900-097600-05100	00000SQAM
M		Norrish Creek	Norrish Creek	10	5447000	563000	100-064000	00000HARR
N		Silverhope River	Yola Creek	10	5454231	617619	100-112900-48200	00000FRCN
O		Squamish River	Ashlu Creek	10	5527287	478757	900-097600-38300	00000SQAM
P		Squamish River	Shovelnose Creek	10	5546254	475393	900-097600-63100	00000SQAM
Q		Squamish River	Squamish River Estuary	10	5505344	486794	900-097600	00000SQAM
R		Squamish River	36 Mile Creek	10	5548995	473750	900-097600-66800	00000SQAM
S		Squamish River	28.5 Mile Creek	10	5540029	475754	900-097600-54800	00000SQAM
T		Theodosia River	Theodosia River	10	5549289	381752	900-309400	00000TOBA
U		Upper Pitt River	Fish Hatchery Creek	10	5494858	526434	100-026700-54900	00000LFRA
V		Upper Pitt River	Homestead Creek	10	5495984	525436	100-026700-56400	00000LFRA
W		Upper Pitt River	Rocky Creek	10	5496410	524564	100-879800	00000LFRA

South Alouette River Forest Technology Project

Objectives
This project was designed to:
- test and refine operational techniques to transport and place materials instream using a skidder with a power winch and skyline as well as small portable hand winching equipment;
- compare the procedures and time components to more conventional methods being used on a large-scale restoration project at the Keogh River;
- maximize future potential of forest worker involvement with minimal large machine use, with minimal riparian disturbance; and
- provide stream rearing fish with increased habitat as well as holding habitat for adult salmon and steelhead.

FRBC Region/MELP Region/MOF Region
Pacific / Lower Mainland / Vancouver

Authors
Daiva Zaldokas and Geoff Clayton.

Proponent
Alouette River Management Society

Implementing Partners
Ministry of Environment, Lands and Parks, Habitat Conservation Trust Fund, Ministry of the Attorney General, Alouette River Correctional Centre and Stave Lake Correctional Centre.

Watershed
Alouette River

Location
The South Alouette River flows from Alouette Lake about 25 km to the Pitt River. This project was located between the BC Hydro dam (at the outlet of Alouette Lake) and the Alouette River Correctional Centre.

Introduction
The Alouette River historically supported all species of salmon but progressive human impacts to the river, including logging (1920's) resulted in significant declines in fish populations. Although logging was carried out 70-80 years ago, large wood is not yet significantly resupplied to the river, which has contributed to these declines. Streamflow is controlled by a dam and is maintained at a minimum flow release of 2.6 $m^3 \cdot s^{-1}$. In 1997, the Watershed Restoration Program (WRP) and then in 1998, the joint activities of the WRP and the Habitat Conservation Trust Fund (HCTF), funded the Alouette River Management Society to construct 48 instream large woody debris structures.

Assessments and Prescriptions
Visual assessments conducted at four sites in the upper reaches (5 km) of the river in 1997 indicated that:
- the channel was very stable;
- there were stable, relatively uniform pool/riffle sequences consisting of short riffles and long, shallow to deep pools;
- boulder and cobble substrates were dominant; and
- there was a severe lack of LWD (Metzger USFS 1997).

A Level 1 Fish Habitat Assessment, as detailed in Johnston and Slaney 1996, conducted in the upper reaches in 1997 confirmed the visual assessments.

It was prescribed that the project should focus primarily on improving coho rearing habitat because there was abundant, high quality steelhead trout habitat provided by existing boulders. Some of these boulders could be used to provide ballasting required for the LWD placed along pool margins, in backwaters, in slow moving areas in large, deep pools and in side channels.

Rehabilitation Work
Rootwads were salvaged from Stave Lake by volunteer labour from Stave Lake Correctional Centre. Two loads of logs (hemlock and fir) were purchased from Interfor Dryland Sort and a third load was donated by the Mission Tree Farm who was clearing for an access road. These rootwads and logs were trucked to a storage site near the South Alouette River for the construction of LWD/boulder complexes.

The Ministry of the Attorney General, Stave Lake Corrections was instrumental in providing heavy equipment, crew supervision and the inmate work force with forest work experience.

In 1997, safe operational techniques applicable to forest worker applications were used and refined. Eight structures were constructed in Reaches 1 and 2; 4 in a side channel of the river.

In 1998, forty structures were constructed at 6 sites along a 5 km section of river (4 reaches). A skidder was used to move the logs and rootwads from the storage site to the river sites (Fig. 2-1). Once access to a site was cleared, a heel block was rigged up in a tree next to the road, above the site. The heel block anchored the skyline used to transport the LWD and rootwads down to the site on the river. The cable was run through a block tied to a stout tree on the far bank of the river. Chokers were placed around each end of the log and fastened to a pulley on the skyline. The skidder pulled the mainline tight and gravity moved the logs and rootwads down the line to the river site (Fig. 2-2). A rope was rigged to act as a haulback line.

Turmaster grip hoists and peaveys were used to move the logs into their final positions with the butt ends on the bank and close to boulders for ballasting (Figs. 2-3 to 2-5). Fastening specifications for lateral triangular log jams, as outlined in Slaney et al. 1997 were utilized, with instream ballasting and bank attachments, similar to Millar 1997.

Alder and cedar tops and branches were added to the structures to provide additional habitat complexity and to begin trapping SOD because the reservoir prevents inputs of wood (Fig. 2-6). The structure types and number of each type constructed are detailed in the following table.

Structure Type	Number
Triangular	30
Single	7
Cluster	1
Oblique downstream	1
Double triangular	1
Debris catcher	1
Perpendicular dam	1
Dam	1
Single rootwad	4
Herringbone	1
Loose rootwads in beaver pond	22

Seventy-eight introduced and 12 local pieces of LWD, 267 rootwads, 54 short logs were used to construct these structures. One hundred and twelve boulders and 34 bank anchors were used for ballasting/anchoring.

Equipment and Materials

- 518 Cat Skidder with a 20-ton winch and a set of lift forks adapted to slide onto the skidder's blade.
- Turmaster Grip Hoist (T-13) 6000lbs (hor.).
- Turmaster Grip Hoist (T-35) 12,000 lbs (hor.).
- Nylon web slings 4", 4800 lbs TWS as a choker.
- Blocks - 1/2", 5/8".
- Shackles - 1/2", 5/8".
- Chokers with nob and bell.
- Cable slings.
- Wire rope – 1/2" galvanized.
- Ryobi 23cc gas driven hammer drill.
- Echo Gas drive wood auger 23 cc.
- Misc. materials (forged cable clamps, epoxy resin, cable cutter, drill bits, etc.).

Anchor Pull Tests

Several pull tests were performed by the UBC Department of Civil Engineering on cable-epoxy boulder anchors to determine their capacity when installed under and above water. These tests were performed using the winch on the skidder and recorded using a load cell mounted in-line between the winch and cable. The three anchors installed above water did not fail despite an applied load well in excess of the load cell capacity of 10,000 lbs (D'Aoust 1998). Five out of the fourteen underwater anchors failed when subjected to loads ranging from 2,500 to 11,000 lbs however, 2,500 lbs is sufficient for most applications (D'Aoust 1998). The application of a degreaser to the cables is an inexpensive procedure that can enhance the quality of the epoxy-metal bond. Doubling of cable clamps is recommended in an effort to reduce the variables affecting cable connection failures.

Cost Summary

1997

Project costs (logs, rootwads, hauling, machine time and labour)	$ 16,234
Equipment and supplies	$ 11,214
Project manager expenses	$ 978
Administration	$ 1,435
Total	$ 29,861

1998

Project costs (equipment rental, logs, rootwads, hauling, machine time and labour)	$ 8,779
Equipment and supplies	$ 7,523
Project manager expenses	$ 1,600
Administration	$ 4,966
Total	$ 22,868

The average amount of effort to construct each structure in 1998 was about 3.8 person days equaling a total of 171.5 person days of work (8 hours per day). Much of the labour was donated from the Ministry of the Attorney General, Stave Lake Correctional Centre.

Production Estimates

The structures developed 3440 m^2 of LWD habitat that was not previously available to juvenile fish. Based on biostandards (Koning and Keeley 1997), estimated annual production benefits from mainstem habitat complexing are 2030 coho and 110 steelhead smolts. Thus, annual abundance of adult coho and steelhead could potentially increase by 200 and 18, respectively.

Monitoring

Snorkel counts conducted in the upper and lower treatment reaches on September 24, 1998 are summarized in the following table. Observations during the snorkel survey in the upper treatment reaches indicated that spawning gravel was limiting. Proposed work for 1999 includes the addition of spawning gravel.

	Coho		Steelhead		Other Salmonids	
	#Fish	Fish/m	#Fish	Fish/m	#Fish	Fish/m
W/O LWD	555	0.12	572	0.12	129	0.03
W LWD	383	0.94	82	0.20	28	0.07

Note: W/O = without; W = with.
Assumes a total reach linear distance of 5 km; each structure assumed to be 8.5 m in length.

All structures inspected during and after a flushing flow release from the dam, or 10 times the base flow (i.e., 26 $m^3 \cdot s^{-1}$) performed well.

Further proposed monitoring of the Alouette River includes trapping chum and pink fry, coho and steelhead smolts using inclined plane traps, a rotary screw trap and mark-recapture methods in spring, 1999. Snorkel surveys will be conducted again in summer, 1999 to examine use of large wood structures by anadromous and resident fish.

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Figure 2-1. A skidder with fork adaptation was used for moving logs and rootwads from the storage site to the river sites. A 20-ton winch on the back end was the skyline donkey.

Figure 2-2. Live skyline rigging to swing logs and rootwads from road to the river site in Reach 4.

Figure 2-3. A deep pool in Reach 2 before bank stabilization and construction of LWD/boulder complexes.

Figure 2-4. A deep pool in Reach 2 after bank stabilization and construction of LWD/boulder complexes.

Figure 2-5. A LWD/boulder complex (triangular) in Reach 1, Structure #1-12.

Figure 2-6. A LWD/boulder complex loaded with alder and cedar tops and branches to increase complexity.

Far Point Habitat Complex

Objectives
To reconnect a large pond and side channel complex of the Cheakamus River opening up significant areas of use by salmonids.

FRBC Region/MELP Region/MOF Region
Pacific / Lower Mainland / Vancouver

Authors
Matt Foy and Harold Beardmore.

Proponent
Community Futures Development Corporation (CFDC) of the North Fraser.

Implementing Partner
Resource Restoration Division,
Fisheries and Oceans Canada.

Watershed
Cheakamus River

Location
This intake side channel complex is located across from the North Vancouver Outdoor School (NVOS). The intake is approximately 620 m upstream of Paradise Road Bridge (locally referred to as "BC Hydro Bridge"). Geodetic map 92 G/14 Cheakamus River.

Introduction
This project involved the installation of a river intake that will deliver water into a relic channel of the Cheakamus River. Bank protection dykes constructed in the 1960's isolated this part of the floodplain from direct river flows and thereby eliminated its use by salmonids. The intake reconnects a large pond and side channel complex to downstream fish habitat opening up significant areas for use by species such as coho and chum salmon, and steelhead and cutthroat trout.

Rehabilitation Work
Phase 1 construction of this project extended from August to November of 1996. Phase 2 commenced early in 1997 and was completed in October 1997. Phase 3 construction commenced on July 6, 1998 and was completed on October 25, 1998. The scope of the 1998 work included the following:

- Construction of a 420 m long spawning and rearing channel. The channel alignment followed an unused skidder road (Fig. 2-7). This habitat featured large woody debris, pools, spawning and insect-producing riffles, off-channel pools, and several different flow velocities.
- Two undercut banks were created: a small one 200 m north of Evans Lake Road built of rocks and a stump, and a deep one 100 m north of Evans Lake Road built of logs covered in filter fabric and planted soil (both on the east side of the channel).
- Twin 9 m 900 mm culverts were placed under the Evans Lake Road.
- Two ponds were excavated upstream and downstream of the Evans Lake Road crossing.
- Introduction of natural spawning gravel into three existing seasonal streams provides insect-producing riffles. Each riffle is approximately 5 m long and separated by 10 to 15 m of pooled stream. The riffles could also support spawning.
- A pond was excavated near the mouth of the NVOS Kisutch Refuge Channel. Excavated gravels from this pond were used for the stream sections in the Far Point project. The pond, fed by groundwater was connected to the upstream end of the Kisutch Refuge Channel and is approximately 200 m^2 in size. Large wood was placed in the pond to provide cover for juvenile salmonids.
- Discussion stations and a trail along 300 m of the channel were constructed in conjunction with the NVOS to provide study opportunities for users of the facility (Fig. 2-8). This trail will also be used to monitor salmonid populations and provide access for maintenance activities.

Equipment
To complete the work, the contractor - John Hunter Company Limited of Squamish - provided:

- Finning Caterpillar 225B LC tracked excavator.
- Finning Caterpillar 966C rubber-tire front end loader
- Kenworth dump trucks, Kenworth truck and demolition trailer, as required.

- Bobcat tracked excavator.

Squamish River Watershed Society provided an additional five-person labour crew for work in environmentally sensitive (protected) areas. This crew carried out much of the instream gravel and wood debris placement in the small seasonal streams (Fig. 2-9).

Cost Summary (1998)

WRP	$ 150,000
BC Hydro	$ 20,000
DFO (project design and management)	$ 20,000
Total	$ 190,000

Production Estimates

The 1998 works have provided an additional 2.0 km (6000 m^2) of restored stream habitats. An additional 1800 m^2 of pond habitat was created. Spawning habitat was estimated to be approximately 2000 m^2.

The 1996-1998 works have provided an additional 3500 m^2 of spawning habitat and 24,000 m^2 of rearing habitat. It is estimated that the Farpoint habitat complex will produce an additional 50,000 chum salmon fry, 12,000 coho smolts and 1000 trout smolts annually

Monitoring

Prior to restoration, the Farpoint habitat complex would receive flow from sidehill streams during rain events and cease flowing during dry periods. Both juvenile and adult salmonids would enter this habitat when available and would be stranded and die during dry periods. The provision of stable flows has provided a secure habitat for all life stages of salmonids. Juvenile coho salmon enumerated and marked during a winter habitat use study in nearby Upper Paradise channel were found to have migrated upstream into the Farpoint complex for overwintering. In 1996, 1997, 1998 adult chum and coho salmon have spawned throughout the habitat complex. Numbers of spawning salmon are expected to increase dramatically over the next few years. Monitoring of adult salmon is undertaken annually and an assessment of juvenile salmonid production is planned in the future.

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Figure 2-7. Logs placed in channel which followed an unused skidder road.

Figure 2-8. Stream complexing and interpretative trail.

Figure 2-9. CFCD crew placing finishing touches on culvert outlet (below photographer).

Chehalis Lake Outlet – Large Woody Debris Placement

Objectives
To complex the outlet of Chehalis Lake with large woody debris (LWD) in order to improve adult cover and juvenile rearing habitat for salmonids (i.e., coho, steelhead, rainbow, and cutthroat). This project complements a spawning gravel placement completed by WRP at the same site in 1996.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Authors
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Proponent
Ministry of Environment, Lands and Parks.

Watershed
Chehalis River

Location
This project is located on the south end of Chehalis Lake at the lake outlet.

Introduction
This project involved the installation of logs at the lake outlet using cabling techniques. Logs were drilled and attached to large boulders using cable and epoxy (Fig. 2-10). Spawning gravel had been placed at the site in 1996 and subsequently used by spawning coho and steelhead. However, the site contained very little cover and prior trapping indicated very little use by juvenile salmonids. The added LWD will improve habitat by providing cover, creating scour pools and collecting additional debris.

Assessments and Prescriptions
Overview and Level 1 fish habitat assessments in the Chehalis River watershed were completed in 1996 and 1997, respectively. Assessment results indicated an absence of cover adjacent to stable spawning areas and the lake outlet was identified as having the stable conditions required to address these deficiencies.

Rehabilitation Work
This project was constructed in early August of 1998 and took 5 days to complete. The scope of the work included the following:

- The excavator opened up an access road to the lake outlet.
- Canfor using a logging truck and a rock truck delivered logs and rootwads to the site.
- Fourty-five logs and 30 boulders were placed by the excavator in various configurations outlined by the Project Manager. This provided more fish cover, helped create more scour holes, and provided the opportunity for future LWD collection from the lake.
- Fine-tuning of the logs and boulders was done with a power saw winch.
- Five New Forest Opportunities workers drilled logs and boulders with a wood drill and a rock drill.
- Cable was secured to boulders using Hilti epoxy resin (Fig. 2-10).
- Washers and quick fix knots were attached to cable ends on logs to secure them.
- Where logs crossed, they were secured with cable using farmer's eyes and staples.
- Line ends were cut off and grout was placed on knob ends for extra security.
- Fifteen rootwads were placed in the log jams with the excavator to improve habitat (Fig. 2-11).
- The access road was partially deactivated leaving a trail to the lake outlet.

Equipment
- Hitachi 400 excavator supplied by Canfor, Harrison Division.
- Highway logging truck supplied by Canfor.
- Front end loader supplied by Canfor.
- Gravel truck supplied by Canfor.
- D8 Cat supplied by Canfor.
- Power saw winch.
- Wood drill.
- Rock drill.

Cost Summary

Labour / supervision	$ 7,270
Machinery	$ 9,913
Tools and materials	$ 4,841
Total	$ 22,024

Production Estimates
This project improved approximately 4000 m^2

of spawning and rearing habitat. According to biostandards we expect coho and steelhead production to be 229 and 20 adults, respectively.

Proposed Work

Structural stability, LWD collection, and juvenile fish use of the structures will be monitored annually. We will also evaluate the number of spawning adults on the placed gravel.

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Figure 2-10. Various techniques used to anchor LWD structures. Some slack was left in the cable to accommodate shifting in high flows.

Figure 2-11. One of the completed log jam structures.

Statlu Creek Off-channel Pond

Objectives
The primary objective of the project was to provide spawning, rearing and flood refuge habitat for wild coho salmon in a portion of the Chehalis River watershed lacking stable off-channel habitat. This included a section of channel habitat as well as a large pond. Secondarily, this project also provides stable habitat for steelhead, cutthroat and rainbow trout.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Authors
CEJ Mussel, Jack Mussel and Chris Picard.

Proponent
Ministry of Environment, Lands and Parks.

Watershed
Chehalis River

Location
This off-channel complex is located at 9.5 Mile on the Chehalis Forest Service Road from Harrison Mills. It is situated on the north side of the Statlu River just upstream from the Main Statlu Bridge.

Introduction
This project involved the installation of an instream intake in a small tributary of the Statlu River. This intake provides the water to a 480 m section of new channel, which supplies the water for a large off-channel pond. From this pond the water was emptied back into the Statlu River via a new culvert. Prior to this project, the slope of the tributary creek was 11% and salmon access was limited to 20 m of channel below the logging road. As well, there was very little spawning and rearing habitat in the creek. The new channel has an average slope of 3.1%, is accessible to all salmonids and provides habitat for spawning, rearing and refuge.

Assessments and Prescriptions
Overview and Level 1 fish habitat assessments in the Chehalis River watershed were completed in 1996 and 1997, respectively. Assessment results indicated a severe lack of off-channel rearing habitat and stable spawning habitat in the Statlu Creek sub-drainage.

Rehabilitation Work
This project was completed in November 1998 and took one month to build. The scope of the work included the following:

- Construction and installation of a new intake prototype designed by Rheal Finnigan, into a small tributary of the Statlu River in order to provide a constant flow of water to the project (Fig. 2-12). The intake was made out of laminated 2x4's and had a 2x6 deck and ramp. It is 22 ft long, 4 ft wide, and 4 ft high. The intake was designed to take all of the creek flow in the low periods and a maximum of 8 cfs in the high flow periods by letting the extra water overflow down the old channel. The intake is designed to be self maintained by flushing bedload through the collection pool thus preventing blockage of the intake.
- Approximately 31 m of 0.3 m diameter plastic pipe was installed from the intake to the top of the new channel in order to provide a constant flow of water to the channel and large pond. An elbow was fastened to the inlet end in order to connect to the bottom of the intake.
- Channel habitat (323 m x 1.5 m) including rearing and spawning areas was constructed. Natural spawning gravel, large logs and boulders were placed in the channel to give it stability. The boulders were delivered from the location of the new culvert crossing to the channel site with a rock truck. The gradient was carefully controlled to ensure fish access from the Statlu River to the upper limits of the new channel.
- A large pond was constructed by building a large earth and clay berm with excavated material (Fig. 2-13). The berm was compacted by the excavator as it ran over it during construction. It flooded out a large section of land to create a pond of 1750 m^2 with depth ranging from 0.3 m to >3 m. This was complexed with old stumps and trees found on site as well as 5-rocktruck loads of LWD donated by Canadian Forest Products from their dry land sort. An area along the pond

margin was downcut with a small dozer. This created a shoal with a water depth of 30 cm. The shoal's purpose was to create a region of elevated primary productivity to enhance overall pond production.
- The first overflow for the pond was built with the dozer at an elevation 50 cm above the pond outlet riffle. It empties extra water into another tributary of the Statlu River that has a 600 mm steel culvert under the logging road.
- An 18 m x 800 mm steel culvert was installed under the Statlu Creek Forest Service Road to accommodate the pond outlet channel (Fig. 2-14). The culvert was installed at 0% gradient and submerged to facilitate perennial fish access.
- Following construction, all disturbed soils were seeded with Coastal Revegetation Seed Mixture and covered with hay to decrease surface erosion into the project. New Forest Opportunities workers also planted several hundred willow whips, 50 Douglas-fir (*Pseudotsuga menziesii*) and 50 western red cedar seedlings.
- During moderate November floods, Statlu Creek back-flooded into the pond, putting stress on the overflow and berm. To address this issue, a second overflow was constructed and a throttle gate was attached to the outlet culvert. The second overflow is located on the south side of the pond and is connected to an existing remnant channel by a new 900 mm diameter culvert to pass flood waters back to Statlu Creek. The throttle gate prevents excessive back-watering into the pond while allowing perennial fish access.

Equipment
- Hitachi 400 excavator.
- Hitachi 200 excavator.
- Rock truck.
- John Deere 350 dozer.

Cost Summary

Labour/supervision	$ 12,320
Machinery	$ 31,817
Tools and materials	$ 7,873
Total	$ 52,010

Production Estimates
This project created approximately 2660 m^2 of pond habitat and 484 m^2 of channel habitat. We expect annual fish production to be 1600 coho smolts and 50 steelhead smolts. Approximately 10 adult coho were observed spawning in the new channel above the pond in December 1998.

Proposed Work
Smolt production from the pond will be evaluated annually. Intake and throttle gate function will be routinely monitored. An option is available to develop a second pond that would nearly double the pond habitat at this site. Whether the second phase proceeds is dependent on intake function and observed smolt production.

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Figure 2-12. Installed and functioning intake designed by Rheal Finnigan, P. Eng. Creek water is diverted through the opening behind the ramp to the head of the new channel via a buried pipe to the right of the intake.

Figure 2-13. Newly excavated pond prior to replanting. Pond depth ranges from >3 m along the berm to the left to 0.3 m to the right. Overflow is located where the person is standing on the berm.

Figure 2-14. New 18 m x 800 mm culvert installed under the Statlu Forest Service Road. Culvert was installed at 0% gradient and submerged to facilitate perennial fish access from Statlu Creek to the new habitat.

Angelwing Pond Complex

Objectives
The Angelwing pond project is one of a series of projects to create and restore productive off-channel spawning, rearing and overwintering habitats for salmonids (chum, coho, pink, chinook, cutthroat and steelhead) in the Chilliwack River watershed.

FRBC Region/MELP Region/MOF Region
Pacific / Lower Mainland / Vancouver

Authors
Matt Foy and Harold Beardmore.

Proponent
Community Futures Development Corporation of the North Fraser.

Implementing Partner
Resource Restoration Division,
Fisheries and Oceans Canada.

Watershed
Chilliwack River

Location
This project is located adjacent to the Chilliwack Lake Road crossing of the Chilliwack River approximately 1.0 km upstream from the confluence of Foley Creek.

Introduction
The Chilliwack River watershed (dry maritime Coastal Western Hemlock (CWHdm) ecosystem) has been extensively logged since the early twentieth century. Most, if not all wild populations of salmonids are presently below historical levels of abundance, for reasons including logging-related habitat changes and urban development.

Assessments and Prescriptions
Many of the side channels in the 15 km section of the Chilliwack River below Chilliwack Lake were formed and historically received flow as a result of large semi-permanent log jams which caused river diversions. Streamside logging eliminated most of the large wood recruitment that was necessary to maintain these jams. As a consequence, the river now flows in a single channel for much of this reach and many of its historic side channels now only receive flow during extreme flood events. The restoration of year-round flow to these abandoned channels is a major goal of off-channel restoration in this part of the Chilliwack River watershed.

Angelwing pond was an abandoned side channel of the Chilliwack River that continued to receive a modest base flow from groundwater sources. The upper reach of the side channel had been impounded by a beaver dam forming a large pond. The lower reach of the side channel was a year-round groundwater-fed stream that crossed the Chilliwack Lake Road through a culvert and via a road ditch adjacent to the Foley Creek Forest Service Road, entered the Chilliwack River. During road construction the lower reach of this stream had been redirected out of its natural course such that it discharged into the main river over a steep bank that prevented anadromous fish access into the side channel.

Works proposed for this site undertaken over a two year period are directed at restoring anadromous salmonid use of this habitat, increasing water flows and maximizing both rearing and spawning habitats in the side channel. In 1997, the first phase of the project made the pond accessible to anadromous fish for the first time since the Chilliwack Lake Road was constructed decades ago. The 1998 work involved increasing river flow into the pond, reconstructing lost spawning habitats and increasing and improving the rearing habitat in this cut off side channel of the Chilliwack River.

Rehabilitation Work
This year's works were constructed between July 27, and October 15 of 1998. The contractor, Skagit Construction, a subsidiary of Cattermole Timber, supplied a Caterpillar 330L excavator, a John Deere 350 bulldozer and Volvo, articulated four-wheel drive, dump trucks. The scope of the phase 1 work included:

- In the fall of 1997, a 200 m long, 2.0 foot diameter, concrete pipeline from the Chilliwack River to the upper end of the existing Angelwing side channel was installed. The actual river intake was constructed in

1998/1999 and provides 10-20 cfs of flow into the top end of the Angelwing pond and side channel (Fig. 2-15).
- The surface water elevation of Angelwing pond was not altered so it would continue to receive groundwater inflows. The combination of surface and sub-surface water supply will provide a stable and moderated flow to the downstream habitats.
- The 100 m long upper spawning channel provides secure spawning for species such as coho salmon and cutthroat trout which rely on the abundant rearing habitat found downstream in the Angelwing pond and side channel to sustain healthy populations of these two species.
- A fishway and beaver box was constructed at the outlet of Angelwing pond. This structure should deter beavers from building dams in the pond outlet streams. The structure also splits the flows from the pond into the north and south channels.
- The south channel is a low-gradient rearing area with abundant wood debris. At the lower end of this side channel a berm was constructed to create an overwintering pond. This pond was heavily complexed with wood debris. A spillway over the berm and an outlet spawning area complete the south channel. This area is designed primarily as rearing habitat for coho salmon and cutthroat trout.
- The majority of the flow from the Angelwing pond is directed into the northern channel which then splits into the Roadside Channel and the North Channel.
- The 500 m long Roadside Channel receives the greatest amount of flow and was constructed to provide a secure spawning area for species such as pink and chum salmon which require large amounts of spawning habitat to sustain their populations (Fig. 2-16).
- Steelhead trout are also expected to use the Roadside Channel habitat for spawning and rearing. The larger and swifter water flows in this section along with instream log and boulder cover should make this habitat attractive to this species.
- The North Channel is a small, heavily complexed habitat that will provide excellent conditions for all stream rearing salmonid species.
- A trail network was built adjacent to the various habitats in this project. Access was provided for the purpose of: monitoring salmonid populations, maintenance, technical tours and the benefit of the general public.
- The site was hand raked and seeded with an erosion grass seed mix and then overlain with hay on steep-sided banks to reduce erosion due to precipitation and to assist in grass seed germination.

Cost Summary

1998	
Construction (WRP)	$ 150,000
Supervision, design and labour (DFO)	$ 30,000
Total	$ 180,000
1997	
Construction (WRP)	$ 71,000
Supervision, design and labour (DFO)	$ 33,000
Total	$ 104,000
1997-1998	
Construction (WRP)	$ 221,000
Supervision, design and labour (DFO)	$ 63,000
Total	$ 284,000

Estimated Production

The 1997-1998 work has restored approximately 2.0 km of stream rearing habitat (13,000 m^2) and 15,000 m^2 of pond habitat (total rearing habitat 28,000 m^2) previously inaccessible to anadromous salmonids. Certain features such as pools with complex cover components, mid-stream boulder and log placements, and complex boulder and brush bank cover have been created in the connecting channel to improve its use by stream rearing salmonids. An additional 2000 m^2 of excellent spawning habitat was also created which is expected to provide major benefits for local salmonid populations.

Monitoring

A minnow trapping survey of the Angelwing side channel in the spring of 1997 indicated that resident cutthroat trout were the only species of fish using this habitat. It is likely that these fish had been isolated in this habitat since its connection to the river was made inaccessible to upstream migrating salmonids in the early 1900's. Monitoring of adult use was undertaken in the fall of 1997 and no adult salmon were observed in the side channel that fall. Juvenile coho pre-smolts were however observed in the side channel in the spring of 1998 post-construction. In the fall of 1998 several hundred chum and coho salmon moved into the new habitat and spawned in the Roadside and Upper spawning habitats. The numbers of these two species using the Angelwing habitat complex is expected to rise rapidly over the next few years. Steelhead spawners are expected to move into the project area in the spring of 1999.

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Figure 2-15. Riffle/pool entrance to Anglewing from the Chilliwack River.

Figure 2-16. Roadside channel spawning habitat.

Bulbeard Side Channel and Ponds

Objectives
The Bulbeard project is one of a series of projects designed to create and restore productive off-channel spawning and rearing habitat for salmonids (coho, chinook, chum, pink, cutthroat and steelhead) in the Chilliwack River watershed.

FRBC Region / MELP Region /MOF Region
Pacific / Lower Mainland / Vancouver

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Proponent
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Implementing Partner
Resource Restoration Division,
Fisheries and Oceans Canada.

Watershed
Chilliwack River

Location
This project is located on the south side of the upper Chilliwack River between Nesakwatch and Centre Creeks.

Introduction
The Chilliwack River watershed (dry maritime Coastal Western Hemlock (CWHdm) ecosystem) has been extensively logged since the early twentieth century. Most, if not all wild populations of salmonids are presently below historical levels of abundance, for reasons including logging-related habitat changes and urban development.

Assessments and Prescriptions
Many of the side channels in the 15 km section of the Chilliwack River below Chilliwack Lake were formed and historically received flow as a result of large semi-permanent log jams which caused river diversions. Streamside logging eliminated most of the large wood recruitment that was necessary to maintain these jams. As a consequence, the river now flows in a single channel for much of this reach and many of its historic side channels now only receive flow during extreme flood events. The restoration of year-round flow to these abandoned channels is a major goal of off-channel restoration in this part of the Chilliwack River. Bulbeard Creek is a small creek, which flows into the Chilliwack River on its south bank between the Centre and Nesakwatch Creeks confluences, approximately 7.0 km below Chilliwack Lake. Prior to 1996, Bulbeard Creek suffered from extremely low flows during the summer months, which greatly reduced the amount and quality of habitat available for use by salmonids at that time of the year. The Centennial Trail side channel (completed in 1996) lies immediately upstream from Bulbeard Creek and now provides a continuous water flow to Bulbeard Creek through a connecting channel constructed as part of the 1996 project. The 1997 Bulbeard restoration works involved constructing a stream channel from the lower most reach of Bulbeard Creek, which then discharges creek flow into an abandoned side channel of the Chilliwack River. This side channel was modified to increase its use to salmonids. The 1998 work was the last stage in this multi-year rehabilitation project that has restored and created a large off-channel habitat complex.

Rehabilitation Work
The project was constructed between July 27 and October 2 of 1998. The contractor, Skagit Construction, a subsidiary of Cattermole Timber, supplied a Caterpillar 325 excavator, a John Deere 350 bulldozer and Volvo, articulated four-wheel drive, dump trucks. The scope of the work included:

- Excavation of two connecting stream channels that directed water flow into two abandoned side channels.
- Excavation of three overwintering ponds adjacent to Centennial Trail channel. These ponds were complexed with both wood debris and boulders to provide cover for juvenile salmonids. The gravel excavated from these ponds was used to construct berms, which were used to impound two large ponds downstream.
- The construction of two gravel berms that re-established the wetted area of a series of abandoned beaver dams.

- Flooding old flood channels of the river created the beaver ponds (Fig. 2-17). The side channels were abandoned or cut off during construction of the logging road.
- Log jams were created at the outlet of the two ponds to reduce future beaver activity in the outlet streams.
- Outlet streams were constructed between the ponds that provide spawning and rearing habitat and a passage around the berms for migrating salmon adults and juveniles (Fig. 2-18).
- Spillways and bypass channels were constructed at strategic locations throughout the project to reduce damage to the restored off-channel habitats from flood flows from the main river.
- A trail network was constructed adjacent to the project, which provides access for: monitoring salmon populations, inspection for barriers and maintenance requirements, technical tours, and general public access.
- All exposed slopes were hand seeded and mulched with hay to prevent erosion and to speed revegetation.

Cost Summary (1998)

Construction (WRP)	$ 190,000
Supervision, design and labour (DFO)	$ 45,000
Total	$ 235,000

Production Estimates

This project has created approximately 35,000 m^2 of rearing pond habitat and has rehabilitated 1750 m of stream or 4000 m^2 of stream channel habitat. It is estimated that approximately 20,000 coho salmon smolts and 1500 trout smolts will be produced from the habitats created in 1998.

The Centennial/Bulbeard complex will collectively provide a large amount of critically important spawning and rearing habitat for salmonids using this part of the Chilliwack River watershed. Over this three year project (1996-1998) approximately 1.5 km (15,000 m^2) of high quality spawning habitat was constructed. A further 6.5 km of small stream habitat (30,000 m^2) was restored. Twelve off-channel ponds account for a further 75,000 m^2 of excellent rearing and overwintering habitat.

Monitoring

Since the first phase was constructed in 1996 significant numbers of adult salmon and trout have moved into the restored habitats for spawning. Peak annual spawner counts have approached 3000 pink, 1000 chum, 200 coho and 100 chinook salmon. In 1997, an estimated 60 steelhead spawners moved into the restored habitats. Salmonid production from this project has been equally impressive. In the spring of 1998, an estimated 40,000 coho smolts migrated from the Centennial/Bulbeard complex. Future monitoring programs will continue to investigate the use of these restored habitats by salmonids, both adult and juvenile. This project provides an excellent opportunity for long-term studies into issues related to stream restoration.

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Figure 2-17. Flooding old channels of the river created the beaver ponds.

Figure 2-18. Outlet streams were constructed between the ponds to provide spawning and rearing habitat.

Foley Creek Side Channel Fish Habitat Restoration

Objectives
To restore pool/riffle ratios, spawning habitat, boulder cover and large woody debris to a side channel of Foley Creek. Much of this habitat has been lost to riparian logging and logging road construction within the riparian zone.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Author
Bruce Usher.

Proponent
Community Futures Development Corporation (CFDC) of the North Fraser Region in partnership with DFO and MELP.

Watershed
Foley Creek within the Chilliwack River watershed.

Location
Foley Creek enters the Chilliwack River approximately 25 km upstream from Vedder Crossing near Chilliwack, B.C.

Introduction
The physiography of the Foley watershed lies within the Skagit Range of the Cascade Mountains. Elevations range from 350 m to 2357 m ASL. Side slopes are steep and the valley floor is narrow. Foley Creek is within the Coastal Western Hemlock moist submaritime biogeoclimatic zone (CWHms1).

This fourth-order stream (1:20,000) originates on Mt. Ling and joins the Chilliwack River 17 km below Chilliwack Lake. Ling Lake and Foley Lake form part of the mid- and upper reaches of the watershed and major tributaries are Williamson and Airplane Creeks.

Average annual precipitation is approximately 1536 mm below 450 m elevation. (Canadian Climate Normals 1960-1990). Precipitation above 450 m elevation would likely approach 2500 mm with most falling in the winter months (M. Younie, pers. comm.). Fifty-year return flood flows reach 127 $m^3 \cdot s^{-1}$.

Soils and bedrock types are diverse, bedrock ranging from plutonic to sedimentary and metamorphic rock. Soils within the watershed are composed of deposits of till, glaciofluvial and fluvial materials and colluvium. Matrix textures of the till can range from sandy to sandy silt. Colluvial material textures range from rubbly to blocky. Dissolved solids levels in the water are typical of the Chilliwack basin (B. Thomson, pers. comm.).

Fish species inhabiting the Foley watershed include steelhead, coho, chum and pink salmon. Resident rainbow trout, anadromous and resident char and mountain whitefish (*Prosopium williamsoni*) are also present.

Past logging practices have added to the decline in populations of the above species of fish. Thirty percent of the watershed has been logged with most timber removed prior to 1978. In the reaches beginning just above Foley lake and ending at the Chilliwack River, 100% of the mainline access road has been constructed within the riparian zone of Foley Creek.

Assessments and Prescriptions
Fish habitat diagnostics for Foley Creek (M.A. Whalen 1995) indicated poor LWD cover, poor spawning gravel, poor off-channel habitat, poor overstream cover and poor to good pool/riffle ratios in the lower reaches of Foley Creek below Foley lake. This project addresses habitat restoration in the reaches below Foley Lake. University of British Columbia Bio-resource engineering student Graham Hill provided an "in kind contribution" to the project by developing a "Fish Habitat Restoration Design for a Foley Creek Side Channel". Design prescriptions included LWD and boulder placements, spawning gravel pads, and a new pool/riffle ratio throughout the length of the 400 m long channel (Fig. 2-19). The design included a wood and boulder flow control structure at intake #1 that would cap the maximum flow into the channel at flood stage in Foley Creek (Fig. 2-20). The structure also permitted a minimum flow to the channel at low flow in Foley Creek. The design also prescribed restricting high flows at intake site #2 (30 m below intake #1). The success of maintaining these low technical intake designs

depends on channel stability and flow stability in Foley Creek.

Rehabilitation Work

The original channel intake was modified to permit a minimum flow of 0.3 $m^3 \cdot s^{-1}$ and a maximum flow rate of 3.0 $m^3 \cdot s^{-1}$ during a 50-year flood. A total of 9 pool/riffle sections were added. The pre-construction pool/riffle ratio was 1:7. The post-construction ratio was 1:1. Approximately 8 pools were created with depths ranging from 0.75 m to 1 m at low flow. Spawning gravel ranging in size from 12 mm to 90 mm was placed to a depth of 0.5 m at the tailout of pools (Fig. 2-21). Approximately 200 m^2 of spawning gravel was added throughout the channel. Approximately 75 pieces of LWD were anchored to boulder clusters consisting of 5 to 7 boulders at some sites and 1 boulder to 1 rootwad at others (Fig. 2-22).

Restoration Results

The addition of spawning habitat, instream cover, pools and riffles are expected to increase production of steelhead, coho, pink and chum salmon in the area. Live count estimates done November 1998 indicate the channel was used by 40 adult coho and 30 adult chum salmon. Using the rule of thumb for off-channel restoration works (adults X2, Koning and Keely 1997) approximately 80 coho and 60 chum salmon can be expected to be produced in the new channel. A live count of steelhead spawners will be done during April to May 1999. A single pass electrofishing survey (open) was done in the upper 200 m of the channel prior to construction. This survey should be repeated next September and survey results compared. Standard monitoring of structure stability will be done throughout the winter of 1998/99.

Equipment

Heavy equipment used for this project included a CAT 320L excavator, a D25D articulated truck and a tandem axle highway truck.

Cost Summary

<u>Supervision and Technical Support</u>	
Site supervision	$ 1,909
Construction crew supervision including hand tool rental	$ 1,170
DFO Engineering and technical support	$ 1,680
MELP Engineering and technical support	$ nil
CFDC-NF Admin. support	$ 1,300
Sub total	$ 6,059
<u>Equipment</u>	
Cat 320L excavator (including operator cost)	$ 8,160
D25D articulated truck (including operator cost)	$ 1,552
Tandem axle hwy. truck	$ 900
Sub total	$ 10,612
<u>Materials</u>	
Spawning mix	$ 600
Rebar pins	$ 194
Cable and misc. (estimate)	$ 2,000
Sub total	$ 2,794
Total NFOL	$ 611
Approximate Project Cost	$ 20,076

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Figure 2-19. New pool/riffle ratio add complexity to the channel.

Figure 2-20. LWD and boulders were used to “cap” maximum flows entering the channel.

Figure 2-21. Spawning gravel was placed at the outfall of pools.

Figure 2-22. Single rootwads were anchored to single boulders to increase complexity. This also shows homogenity of boulder riffle pattern prior to construction.

Little Tamihi Riffle-Pool Sequencing

Objectives
The objective of this project is to improve the instream hydraulics in the lower reach of Little Tamihi Creek by increasing the amount of stable pool and riffle habitat.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Author
Dan O'Donoghue.

Proponent
Steelhead Society Habitat Restoration Corporation (SSHRC).

Watershed
Chilliwack River, Little Tamihi Creek.

Location
Little Tamihi Creek is a small tributary that flows into the south side of the Chilliwack River 10 km above the Vedder Road crossing. The creek crosses the Tamihi-Liumchen Forest Service Road.

Introduction
Little Tamihi Creek rises on the southern slopes of Church Mountain. The total drainage area is 5.3 km^2, 85% of which has been previously logged (Whelan et al. 1996a). According to government records and local knowledge, coho and chum salmon use the lower reach of Little Tamihi Creek. An upstream migration barrier (~350m from confluence) limits anadromous fish from using the upper reaches of the creek.

Assessments and Prescriptions
Little Tamihi Creek was included in the Chilliwack Watershed Restoration Program. Initial biophysical planning and assessment (Whelan et al. 1995), stream inventory and a Level 1 Fish Habitat Assessment were conducted by Whelan and Associates Ltd. for the SSHRC. The fish habitat assessment identified 50% riffle, 17% pool and 33% glide habitats in the lower reach. Cover features (i.e., LWD, boulders, off-channel and over-hanging vegetation) in this reach rated poor to fair (Whelan et al. 1996a). The SSHRC designed the prescriptions for the project.

Rehabilitation Work
The restoration of Little Tamihi Creek occurred largely at the section below the Tamihi-Liumchen Forest Service Road bridge. This section of the creek appeared to have been channelized and severely lacked habitat diversity (Fig. 2-23).

Four riffles were constructed at a frequency of approximately 5 times the average bankfull width (5.6 m). The riffle structures were built with a 2:1 upstream slope and a 15:1 downstream slope. Rocks ranging in size from 0.06-0.5m in diameter were used. Pools were excavated into the streambed immediately upstream of each constructed riffle. The completed project has created approximately 60% riffle habitat and 40% pool habitat.

A debris jam and channel degradation near the confluence of Little Tamihi Creek and the Chilliwack River had created a 60-80cm outfall drop. The constructed riffle at this site will improve access to upstream reaches of the stream and prevent degradation of the channel bed.

Reconfiguring the stream profile into a stepped pattern has created more diverse hydraulic and habitat conditions (Fig. 2-24). It also provides more water depth during low flow periods. The constructed riffles will enhance pools, recruit gravel, re-aerate flows, and assist fish passage. The pools will provide holding cover for spawners and rearing habitat for juvenile and resident salmonids.

Cost Summary

Labour	$ 1,785
Equipment and materials	$14,703
Total	$16,488

Production Estimates
Biostandards for riffle-pool constructions are not well formulated. However, in a similarly sized watershed on the Sunshine Coast (Oulette Creek) riffle-pool construction increased pool habitat 4.5-fold. Fish biomass also increased 5.4-fold after restoration (Newbury et al. 1997).

Proposed Work
Little Tamihi Creek is the site of a potential off-channel project that is in the initial planning stages. The plan is to divert a portion of the surface water from Little Tamihi Creek and create an estimated 300 m channel.

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Figure 2-23. Pre-construction view of Little Tamihi Creek (upstream view, below bridge).

Figure 2-24. Post-construction view of Little Tamihi Creek (upstream view, below bridge).

Slesse Creek Bar Stabilization

Objectives
The primary objective of the project is to stabilize gravel bars and locally reduce the active channel width, which in turn will increase hydraulic diversity within two sections of Slesse Creek. This will be achieved by strategically placing log structures jam on instream gravel bars.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Author
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Proponent
Steelhead Society Habitat Restoration Corporation

Watershed
Chilliwack River Watershed, Slesse Creek.

Location
Slesse Creek is the largest tributary of the upper Chilliwack watershed. Its confluence with the Chilliwack River is approximately 10.5 km upstream of the Chilliwack-Vedder River crossing. The restoration sites are 3.5 km and 5 km upstream of the confluence.

Introduction
Slesse Creek is a fourth-order stream, with 12 km of its mainstem length within Canada. Its drainage area is approximately 166 km^2 (60% of which has been logged in the past). Anadromous fish use in Slesse Creek is concentrated in the lower 8 km of the stream, which is presently aggraded and unstable. Analysis of historical air photos reveals that sections of this lower reach have widened significantly during the last 50 years. Although the focus of restoration activity in recent years has been on the creation of off-channel habitat, a need to decrease active channel width and increase bar stabilization through revegetation has been identified. (Babakaiff and Associates Geoscience Inc. 1998).

Assessments and Prescriptions
Several Level 1 and 2 assessment procedures have been carried out in the Slesse Creek watershed. In 1996, Terrrasol performed a road, landslide and gully assessment, and Whelan and Associates carried out a fish habitat assessment. The prescriptions for the log structures were developed out of a channel assessment carried out in 1997 and 1998 (Babakaiff and Associates Geoscience Inc. 1998).

Rehabilitation Work
The design of the log structures were based on template log jams that naturally occur within Slesse Creek.

Site 1
The two objectives of the LWD structures at this site are:
- to reduce stream power within a flood channel that splits a bar (Fig. 2-25), and
- to increase the likelihood of natural "capture" of additional LWD for the bar head.

These log structures consist of five pieces of LWD (min. dia. 0.6 m, 7-9 m long and rootwads attached) placed near the head of a lateral bar. The structure included two pieces of LWD parallel to the bar edge, and three pieces of LWD placed upright in the lee of these logs (Fig. 2-26). The ends of the upright logs are partially buried such that the buried section exceeds 50% of the exposed mass. The horizontal and perpendicular LWD were appropriately ballasted with rocks. The jam spanned an area 16 m wide to fill a gap in between two existing jams.

Site 2
The objective of Site 2 is to decrease the likelihood of a stream avulsion into a left bank flood channel. This was achieved by constructing a LWD structure at the head of the flood channel. The constructed structure consists of 11 pieces of LWD (5 horizontal and 6 uprights) placed as a jam near the head of the flood channel. A four-piece mini jam extends downstream for approximately 10 m from an existing piece of LWD. Although the width of the jam is much larger in size (28 m), the design specifications are similar to Site 1.

Cost Summary

Machinery, materials	$ 16,752
Labour	$ 1,888
Total	$ 18,640

Production Estimates

The objectives of the log jam are not specifically targeted at one specific species or life stage but are intended to augment natural processes. The benefits that the LWD placement will produce will be a narrower channel with greater number of structural elements in it. The variability in depth and habitat will provide good habitat for all species of fish in the future.

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Figure 2-25. Bar to be stabilized by Site 1 log jam.

Figure 2-26. Construction of Site 1 log jam.

Sleese Creek Off-channel Ponds Complex

Objectives
The primary objective of the Slesse ponds project is to provide stable rearing and overwintering habitat for juvenile coho salmon and other stream rearing salmonids such as steelhead/rainbow and cutthroat trout. This was accomplished by excavating two groundwater-fed ponds and connecting them to an existing side channel of Slesse Creek.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Author
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Proponent
Steelhead Society Habitat Restoration Corporation

Watershed
Chilliwack River Watershed, Sleese Creek.

Location
Slesse Creek is a major tributary of the Chilliwack River. The confluence with the Chilliwack River is approximately 10.5 km upstream of the Chilliwack/Vedder River crossing. The project is situated where an unnamed tributary flows into the west bank of Slesse Creek, approximately 500 m upstream of its confluence with the Chilliwack River.

Introduction
Historic air photo analysis revealed that in the late 1940's or early 1950's, the entire watershed of the unnamed tributary was logged. The tributary is relatively steep, and consequently the creek torrented heavily after the logging occurred. This has resulted in a large fan of alluvial material being deposited where the creek meets the Slesse floodplain.

Local knowledge and site visits suggest that spawning salmonids heavily use the creek and surrounding groundwater channels. However, there is a deficiency of potential rearing habitat in Slesse Creek and surrounding groundwater channels. Therefore, a necessity for stable rearing habitat is present.

Assessments and Prescriptions
The site was chosen during a Channel Assessment in 1997 (Babakaiff and Associates Geoscience Inc. 1998). The report suggested the project site was a relatively stable area, with a small amount of groundwater flow from the alluvial fan. These factors (plus easy access to the site) provided an opportunity to create some off-channel ponds with a high likelihood of success.

Rehabilitation Work
We designed the site to have 2 connecting ponds because the slight step in the topography of the area would mean that a one pond design would require much more excavation to achieve sufficient water depths (Figs. 2-27, 2-28, 2-29). The step between the ponds allows for maximization of depth in each pond. Furthermore, the connecting channel between the two increases potential spawning areas. The surface area of our ponds (approximately 1500 m^2) corresponds with existing research which suggests that 1500 m^2 is close to the optimal pond size for coho production (Slaney and Foy 1998).

Excavation of the ponds occurred in isolation to the groundwater channel. The ponds were excavated to various depths, the majority of which are 1.5 m deep or more. A small island resulted in the upper pond because a massive, immovable stump was encountered during excavation. An overflow directly into Slesse Creek was placed just upstream of the outlet channel. The overflow is designed to overtop when water levels exceed those predicted for a 2-year flood. Most of the spoil material was sidecast onto the southeast banks of the ponds. The pond construction took longer than anticipated because the excavator was difficult to maneuver given the lack of good footing in the soft soil. All stockpiled woody debris was put back into the ponds.

Equipment
All work was completed with a Cat 320 B excavator.

Cost Summary

Machinery, materials	$ 17,784
Labour	$ 1,939
Total	$ 19,723

Production Estimates

The total pond area created within the complex is approximately 1500 m^2. Based on WRP biostandards (Koning and Keeley 1997) the estimated coho smolt production ranges from 750 to 1500. Estimated trout production ranges from 225 to 750. Furthermore, depending on groundwater flows, the pond may provide spawning habitat for coho and chum salmon.

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Figure 2-27. Construction of upper pond.

Figure 2-28. View of completed upper pond.

Figure 2-29. View of completed lower pond.

Young Creek Riffle-Pool Sequencing and Overwintering Ponds

Objectives
The primary objective of the Young Creek project is to improve instream hydraulics and provide off-channel rearing and overwintering habitat for resident and anadromous fish. This has been accomplished through the:

- reconfiguration of the channel profile into a riffle-pool sequence that best suits Young Creek's bankfull width; and
- creation of two overwintering ponds on either side of Young Creek.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Author
Dan O'Donoghue

Proponent
Steelhead Society Habitat Restoration Corporation

Watershed
Chilliwack watershed, Young Creek.

Location
Young creek flows into the north side of the Chilliwack River, approximately 10 km upstream of the Vedder crossing.

Introduction
Young Creek is a small (bankfull width 5.8 m), flashy tributary of the Chilliwack River that drains an area of 8.0 km^2. It is relatively steep (19% overall) with the majority of the creek having a cascade-pool morphology, well incised by steep banks. Two major roads, the Chilliwack Valley Road and Slesse Park Road cross Young Creek. Minnow trapping during the winter low flow of 1998 indicated fish presence (cutthroat and steelhead/rainbow trout) from the confluence at the Chilliwack River to at least 100 m above the Slesse Park Road. The lower 130 m of the creek has been channelized.

Assessments and Prescriptions
The Steelhead Society Habitat Restoration Corporation (SSHRC) performed a channel assessment of Young Creek, in March of 1998. During this time, the lower channelized section of the creek was identified as having two different areas suitable for restoration. At this time, the reach provided no overwintering or rearing habitat and consisted of one long riffle with an average slope of 4.2%. Furthermore, the culvert under the Chilliwack Valley Road was a potential barrier to fish at low flows (Fig. 2-30).

Rehabilitation Work
Construction involved the reconfiguration of the channel into a riffle-pool sequence, followed by the building of two off-channel ponds, one on either side of Young Creek.

<u>Reconfiguration of the Channel</u>
A total of five riffles were constructed along a 130 m reach. The riffles were strategically placed at a frequency of approximately 4.5 times the average bankfull width so as to take advantage of the existing stream profile. Pools were excavated in the streambed immediately upstream of each constructed riffle. The riffle immediately downstream of the culvert has been designed to ensure:

- an increase in the depth of flow in the culvert at low flows (by backwatering the culvert outlet), and
- a reduction of average water velocities within the culvert at high flows.

Additional cover was created during reconfiguration of the creek with the construction of an undercut bank immediately downstream of the culvert passing under the Chilliwack Valley Road (Fig. 2-31).

<u>Overwintering Ponds</u>
The overwintering ponds connect to Young Creek between the first and second riffle of five. This site was chosen because the stream is confined immediately upstream of this point and is therefore unlikely to change its course over time. Two ponds were excavated prior to their connection with the mainstem work. The ponds were excavated along the toe of a slope that runs perpendicular to Young Creek. During construction, spoil material from the ponds was sidecast creating two berms. In turn, the berms are designed to hold the water against the slope, thus creating the ponds. The surface area of the

ponds are approximately 2000 m^2. Once the ponds were excavated, LWD was added to provide cover in approximately 30% of the total area.

Equipment
The heavy machinery used during this project was a Hitachi 225B excavator. Grass seed was by spread by hand.

Cost Summary

Machinery and materials	$ 33,646
Labour	$ 2,228
Total	$ 35,874

Production Estimates
Reconfiguration of the stream profile into the stepped pattern has created more diverse hydraulic and habitat conditions. The constructed riffles enhance pools, recruit gravel and re-aerate flows. The pools provide depth during low flow periods, cover for spawners, and rearing habitat for juvenile and resident salmonids.

Biostandards for riffle-pool constructions are not well formulated, however, in a similarly sized watershed on the Sunshine Coast (Oulette Creek), comparable riffle-pool construction increased pool habitat 4.5-fold. Furthermore, in Oulette Creek, fish biomass has increased 5.4-fold since restoration (Newbury et al. 1997).

Based on WRP biostandards, the estimated coho smolt production from the Young Creek ponds ranges from 1000 to 2000 (0.5 to 1 $smolt \cdot m^{-2}$) (Koning and Keeley 1997). Backwatering the road culvert has increased the water depth in the culvert during low flows and reduced the flow velocity thereby improving access to upstream reaches of the stream for juveniles.

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Figure 2-30. Outlet of culvert on Young Creek before construction.

Figure 2-31. Construction of undercut bank at Young Creek.

Coquitlam River Large Woody Debris Placement

Objectives
To provide increased cover available to juvenile and adult salmonids, and to test a new debris-catcher design.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Author
Chris R. Picard and Matthew P. Foy.

Proponent
Community Futures Development Corporation of the North Fraser.

Watershed
Coquitlam River

Location
The lower portion of the Coquitlam River flows through the municipalities of Coquitlam and Port Coquitlam prior to flowing into Queens Reach of the Fraser River. The project was located in a forested reach upstream of the municipalities.

Introduction
The upper reaches of the Coquitlam River are dammed and the resulting reservoir provides water for a BC Hydro generating station and approximately 20% of the potable water for the Greater Vancouver Regional District. In addition to the dam and flow control, the Coquitlam River has been subjected to several other impacts including logging, road construction, channelization, dyking, instream and streamside aggregate mining, and urban development. The large woody debris project is one in a series of restoration projects that have occurred within the watershed which include chinook salmon re-introduction, wing deflectors in the lower river, off-channel habitat development and stabilizing sediment sources. Prior to dam construction, the river supported sockeye and chinook salmon runs. The river still supports runs of coho, chum, and steelhead. A remnant run of pink salmon exists in the lower river.

Assessments and Prescriptions
Although formal fish habitat assessments were not completed, it has long been realized that instream habitat complexity was severely deficient in the Coquitlam River (Fig. 2-32). To complement other habitat restoration works in the watershed (both past and current), a pilot LWD placement project was identified. Although large reaches of the river are devoid of LWD, we decided to implement a small-scale pilot project to increase the confidence and develop the support of agency and community stakeholders. We decided on five sites located in the upper reach of the river. We used several modifications of a basic lateral debris catcher designed by Rheal Finnigan.

Rehabilitation Work
Five debris catcher structures were constructed using the following steps (Figs. 2-33, and 2-34):

- Logs donated by BC Hydro and the Greater Vancouver Regional District were transported and deposited near the river with a self-loading truck.
- A team of 3 workers using a chainsaw winch (Fig. 2-35), cable, blocks and peaveys moved all logs into their final positions in the river.
- In this pilot project, we decided to anchor the structures using >2-times the ballast recommended. Therefore, a track excavator was used for two hours to place additional large boulders adjacent to the structures.
- Logs were anchored to boulders in the river and on the banks using cable and Hilti-brand epoxy.

Equipment

- Track excavator.
- Self-loading log truck.
- Chainsaw winch.

Cost Summary

Labour/supervision	$ 11,260
Professional services	$ 3,500
Machinery	$ 1,600
Tools and materials	$ 2,700
Total	$ 19,060

Production Estimates
Juvenile coho salmon abundance in the restored reach (at treated and control segments) was

estimated at approximately 11 fry per 100 m^2. Using the biostandards, we expect an approximately 2-fold increase in juvenile salmonid abundance.

Proposed Work

Structure stability and debris-catching ability will be monitored annually. Preliminary monitoring following moderate November and December 1998 flooding indicate debris accumulations (Figs. 2-36, and 2-37) with no shifting of the structures. Juvenile salmonid abundance will be monitored in treated and control segments.

A bioengineering prescription will be implemented in February 1999 on a lacustrine slide in Or Creek, tributary to the Coquitlam River. We are planning to place several additional LWD structures downstream of the pilot reach next summer.

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Figure 2-32. Typical view of the Coquitlam River indicating very little habitat and hydraulic diversity in the channel.

Figure 2-33. Site selected for LWD structure prior to placement.

Figure 2-34. Same site as Fig. 2-33 near completion of debris catcher.

Figure 2-35. Chainsaw winch used to move logs into position in the river.

Figure 2-36. Downstream view of three structures with debris accumulation.

Figure 2-37. Debris accumulated on one structure following a moderate November 1998 flood.

Mamquam Pond Restoration Project

Objectives
The Mamquam pond restoration project is one of a series of projects designed to create and restore productive off-channel spawning and rearing habitat for salmonids (coho, chum, cutthroat and steelhead) in the Mamquam River watershed.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Authors
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Proponent
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Implementing Partner
Resource Restoration Division,
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Watershed
Mamquam River

Location
This project is located on the west side of the Mamquam River near the city of Squamish.

Introduction
The Mamquam River watershed has been extensively logged since the mid-twentieth century. Most, if not all wild populations of salmonids are presently below historical levels of abundance, for reasons including logging-related habitat changes, hydro and domestic water diversion and major dyking along most of the stream reach accessible to anadromous salmonids.

Assessments and Prescriptions
Much of the upper watershed of the Mamquam River has been logged which has resulted in large volumes of sediment being transported from upstream reaches into anadromous salmonids habitats in the lower 6.0 km of the river. This has created extreme channel instability in the lower Mamquam River and has led to dramatic declines in salmon abundance over the last 50 years. Mamquam side channel is a groundwater-fed tributary to the Mamquam River which has provided stable rearing and spawning opportunities for chum, coho, cutthroat and steelhead since its construction by DFO in 1987. The 1998 WRP project was directed at increasing the use of this area as a rearing and overwintering habitat by the construction of an off-channel pond complex in its lower reach.

Rehabilitation Work
Construction occurred from July 6, 1998, to March 31, 1999. To complete the work, the contractor, John Hunter Company Limited of Squamish, provided a Finning Caterpillar 225B LC tracked excavator, a Finning Caterpillar 966C rubber-tire loader, and two Kenworth tandem-axle 26 ton dump trucks. Work on this site was scheduled with the Squamish estuary project so that activity would be continuous during such times as rainy weather and high tides affected work conditions at one site but not the other. The scope of work included:

- Clearing trees and brush from the site and stockpiling this material for later placement in the completed pond.
- Excavation of the pond site and removal of the spoil materials.
- Creation of a series of two ponds connected by a short spawning stream and an outlet spawning stream.
- Complexing the completed ponds with stockpiled wood materials and with rootwads and trees hauled to the site from local land clearing locations.

Cost Summary

Construction (WRP)	$ 25,000
Ministry of Transportation and Highways	$ 15,000
Design and supervision (DFO)	$ 5,000
Total	$ 45,000

Production Estimates
This project has created or rehabilitated approximately 2000 m^2 of rearing pond habitat and 20 m of stream or 100 m^2 of stream channel habitat. It is estimated that approximately 1000 coho salmon smolts and 25 trout smolts will be

produced from the 1998 restoration works. Trail construction adjacent to the site greatly improved access for WRP training workshops and the opportunity for public education on the importance of restoring small stream habitats for the benefit of our native salmonids.

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Norrish Creek Riparian Restoration

Objectives
The objectives are to minimize surface soil erosion, increase slope stability and reduce negative impacts to drinking water quality and fisheries' resources by initiating and improving riparian function.

FRBC Region / MELP Region /MOF Region
Pacific / Lower Mainland / Vancouver

Author
Michael Younie

Proponent
Canadian Forest Products Ltd. in partnership with MELP.

Watershed
Norrish Creek Community Watershed

Location
Norrish Creek drains into the lower Fraser Valley approximately 12 km east of the District of Mission.

Introduction
The entire Norrish Creek watershed is 117 km^2 in area while the community watershed portion is 78 km^2. The water supply system is operated by the Fraser Valley Regional District and serves approximately 80,000 people. Elevation ranges from 10 to 1380 m ASL and annual precipitation averages approximately 2500 mm. The bedrock geology consists of granitic rocks of the Coast Plutonic Complex. Multiple glaciations have resulted in smoothed ridges and peaks and, oversteepened valley side slopes. Surficial materials range from discontinuous veneers to blankets of coarse textured colluvium, till and glaciofluvial sediments.

Timber harvesting, within the watershed, began in the early part of this century with clearcutting of the mainstem riparian areas. While these areas were never replanted, they have regenerated into dense stands of coniferous trees. Harvesting of timber to the edge of the streams resulted in areas of streambank instability. The instability has resulted in loss of riparian function and produced significant sediment sources which continue to adversely impact drinking water quality and fisheries' resources.

More intensive timber harvesting in the 1970's and 1980's on the steeper side slopes of the watershed has resulted in a significant amount of landslides from roads and cutblocks. These problems are being addressed through the MOF, WRP with Canadian Forest Products Ltd. as the proponent.

Assessments and Prescriptions
A Watershed Assessment Procedure was completed for the entire watershed in 1996. The results recommended that a Level 2 Channel Assessment Procedure (CAP) and a Riparian Assessment and Prescriptions Procedure (RAPP; Koning 1999) be completed. These were initiated in 1997 and completed in 1998.

The RAPP and CAP were each split into two parts. The initial overview assessments (Part I) identified impaired riparian areas and prioritized these areas for field inspection and development of rehabilitative prescriptions (Part II). Separation into two parts allowed a more productive allocation of funds.

The overview assessments identified 12 sites that were appropriate candidates for restoration. Revegetation prescriptions were developed and included a general description, revegetation objectives, a geotechnical assessment, sketches and photos (Fig. 2-38), revegetation treatments and cost estimates.

Rehabilitation Work
Five sites were chosen to have their revegetation prescriptions implemented in the fall of 1998. At this time, bioengineering works, using willow were completed. Bioengineering treatments included brush layers, modified brush layers (Fig. 2-39), wattle fences (Fig. 2-40) and live staking. Additional recommended treatments included grass seeding and planting of nursery grown shrub species which will be completed in 1999 provided funding is available. Soil samples were analyzed for various nutrients and the results will be used to guide fertilizer applications in 1999.

Restoration Results
The bioengineering treatments will not begin to grow until the spring of 1999. The treatments were inspected after several heavy rainstorms in the fall of 1998 and suffered little damage. Wattle fences and brush layers were blanketed with sediment that had been retained by the cuttings and boards.

It is expected that funding received throughout the multi-year agreement will allow the remaining sites to have their revegetation prescriptions implemented. More importantly, it will allow monitoring of the sites to ensure that the revegetation treatments are meeting objectives.

While implementing the prescriptions, several innovative techniques were attempted regarding anchoring of wattle fences, using native materials and grass seeding. The success of these techniques will be evaluated and reported over time.

Equipment
No heavy equipment was required. Hand tools included clippers, shovels, pick axes, etc.

Cost Summary

RAPP and CAP overview assessments	$ 30,000
Revegetation prescriptions	$ 35,000
Equipment rentals	$ 3,015
Materials	$ 960
Labour	$ 26,775
Project management, supervision	$ 23,250
Total	$ 54,000
Approximate Project Cost	$ 119,000

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Figure 2-38. Site photo showing completed and proposed treatments.

Figure 2-39. Modified brush layer.

Figure 2-40. Wattle fence.

Yola Creek Rock Deflector

Objectives
The primary objective is to create small-scale fish habitat, specifically rearing areas, in a watershed that lacks stable, hydraulically complex sections. This was attempted by constructing a water flow deflection device, built of rock. The deflector will be treated as a test site to assess the effectiveness of constructed flow deflectors in Yola Creek. If successful it could be a template for further instream works in this reach of Yola Creek.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Author
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Proponent
Steelhead Society Habitat Restoration Corporation

Watershed
Silverhope watershed, Yola Creek.

Location
Yola creek is one of three major tributaries that flow into the Silverhope Creek watershed. It flows into the left bank of Silverhope Creek approximately 20 km upstream of the Fraser-Silverhope confluence. The restoration site is another 1800 m upstream of the Yola-Silverhope confluence.

Introduction
Despite stable streambanks and mature conifers along much of the reach in which the Yola Creek project is in, there are obvious deficiencies in fish habitat. The deficiencies are a lack of cover in the form of LWD and infrequent pools which are small and shallow. Pools in this reach of Yola creek are predominantly induced by scour downstream of boulders. It was proposed that anthropogenic placement of a few key boulders at the project site will induce local scour.

Assessments and Prescriptions
Yola Creek was first surveyed in an Overview/ Level 1 Fish Habitat Assessment in 1996 (Whelan and Associates 1996 b). The restoration site was identified and prescriptions were developed from a channel assessment of the Silverhope watershed in 1997 (Babikaiff and Associates Geoscience Inc. 1998 b). The restoration site was designed based on template scour pools found within Yola Creek.

Rehabilitation Work
The project was completed on the date of September 5, 1998. Construction of the rock deflector consisted of the placement of four 0.7 m boulders within a 15 m^2 area between existing stable boulders. The boulders were placed in two rows approximately 1.25 m apart extending downstream at a 30 to 40 degree angle out from the right bank. A 5-6 m log, with a diameter of approximately 0.6 m, was cabled in between the two rows of boulders. All materials were found locally (Figs. 2-41 to 2-44).

Equipment
A chainsaw winch with blocks and tackle, and pry bars were used to maneuver the boulders. A rock drill, cable and epoxy were used to secure the log to the rocks.

Cost Summary

Machinery and materials	$ 2,882
Labour (professional and general)	$ 144
Total	$ 3,026

Production Estimates
The overall benefits of the structure will be threefold:

- Gravel recruitment upstream of the structure.
- Creation of a scour pool downstream of the deflector, due to the hydraulic diversity around the boulders.
- Increased cover and complexity to the pool will be created by both the boulders and log.

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Figure 2-41. Downstream view of Yola Creek rock deflector.

Figure 2-42. Downstream view of Yola Creek rock deflector site.

Figure 2-43. Side view of rock deflector.

Figure 2-44. Downstream view of constructed rock deflector.

Ashlu South Channel

Objectives
Ashlu South Channel, an abandoned side channel of Ashlu Creek, was rehabilitated to provide a variety of different types of habitat to meet the needs of all life stages of salmonids using Ashlu Creek. The South Channel is designed to provide habitat for chinook, pink, chum, coho and steelhead with off-channel ponds providing overwinter habitat for coho.

FRBC Region/MELPRegion/MOF Region
Pacific / Lower Mainland / Vancouver

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Proponent
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Implementing Partner
Resource Restoration Division,
Fisheries and Oceans Canada (DFO).

Watershed
Squamish River

Location
Ashlu Creek is a fifth-order coastal system lying approximately 28 km north of Squamish, British Columbia, where it drains into the Squamish River.

Introduction
Logging on the Ashlu Creek alluvial fan has resulted in lateral channel shifts due to loss of bank cohesion. As a result several distributory channels have been isolated including the former main channel. The current main channel is still very unstable and quality of the fish habitat is poor.

Rehabilitation Work
Diversion and intake construction was carried out in August and September 1997. South Channel construction was carried out in October and November 1997, and February and March 1998. Site clean-up and revegetation was carried out in March 1998. The South Channel was watered in April 1998.

DFO designed and constructed the river diversion and intake section of the project with assistance from SSHRC. The partners worked on the overall project layout and design of the downstream sections of the project including the form and character of the main channel, off-channel ponds and the number and location of constructed log jams. SSHRC technical staff supervised the daily construction activities, with DFO technical staff reviewing the progress of the project on a weekly basis.

Diversion
The low flow diversion was constructed at the upper end of an island separating two channels of the Ashlu mainstem. The diversion will provide a consistent supply of water to the intake at low flow. Originally, at low flow no water was transported down the left channel where the intake was constructed due to a gravel bar that would form at the side channel entrance. The diversion works were designed to create hydraulic conditions such that a portion of the main river flows down the side channel at all water levels and the gravel bar would not be able to reform after large flood events. Since completion of the diversion, visual observations indicate that at low flows the water is split evenly between the left and right channels. The side channel entrance appears to be stable and gravel is not accumulating during or after flood events.

Intake
The intake is located at the lower end of the left channel and supplies water to the remnant Ashlu South Channel (Fig. 2-45). The design of the intake allows for some fluctuation in flows to mimic a natural hydrograph, although, peak flows are limited.

Channel Design
The channel is designed to accommodate flows that range between 2.83 $m^3 \cdot s^{-1}$ and 8 $m^3 \cdot s^{-1}$ depending on the stage of discharge of Ashlu Creek (Fig. 2-46). Depth of flow and velocities were calculated prior to construction using 24 cross-sections from the survey. A trapezoidal channel was assumed with bank slopes of 1.5:1.

Connecting Channel
A channel was constructed within a small remnant channel to connect the intake to the

former main channel (Fig. 2-47). The channel was constructed with an average width of 10 m at the channel bottom. Spoil material from excavation was used in pond construction.

Channel Morphology Changes
Modifications were done at three locations, totaling 400 m, to provide greater channel capacity and a more natural vertical profile. The remaining sections of the channel were left in their natural state. Flow was diverted from Ashlu Creek through the intake control into the completed channel in April 1998. Gradients in the constructed channel sections were kept high 0.5-1.0 % to improve the ability of the side channel to transport bedload coming through the intake. In addition it was felt that higher velocity areas would be attractive to the salmonids of particular interest, chinook and pink salmon and steelhead trout, which typically do not spawn in the smaller off-channel habitats.

Off-channel Ponds
Four sites were selected to have off-channel ponds constructed. Ponds were designed as dead ended alcoves with water supplied from the South Channel. Ashlu Creek is a glacial stream and has high suspended sediment loads in the summer during glacier melt and in the winter during flood events. Sediment deposition within the rehabilitation project was a major consideration in the design process. Because they are dead-ended and water flow into them only equals the infiltration losses, sediment deposition should be reduced in the off-channel ponds. LWD was added to the ponds to provide cover.

Channel LWD Placements
LWD structures were added to 31 sites. A total of 269 pieces of LWD were used. LWD was added to increase cover, increase hydrologic diversity and to promote scour. Sites were located on the outside of meander bends to increase stability and maximize effectiveness (Fig. 2-48). LWD was arranged in an interlocking manner and triangulated to counter the downstream drag force. Key pieces were dug into the stream bank or cabled to mature trees to stabilize the end of the LWD on the bank. The instream end of the LWD was cabled to a deadman (log) buried 1.5 m into the streambed or cabled to boulders to counter buoyant forces.

Boulder Clusters
Boulders were added to 9 sites. A total of 74 were added. Boulders were added to riffles to provide steelhead parr habitat. The boulders were arranged in clusters with individual boulders approximately 1.0 m apart.

Diversion Berm
For purposes of testing the intake during the first winter a small diversion was created to shunt water from the upper part of the connecting channel back into the Ashlu 300 m downstream of the intake. Ashlu Creek carries a large amount of coarse bedload during flood events and experiences frazzle and anchor ice during extreme winter conditions. Testing of the intake was necessary to ascertain its ability to operate under these extreme conditions.

Bridge Abutments
As part of the agreement between the SSHRC and Interfor, the SSHRC was required to construct bridge abutments that could be used for temporary channel crossing to access proposed cut-block 10-9. Bridge abutments were designed and construction supervised by Hay and Company Consultants Ltd.

Revegetation

Tree Planting
All channel banks without natural vegetation, and all disturbed areas were planted with conifers. Approximately 2800 Douglas-fir and 1200 western red cedar trees were planted.

Grass Seeding
All disturbed areas were seeded with Big Horn™ Coastal Reclamation Mixture.

Construction Cost

Total cost of the project was $443,000.

Production Estimates

The South Channel is 2 km long with 30,000 m^2 of habitat and four ponds with 13,700 m^2 of habitat. Expected numbers of fish to be produced from the South Channel are: 369 chinook, 2787 coho, 10,584 pink (odd year only), 2463 chum and 336 steelhead based on biostandards in WRP Technical Circular No. 9. The expected numbers of fish appear to be reasonable in that the fish produced would be near the average of historical levels prior to the 1970's based on DFO SISS escapement records. Pink numbers are likely over-estimated based on historical levels and will likely only be half of this level. Overall expected fish production from this project would indicate that the benefits are extremely high.

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Figure 2-45. Intake structure on the Ashlu mainstem.

Figure 2-46. Unmodified section of channel.

Figure 2-47. Constructed connecting channel and deadman anchoring of LWD.

Figure 2-48. LWD structure on the outside of a meander bend.

Shovelnose Creek Meander Construction

Objectives
The purpose of this work was to narrow the channel and create a more natural meander sequence.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Author
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Proponent
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Watershed
Squamish River

Location
Shovelnose Creek is the southernmost of three creeks draining Mt. Cayley. Its mouth is located at Mile 31 of the Squamish Mainline.

Introduction
This report contains information on the construction of three meanders and four LWD structures in the mainstem of Shovelnose Creek. Meander pools are intended to create summer and winter habitat for all rearing species of salmonids and holding water for adult salmonids. Gravel will also be transported through this section of channel and will improve spawning habitat for salmonids. LWD was added to four sites to increase cover, hydrologic diversity and to promote scour. All LWD placements are located on the outside of meander bends to increase stability and maximize effectiveness.

Meander Construction
During construction temporary berms were built at meander construction sites. The berms were used to isolate the majority of the excavation work from the creek channel. This allowed for construction to proceed with a minimum of sediment input to the creek.

Construction of the meanders involved stream substrate excavation resulting in the formation of pools (Figs. 2-49 to 2-52). The excavated material was used to construct point bars on the inside of the meander (Fig. 2-53). The bars were constructed with a slope of 15:1, from channel margin to the bank. To help stabilize the bar a row of 0.5 m boulders were placed along the upstream edge. LWD was placed into the pools within the meanders to provide cover and to produce scour (Fig. 2-54).

LWD Placements
LWD was placed into the three pools plus one site upstream of the meanders. The LWD was arranged in lateral jams and triangulated to counter the downstream drag forces. LWD was anchored to mature trees or boulders using galvanized cable to stabilize the structures and to counter buoyant forces. LWD placements and anchoring were built to the standards in WRP Technical Circular No. 9.

Equipment Requirements
A John Deere 892 excavator was used to create the meander sequences and add the LWD to the pools.

Cost Summary

Materials and equipment rental	$ 10,658
Labour (professional and general)	$ 3,000
Total	$ 13,658

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Figure 2-49. Upstream pool location prior to excavation (looking downstream).

Figure 2-50. Upstream pool as-built.

Figure 2-51. Middle pool location prior to excavation (looking upstream).

Figure 2-52. Middle pool as-built (looking upstream).

Squamish River Estuary Channel Restoration

Objectives
The Squamish River training dyke was built in 1972. Prior to this time the lower Squamish River entered its estuary through two major and a number of minor channels. The training dyke cut off most of these channels such that the river now flows into Howe Sound through one channel only. Salmonid access to large amounts of estuarine marsh was lost or severely restricted by the dyke. A period of estuarine residence is believed to be a critical factor in juvenile salmon survival.

The 1998 works were directed at providing salmonid access through the dyke at two locations and reconstruction of river channels between the main river and the estuary. The rehabilitated channels and culverts provide juvenile passage and flow between the river and estuary during all but the lowest tides.

FRBC Region/MELP Region/MOF Region
Pacific / Lower Mainland / Vancouver

Authors
Matt Foy and Harold Beardmore.

Proponent
Community Futures Development Corporation of the North Fraser.

Implementing Partner
Resource Restoration Division,
Fisheries and Oceans Canada.

Watershed
Squamish River

Location
The project is located on the western portion of the Squamish estuary adjacent to Howe Sound.

Rehabilitation Work
Construction occurred from August 1998, to February 1999. The scope of work included:

- 160 m of 5 m approach channel from river's edge to the dyke.
- 550 m of 4 m channel from the dyke to an existing channel which skirts the east edge of the fill area.
- 200 m of channel joining the existing channel to an existing pond at the south side of the fill area.
- The spoil was spread alongside the channel for the first 95 m and the remaining excavation was trucked out and dumped along the protected side of the dyke at 2.4 km from the south end of the dyke and sloped to 3:1.
- Levelling 15 m of the north and east edges of the fill to recommended estuary elevation.
- Installation of two 32 m long, 15 mm thick, steel pipes—one at the pond (900 m from end of dyke) and one at the north side of the fill area (1400 m from end of dyke).
- Due to unsatisfactory performance of asphalt-coated corrugated steel pipe culverts in the estuary, pipe piles were used.
- In each culvert location, one 32 m length of 15 mm rolled-steel pipe was installed level at a geodetic elevation of 1 m. The pipes are 1200 mm in diameter, and the 12 m segments required pre-welding on-site and were installed in one piece.
- During culvert installation, backfill was compacted every 0.6 m by two walk-behind roller compactors until a 1:1 ramp could be built for the Caterpillar roller compactor to drive down.
- Rock armour was placed around the culvert ends to the top of the dyke for bank protection.
- At both ends of the culverts 10 m wide round bays were dug to try to minimize erosion.
- A 1200 m trail through estuary forest, with a footbridge across a ravine, to provide access for public and technical education purposes.

Equipment
To complete the work, the primary contractor-John Hunter Company Limited of Squamish provided:

- Finning Caterpillar 235B LC tracked excavator.
- Finning Caterpillar 225B LC tracked excavator.
- Finning Caterpillar 325B tracked excavator.
- Finning Caterpillar 966C rubber-tired loaders.
- Finning Caterpillar roller compactor.
- Walk-behind roller compactors.

Squamish River Watershed Society provided a five-person labour crew for work during the course of the project.

Cost Summary (1998)

WRP	$ 100,000
HRSEP	$ 100,000
DFO (project design and management)	$ 20,000
Total	$ 220,000

Production Estimates

The 1998 works provide an additional 910 m of inter-tidal estuary channel. In addition salmonid access to the inner estuary was greatly improved by the works. Production benefits are difficult to calculate however it can be assumed that benefits to all populations of salmonids found within the Squamish River watershed have been realized by this rehabilitation project.

Monitoring

Monitoring of juvenile salmon use of the tidal channels and culverts is planned in the future.

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36 Mile Creek Restoration Project

Objectives
The 36 Mile Creek restoration project was undertaken primarily to provide rearing and overwintering habitats for coho salmon, which assessments indicated are lacking.

FRBC Region/MELP Region/MOF Region
Pacific / Lower Mainland / Vancouver

Author
Lorrie Lech

Proponent
Steelhead Society Habitat Restoration Corporation

Watershed
Squamish River

Location
36 Mile Creek watershed enters the Squamish River from the east at mile 36 of the Squamish mainline.

Introduction
The floodplain surrounding 36 Mile Creek, which was logged 30-40 years ago, is now dominated by deciduous forest. The overall length is approximately 700 m (area is 3200 m^2) and has a 1% gradient.

Assessments and Prescriptions
Fish habitat assessments determined that the creek lacked complexity, rearing and overwintering habitats. A large beaver pond is located at the uppermost end of 36 Mile Creek and a remnant dam exists 100 m downstream. The result of the beaver dams has been to limit access to adults and juvenile salmonids and the degradation of spawning habitat. No prior restoration work has been undertaken.

Rehabilitation Work
Construction took place between August 26 and September 21, 1998. Restoration proceeded as follows:

Outlet Channel Configuration
- The outlet channel was constructed in a remnant channel with the upper end near the Squamish mainline entering 36 Mile Creek 50 m below the beaver pond (Figs. 2-55, 2-56). The channel is 150 m in length, 5 m in width and has a gradient of 1% (Fig. 2-57). A total of 3 pool/riffle sequences were constructed based on designs described in Newbury et al. 1997. The upper most riffle was constructed at an elevation of 100.5 m and will act as a control for the pond water elevation. LWD was added to the pools to supply cover.

Berm Construction
- A 4 m wide berm was constructed between the beaver pond and the newly constructed outlet channel, downstream of the pond. The berm is designed to prevent dam failure and pond water level fluctuations. The material used in the berm construction was from the excavated channel, the core consisting of till material with a gravel blanket on the downstream side. All construction material was free of organics.

Spillway
- To prevent berm failure in the event of a blockage of the outlet channel, a 20 m wide spillway adjacent to the uppermost end of the outlet channel was constructed. The spillway was armored with a 0.5 m thick layer of 300 mm boulders and a crest elevation of 101 m (1.0 m below dam design elevation and 0.5 m above pond water design elevation), to allow water to spill out without overtopping the berm.

Beaver Box and Culvert
- To deter beavers from constructing a dam across the outlet channel a beaver box was constructed to connect the pond to the outlet channel (Finnigan and Marshall 1997). The culvert (1 m diameter) passes through the berm at an elevation of 100.5 m. The downstream end empties into a pool above the first riffle (elevation 100.5 m) which controls the water level of the pond.

Alcove
- Immediately upstream of the Squamish mainline bridge at 36 mile, a 100 m long section of channel exists. The alcove invert was excavated to allow for a 2 m water depth at low flow. Prior to excavation the alcove

contained large amounts of LWD (Fig. 2-58). The LWD was removed for the excavation to proceed and later returned to the alcove to provide cover (Fig. 2-59).

Revegetation
- All disturbed areas were seeded with a coastal reclamation seed mixture. Live willow and red-osier dogwood (*Cornus stolonifera*) stakes were planted on all slopes adjacent to the outlet channel. Conifer seedlings, of appropriate species will be planted during March of 1999.

Equipment
- John Deere 892ELC excavator.
- Moxy articulating dump truck.
- Volvo articulating dump truck.

Cost Summary

Materials and equipment rental	$ 42,607
Labour (professional and general)	$ 19,730
Total	$ 62,337

Production Estimates
The restoration work created approximately 4500 m^2 of habitat (750 m^2 of pool/riffle habitat, 3400 m^2 of pond habitat and another 350 m^2 of alcove/pond habitat). Based on a coho smolt production rate of 0.69 (# per m^2) for off-channel pond habitat and 0.87 (# per m^2) for mainstem habitat (Keeley et al. 1996) the newly created habitat will produce approximately 3240 coho smolts annually.

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Figure 2-55. Clearing of the outlet channel.

Figure 2-56. Outlet channel during construction.

Figure 2-57. Outlet channel as-built.

Figure 2-58. Alcove before excavation.

Figure 2-59.   Alcove as-built.

28.5 Mile Creek Restoration Project

Objectives
To improve fish access to an overwintering pond and to increase the dissolved oxygen levels in two alcove ponds.

FRBC Region/MELP Region/MOF Region
Pacific / Lower Mainland / Vancouver

Author
Karl Wilson

Proponent
Steelhead Society Habitat Restoration Corporation

Watershed
Squamish River

Location
28.5 Mile Creek is located within TFL #38 entering the Squamish River, from the east near the 28.5 mile point on the Squamish mainline road.

Introduction
This report contains construction information for 28.5 Mile Creek. Construction took place at two separate areas along the creek. Both sites involved modifications to previous work. Modifications at the downstream location adjacent to the pond, involved protecting the pond outlet from beavers, deactivating a degrading channel to prevent the upstream propagation of a knick point and armouring the pond spillway. Riffles were constructed in the outlet channel to improve access to the pond for juvenile and adult salmonids. The upper site involved modifications to alcoves located in the groundwater channel, in order to improve water quality.

Assessments and Prescriptions
The Steelhead Society Habitat Restoration Corporation conducted a Level 1 Fish Habitat Assessment of 28.5 Mile Creek which led to the development of the original construction.

Rehabilitation Work
To prevent pond water levels from topping the berm, beaver dam construction must be prevented at the outlet channel. Initially a debris jam was placed upstream of the invert of the outlet channel. Beavers were able to build at this location despite rudimentary preventative measures. To further protect the area from beaver dam construction, the Telkwa design (Finnigan and Marshall 1997) was used to discourage beaver dam construction. LWD was added to build up the log jam and placed along the banks to make it difficult for beavers to access the channel and construct a dam. In addition the pond outlet weir invert was lowered so water would not top the berm at the 50-year flood level. To the east of the outlet weir a 0.5 m high berm was constructed to prevent silt from entering the channel from upslope materials.

The existing outlet channel was widened to 6 m (Figs. 2-60, 2-61). Three riffles were constructed at appropriate elevations (0.5 m drop between each). The riffles have a 15:1 slope on the downstream face and were constructed to the standards in WRP Technical Circular No. 9. Angular rock from a nearby quarry site was used to construct the riffles. Minimum diameter of the rock used for the riffle construction is 250 mm. Rocks of approximately the same size were used to armour the banks of the channel. Approximately 60 m^3 of rock was used in construction of the riffles and to armour the banks.

The riffle construction was performed with an excavator and supervised by a biologist from the Steelhead Society Habitat Restoration Corporation. Because of the lack of rainfall and high temperatures experienced during the summer of 1998 the water level in the pond at 28.5 Mile Creek dropped which caused the outlet channel to de-water. This aided the construction of the riffles because all the work could be done “in the dry”. No fish had to be salvaged and there were no problems with possible siltation normally associated with instream work.

A 1 m drop in elevation (knick point) at the head of the west branch of the outlet channel was actively eroding the fine grained bed and bank materials and propagating upstream. To prevent continued erosion, which could have potentially undermined the invert at the pond outlet, the branch was converted to an off-channel pond. A berm was constructed near the downstream confluence of the two branches and the knick point regraded to a 3:1 slope with appropriate fill.

An overflow was designed to spill water out of the pond in the event that the outlet channel should become blocked. A 20 m wide overflow located on the west side of the pond was armored with a 0.6 m layer of 300 mm rock. In order to add the rock, some material was removed from the berm so the finished elevation would be at the design elevation. Rock used for armouring the overflow was obtained from the same quarry as for the riffles on the outlet channel.

Two off-channel alcoves in the groundwater-fed channel suffered from low dissolved oxygen due to poor water circulation. In order to remedy this situation an inlet channel at the upstream end of each alcove was constructed to allow water to circulate through the alcove to increase dissolved oxygen levels. An excavator was used to dig both inlet channels approximately the same dimensions as the outlet channels. The new inlet channels were constructed so the invert was slightly higher than the main channel. This was done so most of the water would continue to flow down the main channel. All spoil material was placed on a bench of land between the alcove ponds and the groundwater channel.

Work Schedule
The heavy equipment was on site at 28.5 Mile Creek from September 21 to October 1, 1998. The site was seeded with a coastal reclamation mix on October 9, 1998.

Equipment
Machinery that was required to complete the project included a John Deere 892LC excavator and a Moxy articulating dump truck.

Cost Summary

Materials and equipment rental	$ 9,090
Labour (professional and general)	$ 4,630
Total	$ 13,720

Production Estimates
Riffles were constructed in a 60 m long outlet channel which improved access to 3200 m^2 of pond habitat. Two alcove ponds with a combined area of 700 m^2 were also restored.

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Figure 2-60. Outlet channel prior to restoration.

Figure 2-61. Outlet channel during restoration.

Theodosia River LWD Project

Objectives
To restore large woody debris jams and create diverse habitat (pools, riffles) in a degraded reach of the Theodosia River

FRBC Region/MELP Region/MOF Region
Pacific / Lower Mainland / Vancouver

Author
Jim Kristmanson

Proponent
Sliammon Development Corporation

Watershed
Theodosia River

Location
The Theodosia River is about 30 km northwest of Powell River.

Introduction
The Theodosia River has been impacted by past logging practices and by the continuing diversion of water into the Powell Lake reservoir. Historically, thousands of coho and tens of thousands of chum salmon spawned in the river. The Theodosia River Integrated Watershed Restoration Project report identified a number of rehabilitation options among which was rehabilitation of the mainstem by introducing large wood. The treatment reach (Reach 1a-1) was assessed as degraded, devoid of large woody debris (LWD) and lacking habitat diversity. A level survey was completed for 450 m of the channel to be restored. Fifteen triangular lateral log jam structures were designed and placed in the river.

Assessments and Prescriptions
The Theodosia River has been the subject of Level 1 Fish Habitat Assessment, a Channel Assessment, and a Riparian Assessment. These studies formed the basis for the Theodosia River Integrated Watershed Restoration Project report. A Level 2 fish habitat restoration prescription was done for the LWD project on Reach 1a-1.

Rehabilitation Work
Due to the extreme lack of LWD in the channel, A-frame lateral log jam debris collectors were chosen as the appropriate rehabilitation technique. These structures will cause local scour pools, trap and hold woody debris to function as cover and reintroduce habitat complexity to the channel.

Fifteen LWD structures were initially placed in channel 1a-1 of the Theodosia River. Ten were A-frame lateral log jam structures and five structures were single log deflectors. Anchoring used cable attached to riparian trees. The logs of the structures were also cabled to each other. Cable fastening used farmer's eyes, cable clamps and dogs. The cable was also wrapped around each log two or three turns and dogged to ease strain on the clamps and eyes.

After installation, the river went into flood with one bankful and one overbank flood event. Two structures were lost; one due to a farmer's eye failure and one that was not anchored due to lack of cable. Four single log structures were modified into A-frame structures by hand between the two flood events. At project completion, there were twelve A-frame debris collectors and three single log deflectors successfully installed.

The surveying, construction and monitoring activities resulted in 66 person days of employment.

Equipment
A logging truck delivered the logs to the site. The hoe was used to stockpile the logs, and place them at the sites.

Cost Summary

Labour	$ 7,000
Equipment	$ 6,600
Materials and rentals	$ 9,000
Supervision	$ 4,000
Professional services	$ 5,000
Total	$31,600

Production Estimates
This type of LWD structure does not have biostandards available yet but LWD additions

typically double the target fish population. The range in the literature is from a 2- to 5-fold increase.

Proposed Work

Extensive monitoring activities were completed for the pre-construction phase. These studies need to be repeated in order to quantify the effects of the structures and develop biostandards for this technique. Further rehabilitation work has been proposed in the form of off-channel habitat.

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Fish Hatchery Creek Restoration Project

Objectives
The Fish Hatchery Creek restoration project is one of a series of projects designed to create and restore productive off-channel spawning and rearing habitat for salmonids (sockeye, coho, cutthroat and steelhead) in the upper Pitt River watershed.

FRBC Region / MELP Region /MOF Region
Pacific / Lower Mainland / Vancouver

Authors
Matt Foy and Harold Beardmore.

Proponent
J. S. Jones Holdings Ltd.,
Pitt Lake Logging Division.

Implementing Partner
Resource Restoration Division,
Fisheries and Oceans Canada.

Watershed
Upper Pitt River

Location
This project is located on the east side of Corbold Creek which flows into the upper Pitt River.

Introduction
The Pitt River watershed has been extensively logged since the early twentieth century. Most, if not all wild populations of salmonids are presently below historical levels of abundance, for primarily logging-related habitat changes.

Assessments and Prescriptions
Many of the side channels and tributaries along the Pitt River have been degraded from a variety of activities including logging. Corbold Creek is a glacial-fed tributary of the upper Pitt River which supports the most numerous population of sockeye salmon spawning in the watershed. A historic channel of the Corbold Creek would have entered Fish Hatchery Creek which enters the upper Pitt River downstream from its confluence with Corbold Creek. This side channel was blocked off by a berm and bank armouring to protect the main logging road bridge. To mitigate some of this production loss, a side channel and river intake was constructed to provide year-round flow to the abandoned side channel which flows through a series of seasonally wetted ponds before emptying into the lower end of Fish Hatchery Creek. The river intake is located adjacent to the intake providing water to the Corbold Creek side channel. The primary fish species expected to benefit from the work are coho salmon, and steelhead and cutthroat trout.

Rehabilitation Work
The project was constructed between August 10 and September 4, 1998. J. S. Jones Holdings Ltd., the local forest licensee supplied a Caterpillar 330L excavator, a Caterpillar 966 loader and a Volvo all-wheel drive articulated truck. The scope of the work included:

- Installation of a steel trash rack river intake.
- Two 12-inch PVC pipes deliver flow from the river to the downstream channel. Valves at the downstream end of the pipes control water flows.
- A 55 m long spawning channel was constructed at the upstream end of the project. Spawning gravel and large wood was placed in this habitat to promote its use by spawning salmon and trout (Fig. 2-62).
- Flow from the spawning habitat was directed downstream into an abandoned channel.
- Flows were directed downstream through this forested side channel by hand digging around obstructions.
- After flowing for approximately 200 m, the water inundates a large pond complex (Fig. 2-63). Previous to the restoration work this area would be wetted in the winter and large parts of it would be dry during the summer. Increased flows of cooler water to this habitat has greatly increased its usefulness to salmonids. The completed habitat complex is approximately 2.0 km in length and covers an area of 7.5 ha (75,000 m^2).

Cost Summary

<u>1998</u>

Construction (WRP)	$ 50,000
Supervision, design and labour (DFO)	$ 15,000
Total	$ 65,000

<u>1997</u>

Construction (WRP)	$ 27,000
Supervision, design and labour (DFO)	$ 13,000
Total	$ 40,000

<u>1997-1998</u>

Construction (WRP)	$ 77,000
Supervision, design and labour (DFO)	$ 28,000
Total	$105,000

Production Estimates

The total rearing habitat created or improved is 75,000 m^2 with an estimated 200 m^2 of spawning habitat. Considering some of the habitat had previous value to salmonids, the increased production from this project is expected to be 20,000 coho smolts annually.

Monitoring

In the spring of 1997, smolt traps were operated at five completed and proposed restoration sites in the Pitt River watershed. This data will be used when assessing pre- and post-restoration fish production. Crew members for the trapping program included members of the Katzie First Nation which is a member group of the Pitt River Watershed Committee. Adult counts were carried out by the Pitt River hatchery staff in the fall of 1998. An estimated 75 coho salmon spawned in the upper spawning channel in the fall of 1998. An additional 250 coho salmon were observed spawning in the lower reaches of the project where suitable gravel was available. Future studies will look at adult spawner use of the habitat and assess the juvenile salmonid production from the restored areas.

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Figure 2-62. LWD placed in upper portion of channel below intake.

Figure 2-63. Lower portion of Hatchery Creek showing ponds created from addition of constant water source.

Homestead Creek Restoration Project

Objectives
The Homestead Creek restoration project is one of a series of projects designed to create and restore productive off-channel spawning and rearing habitat for salmonids (sockeye, coho, cutthroat and steelhead) in the upper Pitt River watershed.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Authors
Matt Foy and Harold Beardmore.

Proponent
J. S. Jones Holdings Ltd.,
Pitt Lake Logging Division.

Implementing Partner
Resource Restoration Division,
Fisheries and Oceans Canada.

Watershed
Upper Pitt River

Location
This project is located on the west side of Corbold Creek which flows into the upper Pitt River.

Introduction
The Pitt River watershed has been extensively logged since the early twentieth century. Most, if not all wild populations of salmonids are presently below historical levels of abundance, for primarily logging-related habitat changes.

Assessments and Prescriptions
Many of the side channels and tributaries along the Pitt River have been degraded from a variety of activities including logging. Corbold Creek is a glacial-fed tributary of the upper Pitt River which supports the most numerous population of sockeye salmon spawning in the watershed. A historic channel of the Corbold Creek would have entered Homestead Creek which enters the upper Pitt River upstream from its confluence with Corbold Creek. This side channel was blocked off by a berm and bank armouring to protect the main logging road bridge. To mitigate some of this production loss, a side channel and a water supply developed from the Pitt River hatchery intake now provides year-round flow to the seasonally flowing creek. The primary fish species expected to benefit from the work are coho and sockeye salmon, and steelhead and cutthroat trout.

Rehabilitation Work
The project was constructed between August 10 and September 4, 1998. J. S. Jones Holdings Ltd., the local forest licensee supplied a Caterpillar 330L excavator, a Caterpillar 966 loader and a Volvo all-wheel drive articulated truck. The scope of the work included:

- A 12-inch PVC pipe delivers flow from the hatchery water supply to the downstream channel. A 150 m long spawning channel was constructed at the upstream end of the project. Spawning gravel and large wood was placed in this habitat to promote its use by spawning salmon and trout.
- Flow from the spawning habitat was directed downstream into Homestead Creek which previously flowed only during wet periods of the year.
- A gravel berm was constructed at the lower end of the stream which creates a large ponded area (Fig. 2-64). A short stream section was constructed to pass adult and juvenile salmonids upstream into the pond.
- A gravel borrow pit was excavated deeper, complexed with wood debris and connected to the creek to provide additional rearing habitat.
- The completed habitat complex is approximately 500 m in length and covers an area of 9000 m^2.

Cost Summary

1998	
Construction (WRP)	$ 50,000
Supervision, design and labour (DFO)	$ 15,000
Total	$ 65,000

<u>1997</u>	
Construction (WRP)	$ 7,500
Supervision, design and labour (DFO)	$ 13,000
Total	$ 20,500

<u>1997-1998</u>	
Construction (WRP)	$ 57,500
Supervision, design and labour (DFO)	$ 28,000
Total	$ 85,500

Production Estimates
The total rearing habitat created or improved is 9000 m^2 with an estimated 750 m^2 of spawning habitat. Production from this project is expected to be 8000 coho smolts annually.

Monitoring
In the spring of 1997, smolt traps were operated at five completed and proposed restoration sites in the Pitt River watershed. This data will be used when assessing pre- and post-restoration fish production. Crew members for the trapping program included members of the Katzie First Nation which is a member group of the Pitt River Watershed Committee. Adult counts were carried out by the Pitt River hatchery staff in the fall of 1998. An estimated 50 coho salmon spawned in the upper spawning channel in the fall of 1998. Future studies will look at adult spawner use of the habitat and assess the juvenile salmonid production from the restored areas.

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Figure 2-64. Large overwintering pond built on lower end of project.

Rocky Creek Overwintering Ponds

Objectives
The primary objective of the Rocky Creek project is to provide permanent spawning and rearing habitat for coho salmon in an area that seasonally dries up. This was achieved by creating a series of groundwater-fed ponds connected to an existing beaver pond.

FRBC Region / MELP Region / MOF Region
Pacific / Lower Mainland / Vancouver

Author
Dan O'Donoghue

Proponent
Steelhead Society Habitat Restoration Corporation

Watershed
Upper Pitt River watershed, Rocky Creek.

Location
Rocky Creek flows into upper Pitt River approximately 5 km upstream of Pitt Lake. The project is 80 m north of the bridge where Rocky Creek passes under a forest service road.

Introduction
The majority of Rocky Creek is very steep (>100%) with only the lower 500 m having significant fish value. An alluvial fan (of gravel- and cobble-sized materials) has been deposited below the gradient break. In the past, the creek probably moved frequently on its alluvial fan. To protect the forest service road, which was constructed in the 1950's, Rocky Creek was confined by extensive rip-rap.

Five hundred metres north of Rocky Creek, a small tributary has been beaver-dammed and forms a large pond that is used by juvenile coho salmon and cutthroat trout. The project is situated in a low-lying area between the two creeks.

Assessments and Prescriptions
The upper Pitt River watershed is currently under-going a fish habitat assessment and culvert assessment on all major tributaries. The Pitt Watershed Steering committee identified Rocky Creek as a potential project.

Rehabilitation Work
The project was constructed between the dates of August 10, and August 27, 1998. Stable rearing habitat was created by making a series of stepped ponds. A 75 m groundwater channel at the south end of the ponds will provide a good flow of water through the system as well as spawning habitat for coho and chum salmon (Figs. 2-65, 2-66). Access to an adjacent beaver pond (which presently sustains a cutthroat trout population) was also improved.

The resulting pond area is approximately 6000 m^2 of varying depths (half of which is >2 m). The ponds were constructed by a combination of excavation of material below the groundwater table and construction of berms to detain water. The lower-most pond was designed to be the same level as the existing beaver pond and the two were connected. Connecting channels between the different pond levels were protected from damming by beavers with a culvert/beaver box structure (Fig. 2-67).

Equipment
- Cat 320 B excavator used for excavating the ponds, groundwater channel, and berm construction.
- Cat D300 rock truck for transporting material in construction of overflow and connecting channel.
- Cat 980 front-end loader for moving construction material from the road.

Cost Summary

Machinery and materials	$ 56,334
Labour	$ 3,063
Total	$ 59,397

Production Estimates
Based on biostandard estimates in Koning and Keeley (1997) expected productions are:
- 3000-6000 coho smolts (0.5-1 smolts per m^2)
- 28,000 chum fry outmigrants (225 outmigrant fry per m^2) from the groundwater channel.
- 900-3000 trout (0.15-0.5 smolts per m^2).
- Improved access to 10,000 m^2 of existing pond and marsh habitat.

For Further Information, Contact:
Mike Engelsjord or
Dan O'Donoghue
Steelhead Society Habitat Restoration Corporation
103-131 Water St
Vancouver, BC V6B 4M3
Tel: (604) 684-6242 Fax: (604)684-4745

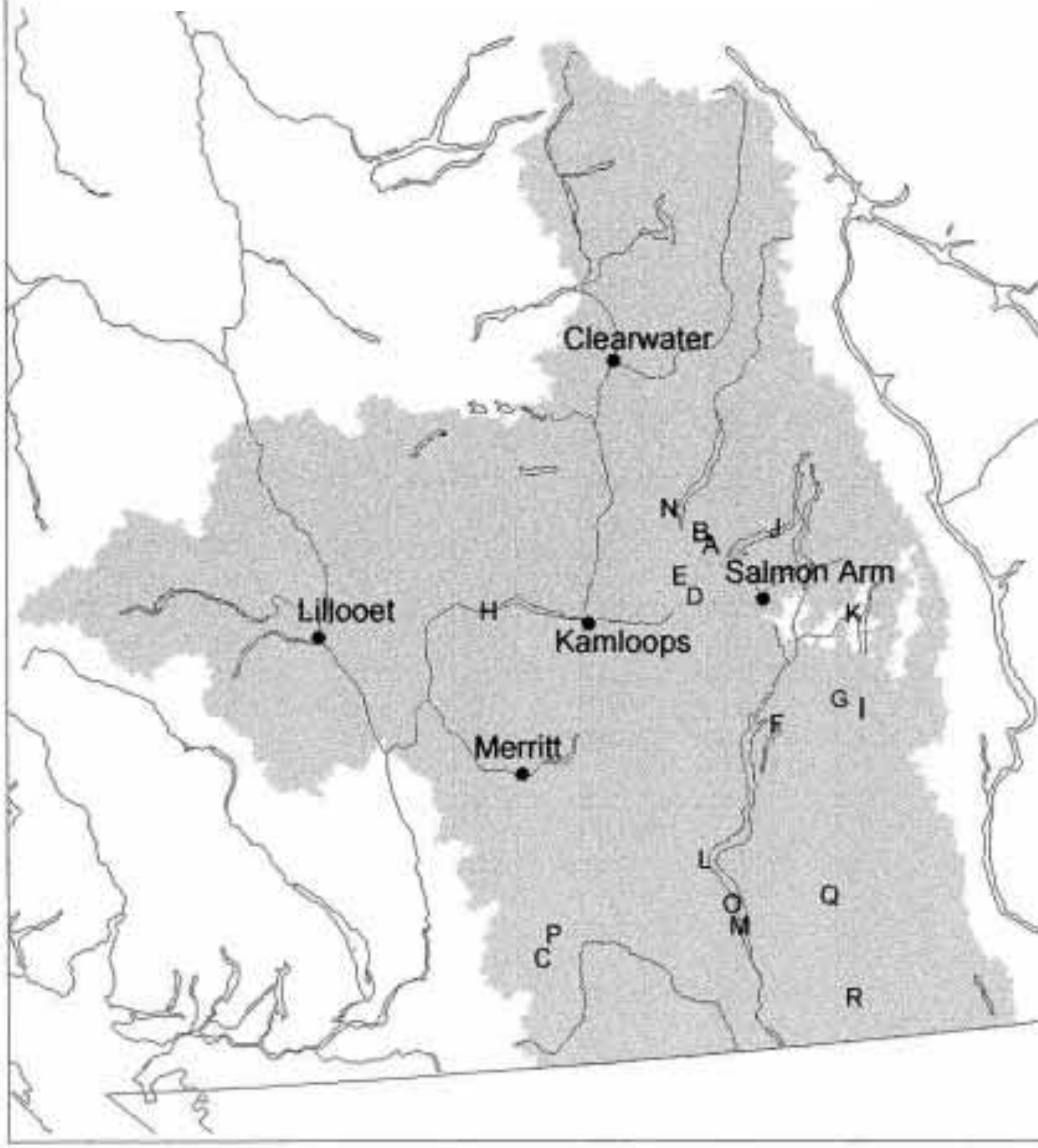
Figure 2-65. Groundwater channel pre-construction.

Figure 2-66. Groundwater channel post-construction.

Figure 2-67.   Installed beaver box.

Southern Interior Region

Region 3. Southern Interior



WRP Projects

- A Hiuihill Creek
- B Nikwikwaia Creek
- C Arrastra Creek
- D Middle Chase Creek
- E Upper Chase Creek
- F Coldstream Creek
- G Creighton Creek
- H Deadman River
- I Bessette/Harris Creek
- J Hudson Creek
- K Kingfisher Creek
- L Peachland Creek
- M Shingle Creek
- N Sinmax Creek
- O Trout Creek
- P Granite Creek
- Q Trapping Creek
- R West Kettle River

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 3, Southern Interior.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
A	**Southern Interior**	Adams River	Hiuihill (Bear) Creek	11	5644501	314931	128-453400-03900	00000ADMS
B		Adams River	Nikwikwaia (Gold) Creek	11	5646359	313414	128-453400-05400	00000ADMS
C		Arrastra Creek	Arrastra Creek	10	5476360	663284	310-367800-62000-25300-4600	00000SIML
D		Chase Creek	Middle Chase Creek	11	5634500	309800	128-371300	00000STHM
E		Chase Creek	Upper Chase Creek	11	5634500	309800	128-371300	00000STHM
F		Coldstream Creek	Coldstream Creek	11	5566028	338554	310-939400-15400	00000OKAN
G		Creighton Creek	Creighton Creek	11	5567840	360543	128-835500-54100-51800	00000USHU
H		Deadman River	Deadman River	10	5623418	646780	120-714600	00000DEAD
I		Harris Creek	Bessette/Harris Creek	11	5563005	356939	128-835500-54100-73600	00000USHU
J		Hudson Creek	Hudson Creek	11	5647992	348015	128-637100	00000SHUL
K		Kingfisher Creek	Kingfisher Creek	11	5608155	376640	128-835500-35300	00000USHU
L		Peachland Creek	Peachland Creek	11	5513499	301059	310-725700	00000OKAN
M		Shingle Creek	Shingle Creek	11	5484068	311780	310-616000	00000OKAN
N		Sinmax Creek	Sinmax Creek	11	5662023	304819	128-453400-13600	00000ADMS
O		Trout Creek	Trout Creek	11	5493459	310220	310-650900	00000OKAN
P		Tulameen River	Granite Creek	10	5486115	668281	310-367008-62000-25300	00000SIML
Q		West Kettle River	Trapping Creek	11	5492166	351403	320-520100-50800	00000KETL
R		West Kettle River	West Kettle River	11	5447874	356174	320-520100	00000KETL

Hiuihill (Bear) Creek Bank Stabilization

Objectives
The primary objective of this project was to complete bank stabilization works to reduce sediment delivery to the Lower Adams River.

FRBC Region/MELP Region/MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Watershed
Adams River

Proponent
International Forest Products,
Adams Lake Lumber Division.

Rehabilitation Work
Work was planned by Liv Hundall of Agra Earth and Environmental and carried out by Gentech Engineering of Chase, B.C. Tree revetments and rock spurs were utilized to stabilize the banks. Riparian planting adjacent to disturbed areas of Hiuihill Creek was completed.

Cost Summary
Approximately $100,000 was invested in this project.

For Further Information, Contact:
Al Thorne
International Forest Products Ltd.
RR#2, Chase, BC V0E 1M0
Tel: (250) 679-3234
Fax: (250) 679-3545

Nikwikwaia (Gold) Creek Slope Stabilization

Objectives
The primary objective of this project was to stabilize slopes of deactivated roads at two sites directly adjacent to upper Nikwikwaia Creek in order to reduce sediment delivery to the Lower Adams River.

FRBC Region/MELP Region/MOF Region
Thompson-Okanagan /Southern Interior / Kamloops

Watershed
Adams River

Proponent
International Forest Products, Adams Lake Lumber Division.

Rehabiliation Work
Planning and implementation was conducted by Silvatech Consultants Limited of Salmon Arm, B.C. utilizing labour from the Adams Lake First Nations. All work was done by hand labour on sites previously deactivated.

Site A
Construction of modified brush layers (132) of cottonwood and willow as well as 107 m of live pole drain and 25 m of wattle fencing. This project generated 12.5 person days of employment.

Site B
Construction of 15 m of live pole drain, and extensive live staking. This project generated 2.5 person days of employment.

Cost Summary
Approximately $28,000 was invested in this project.

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International Forest Products Ltd.
RR#2, Chase, BC V0E 1M0
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Fax: (250) 679-3545

Arrastra Creek Fish Habitat Restoration Project to Address Sediment Input and Transport

Objectives

The objectives of this project were to:

- reduce the input and transport of eroded sediment downstream through the watershed;
- address current and prevent future channel avulsions within areas of riparian disturbance; and
- provide overwintering and rearing habitat for rainbow trout adjacent to a new bridge crossing.

FRBC Region / MELP Region / MOF Region

Thompson-Okanagan / Southern Interior / Kamloops

Author

Jan den Dulk

Proponent

Ardew Wood Products Ltd., Merritt, B.C.

Partners

Ministry of Environment, Lands and Parks, and Ministry of Forests.

Watershed

Arrastra Creek

Location

Approximately 18.5 km on the Arrastra Creek Forest Service Road, 50 km west of Princeton, B.C.

Introduction

The Arrastra Creek watershed drains an area of approximately 150 km^2. The watershed is located within the Montane and Engleman Spruce-Subalpine Fir biogeoclimatic zones. The mainstem flows from west to east and enters Granite Creek and eventually the Tulameen and Similkameen Rivers to join the Okanagan drainage. This area is primarily used for recreation and timber harvesting.

Rainbow trout populations are resident within the watershed. Habitat features have been limited by a combination of the loss of LWD input to the channel, low summer flows and excessive sediment transport downstream through the watershed (Fig. 3-1). The primary goals of this project were to stabilize the eroding bed and banks (Fig. 3-2); protect the channel from existing and future lateral avulsions; re-establish hydraulic variability and restore instream LWD and boulder features suitable for providing overwintering and rearing habitat.

Assessments and Prescriptions

Preliminary assessments identified existing habitat conditions and provided potential areas for restoration projects. Due to work window timing restrictions, prescriptions were refined in the field with assistance from P. Epp and B. Hampton and then implemented.

Rehabilitation Work

The project utilized 125 whole trees (>0.3 m dia. x 20 m length) stock piled by the Small Business Program during the establishment of the access road and 30 boulders (>1.2 m dia.) collected from a talus slope near the work site. The following restoration was completed:

- In areas of channel aggredation, LWD was used to protect eroding banks, encourage point bar development to create a channel with a higher width:depth ratio and increased hydraulic complexity.
- In areas of channel degradation, LWD was used to create low profile, cross-channel structures which promote the local deposition of mobile sediment and create downstream plunge pool features.
- In areas with channel avulsions, LWD was used to create lateral debris jams which provide protection to unstable banks.
- An upstream "V" structure was constructed 50 m downstream of the bridge crossing to provide a large (>1.0 m depth), stable plunge pool feature for overwintering habitat (Fig. 3-3).

Note that all disturbed areas were revegetated using an interior erosion control seed mixture (formulated specifically for the local biogeoclimatic sub-zone) and modified brush layers (using resident willow and cottonwood stock) were constructed to accelerate the riparian zone recovery.

Equipment

Equipment and labour used included:

- Hitachi EX150 track excavator - Lower Nicola Backhoe Inc.
- Komatsu PC200LC track excavator - Lower Nicola Backhoe Inc.
- Overall project management, technical design, environmental monitoring and reporting - EcoTec Environmental Consultants Inc.
- Bioengineering technician, WCB First Aid, and general labour - EcoTec Environmental Consultants Inc.

Cost Summary

General cost breakdown:

Hitachi EX150 and Komatsu PC200LC track excavators	$ 8,600
Overall project management, technical design, environmental monitoring and reporting	$ 5,000
Bioengineering technician, WCB First Aid and general labour	$ 900
Materials (seed, etc.)	$ 1,000
Total	$ 15,500

The total project costs were $15,500 to restore 500 m of channel bank and instream spawning, rearing and overwintering fish habitat and to create 26.5 person days of employment.

Production Estimates

This project restored approximately 500 m of channel habitat for rainbow trout. This area has the potential to produce an estimated 190 rainbow trout juveniles.

For Further Information, Contact:

Jan den Dulk
Senior Watershed Restoration Specialist
EcoTec Environmental Consultants
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RR 1, Blind Bay, BC V0E 1H1
Tel: (250) 675-4449
E-mail: ecotec-west@bc.sympatico.ca

Figure 3-1. Pre-construction conditions in Arrastra Creek.

Figure 3-2. Large woody debris placement to stabilize the Arrastra Creek mainstem channel.

Figure 3-3. Upstream "V" structure to create pool habitat on Arrastra Creek.

Middle Chase Creek Channel Stabilization Installations

Objectives
To implement a series of high priority restoration prescriptions from a set of 126 site prescriptions designed to add channel stability to the middle reaches of Chase Creek using bar stabilization and bank techniques.

FRBC Region/MELP Region/MOF Region
Thompson-Okanagan/ Southern Interior / Kamloops

Author
Michael Wallis, R.P.Bio.

Proponent
Chase Creek Community Association

Watershed
Chase Creek

Location
Chase Creek drains a watershed area of 290 km^2 into the South Thompson River at the community of Chase (approximately 50 km east of Kamloops). The restoration activity summarized here occurred at locations within a 30 km reach referred to as middle Chase Creek, which comprises the majority of the mainstem creek length (below Pillar Lake).

Introduction
Numerous recent floods have resulted in rapid stream morphology changes including bank erosion, loss of riparian vegetation, development of large debris jams, excessive sediment deposition and braided channels. By contrast, historical information indicates that Chase Creek was typically a "single channel, slightly entrenched, sinuous, gravel dominated, riffle/ pool morphology with a well developed floodplain"[1]. Large quantities of mobile sediments continue to move through the system. These sediment wedges exacerbate erosion and riparian vegetation loss through this corridor of private land. Mobile fines, associated nutrient loading and loss of shading are seriously impacting water quality. Past forest, road construction and land use practices appear to be contributing to the current condition within the system.

There are significant trout populations distributed throughout the system. Anadromous fish do not utilize the system above a falls located approximately 2 km upstream from the confluence of Chase Creek and the South Thompson River. Downstream water quality impacts are considered an important factor because receiving waters are utilized by anadromous and non-anadromous fish species as well as being utilized as a water supply by the city of Kamloops. In addition, stabilization of mobile sediments is key to reducing difficulties occurring downstream in the village of Chase that are associated with mass sediment transport to the townsite.

Assessments and Prescriptions
Interest shared by landowners, citizens, forest licensees and agencies resulted in the development of a restoration plan for middle Chase Creek in 1997-98. The Chase Creek Community Association undertook the role, using FRBC funding to co-ordinate the planning and implementation process. A restoration template including 145 prioritized prescriptions for restoration was developed and restoration activity undertaken beginning in 1997 has continued through 1998. All 15 sites prioritized as critical are completed or underway.

Rehabilitation Work
During 1998 two operational time windows occurred (spring '98 and fall '98). In total 23 prescriptions were implemented during the 1998 period. Techniques utilized included: rootwad tree revetment, log crib revetment, wood spur, whole tree bar stabilization, rock spur, brush traverse, brush layer, facine (wattle), rooted and unrooted planting (Figs. 3-4 to 3-6). Debris jam management as a means of utilizing natural structure was undertaken with MELP consultation at 10 locations. Fencing is planned or completed at 17 of the sites.

In total 3269 m^3 of rock was placed in rootwad, spur, whole tree and other bank/bar stabilization structures. A total of 79 rootwad structures and 43 large log structures were installed and 23 rock spurs were constructed using this material. A total of 2707 m of linear streambank was worked on during these projects. Individual sites varied in length from approximately 50 to 150 m. Spring operations included a larger proportion of this linear distance (1030 m) because of the emphasis put upon brush layer and other bank stabilization techniques. Fall installations (677 linear m) placed more emphasis on structures perpendicular to the creek bank for bar stabilization purposes. Plantings during 1998 included 8848 rooted stock and 41,091 unrooted stock. Native species were utilized. Additional plantings are planned for spring 1999.

Cost Summary

The cost of the 1998 restoration work was $307,133. This includes materials, equipment and labour. This calculates to an average rate of $113 per lineal m of stream bank.

Restoration Results

The structures installed during 1998 are part of an ongoing restoration plan for a 30 km length of Chase Creek mainstem. The goal is to enable natural recovery processes in unstable reaches by installing structures at key locations. The structures installed are expected to improve bank and bar stability over the 2707 m of stream length at the precise locations of the installations. In addition the structures and continuity provided through this series of individual site installations is expected to provide a net effect to the integrity of the system which is greater than the sum of the individual treatments. The desired result is to re-establish linked complexes of individual habitat units, which offer greater hydraulic and ecological value to the system than the sum of the individual components. Long-term success of this restoration program will be determined by upstream activity and the capacity to complete the restoration process now underway in middle Chase Creek. Fish habitat, water quality improvement and land base protection are expected to result from these restoration structures.

For Further Information, Contact:

Chase Creek Community Association
RR2, Site 22, Comp 15
Chase, BC V0E 1M0

[1] From Agra Earth and Environmental. Jan.1998. Chase Creek Assessment and Prescription Design. VW1001.00

Figure 3-4. Chase Creek bar stabilization structures under construction, spring 1998.

Figure 3-5. Chase Creek brush layer following construction, summer 1998.

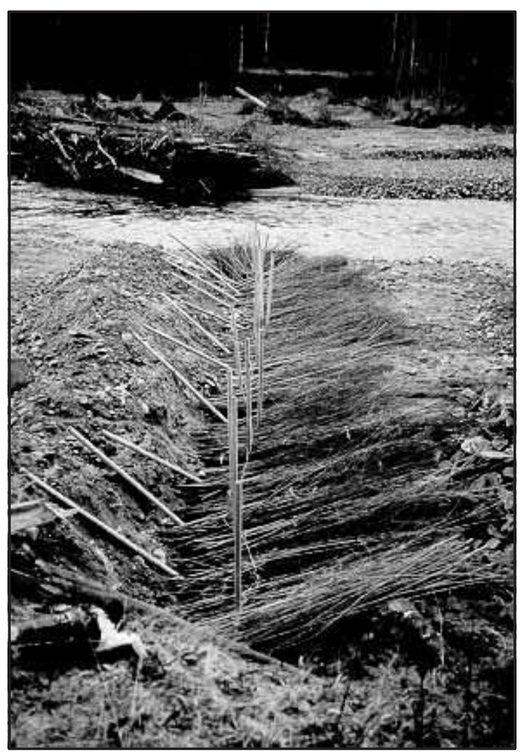

Figure 3-6. Chase Creek brush traverse under construction, spring 1998.

Upper Chase Creek Stream Rehabilitation

Objectives
The primary objective of the Upper Chase Creek stream rehabilitation works was to reduce sediment delivery into the stream through several methods, which included steam diversion and the installation of various instream structures.

FRBC Region / MELP Region / MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Author
Bernard Teufele, B.A.Sc.
EBA Engineering Consultants Ltd.

Proponent
Riverside Forest Products Ltd.

Watershed
Upper Chase Creek

Location
Upper Chase Creek is located in the Interior of B.C., approximately 30 km southeast of Chase. Upper Chase Creek drains west into Chase Creek, which in turn flows north and empties into the South Thompson River at Chase.

Introduction
Upper Chase Creek supports rainbow trout and has been recognized as a significant sediment source to the lower Chase Creek valley. Impacts of sediment delivery to downstream resources are reported to include aggradation and disruption of the floodplain in the lower Chase Creek valley, as well as turbidity in Chase Creek and the South Thompson River, which is the source of drinking water for the city of Kamloops.

The stream rehabilitation works for this project were conducted over an approximately 500 m section of Upper Chase Creek, which is adjacent to a series of landslide prone slopes. Landslide activity in the Upper Chase Creek watershed pre-dates forestry development in the area, however to some extent timber harvesting and road construction in the study area are responsible for the increased activity of pre-existing landslides. A previous (EBA, January 1998) geotechnical investigation and landslide mitigation project on the slopes above the stream explored the possibility of stream diversion to prevent high flows from impacting on large volumes of loose depositional slide material (EBA, May 1998).

Assessments and Prescriptions
The assessment of the stream was conducted during the summer of 1998. The assessment recognized several areas where instream mitigative works could reduce the potential for sediment delivery and promote fishery habitat.

Rehabilitation Work
The following is a summary of the work performed:
<u>Channel Construction / Stream Diversion</u>
A short section (approximately 120 m) of abandoned channel was assessed and prescriptions were developed to re-activate the channel to receive flows. The objective was to re-direct the flows from the original north channel to prevent stream erosion of the depositional material of a large landslide off the valley wall of Upper Chase Creek. The landslide is part of an on-going mitigation and monitoring project. Elevated stream flows result in toe erosion and extreme sediment delivery to the stream and subsequent and continuous destabilization of the slide itself.

The abandoned channel was reconstructed to meet the hydrological dimensions and characteristics of the existing channel. Three upstream facing rock weirs (Fig. 3-7) were constructed in the new channel to direct elevated stream flows to the center of the channel in order to prevent erosion of the newly formed channel banks. The weirs will provide additional roughness to the channel and create a small hydraulic jump at low and moderate flows. Over time, flows will scour a pool on the downstream side of the weir, creating a riffle/ pool formation enhancing fisheries values. A berm was constructed across the existing channel once flows were diverted into the new channel. The berm was constructed using available rock material and whole trees with rootwads directed upstream.

Whole Tree Revetment System

At a separate location, the stream curves sharply and impacts against a section of steep slopes, which are subject to continual raveling and surficial sloughing of loose material. Prescriptions were created to construct a series of whole tree revetments along the length (50 m) of the stream curve (Figs. 3-8, 3-9).

The whole trees were anchored into place with pin logs and boulder/ cable fastening systems. The objective of the revetment system is to provide direct erosion control of the streambank from elevated flows and trap sediment between the component parts. The upstream facing rootwads and limbs retained on the trees will provide roughness and help distribute flow velocities and promote the retention of instream sediments and organic debris. The whole trees will also provide cover and shading for the stream, which will enhance fish habitat.

Other Works

Two other sites were identified as locations where high flows result in streambank erosion and subsequent sediment delivery to the stream. Each of the sites coincides with a sharp bend in the stream and prescriptions were created to construct protection using available large woody debris, whole trees and rock material.

The whole trees were anchored in place using a combination of LWD pin logs as well as cable / boulder anchor systems. The objective of the structures was to provide direct protection for the erodible streambank soils as well as providing roughness to help distribute flow velocities, which will promote the retention of instream sediments.

A third site is an elevated point bar deposit on the inside of the stream bend, where a lack of LWD was identified as contributing to high stream velocities and subsequent bedload destabilization during high flows. Using available large woody debris, a small catchment structure was constructed. The structure consists of two buried logs resting on a third log, which is perpendicular to the direction of flow. The objective of the structure is to act as a catchment system to promote debris jams during elevated channel flows. The retention of large woody debris is intended to provide additional roughness to the channel during peak flows, which will help slow stream velocities and promote the retention of sediment as well as enhancing fish habitat.

Project Implementation

Rehabilitation works on Upper Chase Creek were started on September 22, 1998 and completed by September 30, in conjunction with the fisheries window of operations for the region. The supervised work was completed using a Hitachi EX 200 excavator with a mechanical thumb. A swamper / faller assisted the excavator. Instream construction procedures were as follows:

- All construction took place in either dry conditions or at very low stream flows, which facilitated the construction and minimized the release of sediment. The project was completed within the fisheries window established by MELP.
- Sediment control for the stream diversion was accomplished by the construction of a catch basin and filtration system at the distal end of the new channel. Once the stream was diverted into the new channel, sediment laden water was contained in the catchment pond and pumped into the forest for natural filtration until the water reached background levels (approximately 6 hours).
- A total of 25 whole trees were identified and collected for use in the various components of the project. Tongs attached to the bucket of the excavator were used to minimize damage in the retrieval of the whole trees. The cut-off berm for the new channel required 9 trees and the revetment system along the existing stream curve required 8 trees. The remaining whole trees were used in the other systems.
- Whole tree systems were secured into place using several methods, which included embedment, pinning between anchor logs and epoxy cable lashing to boulders.
- All soils exposed during construction were seeded with a reclamation mix to promote the quick establishment of grass and minimize erosion.

Cost Summary

Professional	$ 2,900
Labour, supervision	$ 7,725
Materials, equipment	$ 8,000
Total	$ 18,625

Restoration Results

The project completed works on approximately 300 m of stream. It is expected that the stream diversion will significantly reduce the amount of sediment delivery into Upper Chase Creek by directing flows away from the active landslide, which will also help stabilize the slide by preventing continual de-buttressing of the toe. In addition to the stream diversion, the other systems will provide protection to erodible stream banks while promoting the retention of sediment and enhancing fisheries values.

Monitoring and further assessment of the sites will be undertaken in March or early April 1999, to determine the overall effectiveness of the project.

For Further Information, Contact:

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Suite 550 – 1100 Melville Street
Vancouver, BC V6E 4A6
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E mail : teufele@eba.ca

Figure 3-7. Rock weir within new channel.

Figure 3-8. Constructing log crib wall along toe of slide.

Figure 3-9. Log crib wall.

Coldstream Creek Rehabilitation Project

Objectives
The objectives of the Coldstream Creek rehabilitation project were to increase channel stability and spawning and rearing habitat in two sections of the creek. This was accomplished through integrated bank stabilization methods utilizing large rock and large organic debris.

FRBC Region/MELP Region/MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Author
Lee Hesketh

Proponent
Whitevalley Community Resource Centre

Watershed
Coldstream Creek

Location
The Coldstream Creek watershed is located in the Okanagan water basin 10 km east of Vernon B.C. Drainage area covers an estimated 100 km^2. Coldstream Creek flows from Norris Canyon through the Coldstream Valley and enters the north end of Kalamalka Lake.

Introduction
Coldstream Creek has historically supported resident populations of rainbow trout and adfluvial rainbow and kokanee populations. The watershed has been impacted by logging, agricultural and recreation use for over 90 years. The municipality of Coldstream as well as private landowners draw water off it for domestic use. Due to the high values the creek has spawning habitat. A number of local clubs and school groups have been involved with habitat awareness projects as well as habitat development sites in the lower reaches.

High runoff levels in 1997 created some minor erosion problems in Coldstream Creek park. Spawning beds developed for kokanee were damaged and a bank was left in an eroded state with the potential of contributing large amounts of sediment during the next freshet. A section of the creek above the municipal water intake became highly aggraded as well, with the potential for filling up the intake reservoir.

Assessments and Prescriptions
No assessments have been carried out for the Coldstream Creek watershed. The sites that were worked on were noted by Ministry of Environment as requiring rehabilitation. Conceptual designs for the rehabilitation activities were submitted by the contractor and approved by the Ministry of Environment.

<u>Site #1 Upper Coldstream</u>
This section of creek was severely aggraded with over 1 m of bedload built up behind a log jam. The prescription carried out was the excavation and stabilization of an old channel. This allowed for the work to be carried out in the dry and the new flow pattern to be directed away from the forestry access road located nearby. Large rock was used to create riffles and stabilize banks. Large organic debris was secured along the creek's edge to provide habitat.

A 150 Hitachi excavator used on this site allowed easier movement in the riparian area without damaging the trees due to its short track length. Blow down and dead standing material was utilized for large organic debris.

<u>Site #2 Coldstream Creek Park</u>
Several of the log weirs in the kokanee spawning beds were starting to undermine. These were upgraded or replaced using large rock. A lower section of the creek had started to erode a cutbank due to a large tree falling into the creek and redirecting the flow. The log position was reoriented to provide instream habitat but not create flow restriction. Large rock was placed at the base of the bank which was then sloped and planted with Pacific willow (*Salix lucida spp. lasiandra*) cuttings and grass seeded.

Cost Summary

Total project budget	$ 6,319

For Further Information, Contact:
Lee Hesketh
Box 326
Lumby, BC V0E 2G0
Tel: (250) 547-6586

Creighton Creek Riparian Restoration

Objectives
The objective of this project is to accelerate the recovery of channel stability and fish habitat through restoration of the riparian corridor.

FRBC Region/MELP Region / MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Author
Brian Nuttall (MELP)

Proponent
Tolko Industries Ltd., Lavington Division.

Watershed
Creighton Creek

Location
Creighton Creek drains north then west and discharges into Bessette Creek at the village of Lumby. Creighton Creek drains approximately 160 km^2 originating at an elevation of 1800 m ASL and discharges into Bessette Creek at an elevation of approximately 500 m ASL. Bessette Creek in turn discharges into the Shuswap River upstream of Mabel Lake.

Introduction
Both Bessette and Creighton Creeks historically were utilized by anadromous runs of chinook and coho salmon and adfluvial and resident populations of rainbow trout. Several decades of adverse land use practices has reduced the spawning, rearing and overwintering habitat within the watershed for these species. Recent runs of coho salmon have been less than 5% of historical runs. Within the Bessette Creek watershed, Creighton Creek has some of the better habitat despite its impacted condition. Water quality and quantity within Creighton Creek is more favourable particularly during low flow periods. Land use within the watershed is predominantly forest harvesting in the upper watershed and agriculture within the lower watershed. Recent interest by local landowners in restoring channel stability and fish habitat presented an excellent opportunity to undertake critical work within the lower reaches of the watershed.

Assessments and Prescriptions
Both the Department of Fisheries and Oceans and MELP WRP have undertaken assessments within the Bessette Creek watershed. DFO in particular has been monitoring conditions within the Creighton Creek basin for a number of years. DFO engaged the services of a local consultant to identify high priority restoration sites and to make initial landowner contacts in the spring of 1998. Four high priority sites were identified. All four sites have experienced a steady decline in quantity and quality of riparian area over the last half century. Loss of riparian habitat has lead to streambank erosion and loss of LWD and subsequent loss of riffle /pool habitat type and channel capacity. Channel widening and loss of channel depth are common. Prescriptions drafted by the consultant focused primarily on planting cottonwood and Pacific willow within the floodplain and adjacent uplands as well as construction of a small number of log jams on eroding bends of the stream. Instream work at this point in time was minimized due to reduced channel capacity.

Rehabilitation Work
Due to the compact nature of the bars within the floodplain, a Hyundai 130 excavator was utilized to dig trenches for planting willow and cottonwood. Trenches were excavated to a depth where groundwater was encountered. Willow and cottonwood stakes/poles were then placed into the trench in contact with the water and backfilled. All areas planted were also fenced off to exclude cattle from impacting the works. In total, 2.9 km of riparian area was planted and fenced.

Cost Summary

Total project cost	$ 78,976

For Further Information, Contact:
Brian Nuttall
Ministry of Environment, Lands and Parks
2501 – 14th Ave.
Vernon, BC V1T 8Z1
Tel: (250) 558-1705

Deadman River - Channel Condition Restoration in an Interior Dry-belt Watershed

Objectives

The objectives of this project were to:

- reduce the input and transport of sediment downstream throughout spawning reaches; and
- (where possible) provide over-wintering/ rearing habitat for coho salmon and steelhead trout within the Deadman River watershed.

FRBC Region / MELP Region / MOF Region

Thompson-Okanagan / Southern Interior / Kamloops

Author

Jan den Dulk

Proponent

Ministry of Environment, Lands and Parks

Partners

Skeetchestn Indian Band

Watershed

Deadman River

Location

Approximately 75 km west of Kamloops and parallel to the Deadman River Road.

Introduction

Deadman River lies within the Bunchgrass (lower), Ponderosa Pine (middle) and Interior Douglas-fir (upper) biogeoclimatic zones. The watershed contains numerous tributaries and small lakes and drains an area approximately 100,000 ha. The drainage flows from north to south and enters the Thompson River downstream of Kamloops Lake. This area is heavily used for agriculture, recreation, livestock ranging and timber harvesting.

Pink, sockeye, chinook and coho salmon, steelhead and rainbow trout all utilize the watershed for spawning and rearing. Numerous non-salmonid species are also resident.

The lower half of the watershed has been most heavily influenced by timber harvesting, channel alteration and agricultural practices and is completely privately owned (First Nations and ranchers). The Deadman River is also arguably the most important tributary to the Thompson River for coho and steelhead production. B.C. MELP has and will continue to conduct intensive spawner/outmigrant enumerations.

Assessments and Prescriptions

Preliminary interviews with landowners identified those which were amenable to participating in the restoration works. Agreements were formalized which included requirements of: voluntary release of 15 m of riparian exclusion on both sides of the creek; the installation of cattle exclusion fencing; and the guarantee of irrigation over-spray to ensure survival of the riparian plantings. Due to work window timing restrictions, prescriptions were refined in the field with assistance from M. Crowe (DFO) and then implemented.

Rehabilitation Work

The work included the removal of over-hanging and under-cutting bank material to a slope of 1:3 (Fig. 3-10). Rip-rap (>0.25 m dia.) was placed from the toe of bank up to an elevation equal to bankfull. Tree revetments where placed along the outside of each meander (45^o downstream) above the rip-rap using thinning stock (> 10 cm dia. x 4 m length) (Figs. 3-11, 3-12). In areas of excessive erosion or where constrictions were required (bridge crossings for example) larger woody debris (> 0.5 m dia. x 6 m length) were used in conjunction with large boulders (> 0.75 m dia.) and rootwads.

In areas of low energy (no evidence of natural bank erosion) a variety of bioengineering techniques were used. These included live pole staking, whip fences and modified brush layers. All stock was cut locally from willow and cottonwood stands and hand placed along the banks. All disturbed areas were treated with an Interior erosion control seed mixture (formulated specifically for the local biogeoclimatic sub-zone).

Five-strand smooth wire fences were installed along 2.5 km of streambank with a minimum of 15 m riparian buffer. Live stakes of willow and cottonwood were planted within the buffer and irrigation over-spray is guaranteed by the landowner to ensure success. In early 1999, several thousand ponderosa pine (*Pinus ponderosa*; donated by the MOF) will be also be planted within the riparian buffer.

Equipment

Equipment and labour used included:

- Hitachi EX200 track excavator - Savona Enterprises Ltd.
- Rock trucks - Skeetchstn Indian Band.
- Project management, technical design, environmental monitoring and reporting - EcoTec Environmental Consultants Inc.
- General labourers - Skeetchstn Indian Band.

Cost Summary

General cost breakdown:

Hitachi EX200	$ 16,250
Rock trucks	$ 3,000
Project management, technical design, environmental monitoring and reporting	$ 15,000
General labour	$ 15,000
Fencing materials	$ 10,000
Total	$ 59,250

The total project costs were $59,250 to stabilize 550 m of channel for salmonid spawning and rearing.

Production Estimates

This project addresses approximately 2500 m^2 of channel for spawning and rearing (overwintering) habitat. This area has the potential to produce an estimated 1540 coho smolts and 39 steelhead trout juveniles annually.

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Figure 3-10. Bank stabilization on Deadman River.

Figure 3-11. Tree revetments and live pole riparian restoration on Deadman River.

Figure 3-12. Tree revetments to stabilize banks on Deadman River.

Bessette/Harris Creek Rehabilitation Project

Objectives
The objectives of the Bessette/Harris Creek rehabilitation project were to increase channel stability, increase fish habitat and develop a healthy riparian management zone. This was accomplished through integrated bank stabilization methods utilizing large rock, large organic debris, fencing and tree planting.

FRBC Region / MELP Region / MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Author
Lee Hesketh

Proponent
Riverside Forest Products, Lumby Division.

Watershed
Harris Creek

Location
The Harris Creek watershed is located in the Thompson-Okanagan watershed 30 km southeast of Vernon, B.C. Drainage area covers an estimated 360 km^2. Harris Creek flows into the middle Shuswap River 15 km northeast of Lumby, B.C.

Introduction
Bessette/Harris Creek has historically supported anadromous species of chinook and coho salmon. Rainbow trout exist as both adfluvial and resident populations. A combination of factors has seen the relative health of the fish population decline in recent years, the largest impact being the loss of habitat due to channel instability.

Assessments and Prescriptions
Overview fish habitat and channel assessments were conducted in 1996 for the upper reaches of the Bessette/Harris system and 1997 for the lower section of creek from the base of Satellite Hill into Lumby. These reports indicated that portions of the lower section were in an aggraded state due to non-cohesive banks and old slides contributing bedload to the system during freshets. The lower section also lacked a healthy riparian corridor due to heavy agricultural use. Channelization of the creek had also taken place along some of the lower sections leaving the creek with very little instream habitat.

Due to time and budget restraints, the sites chosen for restoration were areas which would give the best overview in time of the effectiveness of the rehabilitation techniques.

Rehabilitation Work
Activities on the Bessette/Harris Creek restoration project commenced in the beginning of March and were completed on January 20, 1999. Due to the wide variety of prescriptions carried out on 5 separate sites, scheduling of activities was based on instream work windows, material availability, economic factors, and having to work around industrial work closures due to the extremely high fire hazard.

Individual implementation schedules for these sites and the basic activities carried out are as follows:

Site # 1 Upper Harris Creek
The stabilization of a large slide which was contributing large amounts of sediment into the creek during peak flows due to its non-cohesive bank structure started at the end of August. Due to poor road access, the material on site was used. This consisted of large cobble rock being re-oriented along this section of reach and the introduction of large organic debris consisting of blowdown obtained from outside the 60 m riparian zone under special use permits through the Ministry of Forests.

Machinery used on this site consisted of a 200 Hatachi excavator for material development and construction, and an Iron Horse 1-man skidder. The ground crew consisted of the site supervisor and 2 assistants as well as the excavator operator.

Work methodology consisted of developing the large organic debris required to construct the debris catchers and log jam to remove the high flow pressures from the base of an old slide. With the completion of these structures, several instream V-weirs, bend-a-way weirs and more debris catchers were built downstream to compensate for the possible flow pattern change.

These also developed fish habitat by creating a higher percentage of pool-riffle sections. The total work area, covered 300 m of streambed and had 11 instream structures developed. Mapping and photos of structures were taken for future monitoring.

Site # 2 Upper Harris Creek

This section of the creek had become highly aggraded due to flow pattern changes occurring during the previous spring runoff. The channel is wide with extensive gravel bars consisting of homogeneous bed texture. Based on conceptual designs, work to stabilize the gravel bars commenced over a 12 day period in the beginning of September. Due to the close proximity of the forestry access road to the creek, large rock was developed from along the road right-a-way and brought onto site with the use of a rock truck. A portion of the large organic debris was developed from an old blowdown from along the road right-of-way. Due to the volume required and industrial closures of forestry activities in the area, a logging truck load of material was also brought in. The work consisted of constructing several instream structures designed to reduce downcutting; bank stabilization to prevent further flow pattern changes and the introduction of large organic debris structures to help absorb the energy during high flow periods.

The machinery used on this site consisted of a 200 Hitachi excavator used for material development and stream rehabilitation activities. A rock truck was used to haul rock and wood debris to the site; a small 440 John Deere skidder was used to develop large organic debris and a hook truck was used to bring in purchased material. The ground crew consisted of a site supervisor and one crew person as well as the equipment operators.

A total of 16 individual structures over 310 m of streambed were completed. Photos and mapping of the work site were completed for future monitoring.

Site # 3 Bessette/Harris Creek Below Horner Road Bridge

This section of the creek also showed signs of streambed aggradation. Bank stability and riparian cover have been compromised by the removal of the conifers from the stream's edge and heavy grazing for the past 40 years. The present riparian zone was a mature cottonwood stand with some mature conifers. Due to the constant shifting of the flow pattern, instream fish habitat was lacking, with no established pools. With the cooperation of the land owners, a riparian corridor was established by planting willows. In order speed up the natural healing process along this section of creek, instream works were carried out to stabilize the flow pattern and to provide fish habitat. This was accomplished by the construction of habitat recruitment structures at points that were noted as being unstable with present bank structures being undermined. These structures were based on conceptual designs and were constructed from rock and large organic debris brought on site from local sources. These works were carried out in mid-August in accordance with the instream work window. The planting of the gravel bars with Pacific willow cuttings took place in January to allow for the collection of material and to make sure the cuttings would have the best chance of establishment.

Machinery used on this site consisted of a 150 Hitachi excavator, dump trucks and a hook truck. The ground crew consisted of a site supervisor, and 4 crew members.

Over 800 m of riparian management area was developed with set-back fencing, planting of willows, instream habitat development as well as bank stabilization. A total of 250 m of large angular rock and over 140 m^3 of large organic debris was utilized on this project. Photos and mapping of the area were completed for future monitoring.

Site # 4 Small Site Above Horner Road Bridge

This site consisted of a gravel bar area which was planted with large Pacific willow cuttings. The 2" - 4" x 8' cuttings were excavated into the gravel to a depth of 1.2 m and aligned to act as debris catchers. The gravel bar is estimated to cover an area of 10 m x 50 m.

Site # 5 Planting, Fence Construction Along Bessette/Harris Creek at Bloom Road

A land owner provided set-back along a stable section of creekbank which bordered a hay field utilized as fall pasture. The establishment of the riparian management zone over this 250 m section of creek will allow for increased overstorey as the natural vegetation is allowed to re-establish.

The close proximity of this section of creek to several houses and to light industrial activities will make this area very valuable for wildlife as an established green space.

Cost Summary

Total project budget	$119,000

Restoration Results

Over 1 km of riparian management zone has been established along the private land bordering Bessette/Harris Creek. Two major sources of bed load have been stabilized in the upper portion of the system which will have positive long-term effects on the lower reaches.

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Hudson Creek Channel Reconstruction

Objectives
The objective of the project was to reconstruct the lower reach of Hudson Creek at Anglemont which had suffered a debris torrent. Private property including a home had been directly affected by the debris torrent in late May 1997. Reconstruction of the channel remained necessary to prevent further damage to private property and public infrastructure.

FRBC Region/ MELP Region/ MOF Region
Thompson-Okanagan/ Southern Interior / Kamloops

Author
Bill Franz

Proponent
Hudson Creek Preservation Society

Watershed
Hudson Creek

Location
Hudson Creek is a community watershed located on the north shore of Shuswap Lake near Salmon Arm. The community of Anglemont is located at the mouth of Hudson Creek.

Introduction
Hudson Creek at Anglemont had suffered a debris torrent in May 1997. Private property including a home had been directly affected. The intake works and related infrastructure of the water utility that serves the community were also damaged, as were roads in the area including the main road along Shuswap Lake during the main and subsequent events.

The most significant contributing factors to the failure were natural instability of the terrain class V slope in the area of initiation of the debris torrent, and the concentration of drainage from the crossdrain of the forestry road onto the slope above the failure. Above normal soil moisture conditions and above normal snow pack were also factors.

Corrective action was taken to control drainage above the initiation point of the debris torrent by the Ministry of Forests. The Provincial Emergency Program (PEP) and the Ministry of Highways and Transportation had assisted in the clean-up after the events. Reconstruction of the channel remained necessary to prevent further damage to private property and public infrastructure.

Hudson Creek is a community watershed but is not considered to be a significant fish stream. The shore of Shuswap Lake which Hudson Creek is tributary to is considered to have high productive capacity and therefore is critical habitat for shore spawning for sockeye salmon and lake char (*S. namaycush*) and rearing of anadramous salmonids and trout.

Assessments and Prescriptions
An independent assessment of the torrent and the initiation zone had been conducted to determine the risk of further torrent activity. Significant damage to the Anglemont Estates Ltd. water supply intake works had also been assessed.

An engineering prescription was obtained for the restoration of the channel reach above Airstrip Road and downstream to the Anglemont-Squilax Road. Forest Renewal BC funding through a contribution agreement enabled the newly formed Hudson Creek Preservation Society to pay for the engineering prescription, services of an on-site construction supervisor, and heavy equipment and material costs. Forest Renewal BC funding also enabled the Society to pay for a conceptual study for a debris flow containment structure.

The engineering prescription for the restoration of the channel took into consideration affected private property owners, highways infrastructure, the water utility's works, and downstream fisheries values. A site survey of the channel at Airstrip Road prepared earlier served as the base plan for the engineering prescription. A cost estimate for the remedial work on the channel was prepared estimating 1500 m^3 of rock rip-rap required. A rock outcrop along the 1000 Forest Service Road was sourced as the rock supply to be blasted; haul distance was approximately 7 km to the work site.

The engineering prescription identified four priority items:

- Heavy armouring of 160 m of channel downstream of Airstrip Road, adjacent to the two affected residences (Figs. 3-13, 3-14).
- Armouring of the channel immediately upstream of the highway crossing to prevent further channel degradation and subsequent obstruction of the highway culverts.
- Restoration of the natural channel width upstream of Airstrip Road for approximately 140 m, and reconstruction of 60 m of rip-rap.
- Debris removal from channel banks, restoration of a 3 m bottom width, and resloping banks to a 1:1, preferably 1.5:1 slope where armouring was not proposed.

Rehabilitation Work

Approval under Section 9 of the Water Act was obtained. As there were fisheries concerns downstream along the shore of Shuswap Lake, no silt or other deleterious substance was allowed to enter the water. The Approval required the use of a streamflow bypass pipe and all work had to be conducted in the dry portion of the channel.

Work commenced in the middle of February 1998 involving a Cat 235B for rock development, Terex off road rock trucks for hauling, and a Cat 235C for site development. A smaller excavator, a Hitachi 220, was used for pullback of the creek banks and debris cleanup. Big "O" pipe 400 mm diameter was loaned by the Forest Service for the stream bypass (Fig. 3-15). Two in-situ sediment traps using silt fencing were constructed downstream of the work site as a backup. Geotextile filter cloth was employed for a filter layer under the rock rip-rap placed. In addition to prescribed works, assistance was provided in re-establishing a watermain crossing augered under the channel, and the installation of 2 private bridge crossings. The work was in progress for approximately 3 weeks. The weather cooperated with generally warm and dry conditions. Disturbed areas were grass seeded.

Cost Summary

Engineering prescription	$ 5,000
On-site supervision	$ 9,550
Materials, equipment	$108,027
Total	$122,577

Restoration Results

Reconstruction of the channel was accomplished prior to the spring 1998 freshet. Approximately 300 m of channel was reconstructed, including 160 m of channel armoured with new rip-rap and 60 m of channel re-armoured with existing rip-rap. The work was accomplished with minimal impact to water quality and downstream fisheries resources in Shuswap Lake. The potential of further damage to private property and public infrastructure was limited.

The works were monitored during the freshet in May 1998 to confirm project effectiveness (Fig. 3-16).

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Figure 3-13. Cat 235 C placing heavy rock rip-rap to prevent down-cutting of channel, February 1998.

Figure 3-14. Hudson Creek channel reconstruction, February 1998. Note houses left and right of excavator.

Figure 3-15. Streamflow bypass pipe in Hudson Creek, February 1998.

Figure 3-16. Freshet flow Hudson Creek, Anglemont May 1998.

Kingfisher Creek Instream and Off-channel Fish Habitat Restoration Project

Objectives
The objectives of this project were to:
- provide off-channel spawning, overwintering and rearing habitat for resident rainbow trout and coho salmon;
- provide instream spawning and rearing habitat through the establishment of large woody debris-boulder structures;
- provide stream channel and floodplain stability to reduce the input of sediment and prevent channel avulsions; and
- provide template structures and techniques to be used in other restoration projects throughout the Kamloops Forest Region.

FRBC Region / MELP Region / MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Author
Jan den Dulk

Proponent
Ministry of Environment, Lands and Parks

Partners
Riverside Forest Products Ltd., Lumby Division, Ministry of Forests, Kingfisher Environmental Interpretive Centre Society, Spallumcheen First Nations.

Watershed
Kingfisher Creek

Location
Adjacent to the Three Valley-Mabel (Kingfisher) Forest Service Road (FSR), approximately 37 km east of Enderby, B.C.

Introduction
The Kingfisher Creek watershed includes both Danforth and Hunter Creeks in addition to the mainstem river and drains an area approximately 750 km^2. The watershed lies within the Interior Cedar-Hemlock biogeoclimatic zone. The drainage flows from north to south and enters the Shuswap river east of Enderby, B.C. near the outflow from Mabel Lake. This area is heavily used for recreation, tourism and timber harvesting. Within the watershed, both rainbow and bull trout (*S. confluentus*) populations are resident and there is evidence that adfluvial rainbow trout from Mabel and Mara Lakes utilize all three creeks for spawning. Anadromous salmonids within the watershed include a threatened population of coho salmon, and small numbers of chinook and sockeye salmon which periodically utilize the lower reaches for spawning.

Kingfisher Creek was chosen as the representative (demonstration) watershed for the northern portion of the Region. It is anticipated that future WRP projects will utilize the structures and techniques established here as templates for other works.

Assessments and Prescriptions
Preliminary feasibility studies indicated species presence and distribution and provided potential areas for restoration projects. Due to fisheries work window timing restrictions, prescriptions were refined in the field with assistance from P. Slaney, R. Finningan, B. Symonds and B. Franz and then implemented in 1998.

Rehabilitation Work
The work included:
- Development of off-channel spawning and rearing habitat within the floodplain of the lower reach of the Kingfisher Creek mainstem. Using a combination of groundwater sources (0.05 $m^3{\cdot}s^{-1}$) and a controlled surface water diversion (maximum of 0.85 $m^3{\cdot}s^{-1}$), 1200 m of channel and 6000 m^2 of pond habitat were restored. Habitat complexing within this channel included the development of riffle, run and pool sequences using a variety of rock and woody debris structures. The techniques utilized were chosen for their applicability to the specific hydraulic conditions of each reach and for the purpose of demonstration and training. Groundwater sources were natural, perennial springs. The surface water diversion included a 1000 m^2 settling pond and head-gate protected by a 3.5 m berm from freshet flows.
- Upgrading of fish access throughout the groundwater channel adjacent to Hunter

Creek at 10.5 km on the Forest Service Road. This included the hand-placement of rock (Fig. 3-17), minor excavation of the channel and the addition of 75 unused Christmas trees as LWD to the rearing ponds. Trails were also upgraded and 5000 willow whips were planted throughout the site.
- Stabilization of 200 m of Danforth Creek eroding channel bank under the BC Hydro right-of-way at 12 km on the FSR. Overhanging and under cutting of the bank (1500 m^3) was removed, 500 m^3 of rip-rap (>0.5 m diameter) was placed, 24 pieces of LWD (>0.5 m diameter x 10 m length) and 5 rootwads (>2 m diameter) were placed within this reach to create 3 triangular debris catchers (Figs. 3-18, 3-19), 1 Newbury riffle, 50 m of lateral debris jam (Fig. 3-20) and 75 m of protected streambank. Intensive bio-engineering revegetated 1 ha of riparian zone with low growing willow species (BC Hydro requirement).
- Restoration of instream fish habitat throughout 250 m adjacent to a bridge crossing of Danforth Creek. Work included the construction of 2 Newbury riffle structures, 4 triangular debris catchers and 25 m of lateral debris jam.
- Excavation of three (50 m^2 x 1 m deep) off-channel ponds within a spring-fed side channel to Danforth Creek under the BC Hydro right-of-way at 18.5 km on the FSR. Habitat complexing within these ponds includes the addition of woody debris (40% surface area cover) and grade controls to maintain pond depth. Sixty-five pieces of LWD (> 0.5 m diameter x 5 m length) were added to 450 m of the mainstem channel to provide instream fish habitat features and bank and floodplain stability. These were used to augment the few remnant LWD (>1.0 m diameter x 10 m length) remaining from right-of-way construction 25 years ago.

Equipment
Equipment and labour used included:
- Hitachi EX270 track excavator - Friessen's Excavating Ltd.
- Komatsu PC200LC track excavator - Friessen's Excavating Ltd.
- Schaeff HSM 41 mobile walking excavator - J.W. Berry Trucking Ltd.
- Various skidders and rock trucks - Friessen's Excavating Ltd.
- Overall project management, technical design, environmental monitoring and reporting - EcoTec Environmental Consultants Inc.
- General surveying and on-site supervision - Tillicum Management Services.
- Two labour crew chiefs - Spallumcheen First Nation.
- Seven labourers - Kingfisher Environmental Interpretive Centre Society.
- Workers Compensation Board Level III First Aid Attendant - EcoTec Environmental Consultants Inc.

Cost Summary

Hitachi EX270 and Komatsu PC200LC excavators	$ 34,750
Schaeff HSM 41 excavator	$ 13,250
Various skidders and rock trucks	$ 5,000
Overall project management, technical design, environmental monitoring and reporting	$ 25,000
General surveying and on-site supervision	$ 20,000
Two labour crew chiefs	$ 14,500
Seven labourers	$ 14,500
First aid attendant	$ 7,500
Materials and supplies	$ 21,000
Total	$155,500

The total project costs were $155,500 to restore 1500 m and 6125 m^2 of off-channel and 1000 m of instream spawning, rearing and overwintering fish habitat and to create 356 person days of employment.

Production Estimates
This project has the potential to produce an estimated 12,910 coho smolts and 1633 rainbow trout juveniles annually. To determine the success of the restored habitat, a long-term monitoring program will be implemented. This program will measure fish production and habitat use in order to better refine fish habitat restoration prescriptions for southern interior watersheds.

For Further Information, Contact:

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Figure 3-17. Hand placement of rock on Kingfisher Creek side channel.

Figure 3-18. Triangular debris catcher on Danforth Creek (Kingfisher).

Figure 3-19. Triangular debris catcher on Danforth Creek (Kingfisher).

Figure 3-20. Lateral debris jam construction on Danforth Creek (Kingfisher).

Peachland Creek Streambank Protection Project

Objectives
The primary objective of the project was to provide protection to the streambank adjacent to a mobile home park, while maintaining and attempting to improve the fish rearing habitat of the stream.

FRBC Region / MELP Region / MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Author
Bernard Teufele, B.A.Sc.
EBA Engineering Consultants Ltd.

Proponent
The Corporation of the District of Peachland, Edgewater Pines Mobile Home Park.

Watershed
Peachland Creek (Deep Creek).

Location
Peachland Creek is located in the southern interior of B.C. in the municipality of Peachland. The project site is situated immediately upstream of Peachland Creek's confluence with Okanagan Lake.

Introduction
Peachland Creek supports rainbow and brook trout (*S. fontinalis*) and is also recognized as an important kokanee spawning channel. An extensive series of channel bed stabilizers have been constructed in the lower reaches of the stream to retain imported spawning gravel. Flood waters from the 1997 freshet knocked out a small bridge and caused localized erosion on the streambank and threatened property of the mobile home park. Imported spawning material was also washed away by the fast stream flows.

Assessments and Prescriptions
The assessment of the stream was conducted during the summer of 1998. The assessment recognized several areas where instream mitagative works would reduce the potential for bank erosion and enhance fishery values.

The prescriptions for the stream included:

- Removal of an existing (10 m long) rock-stack wall.
- Removal of several improperly functioning channel bed stabilizers.
- Construction of two upstream rock weirs.
- Streambank armouring with rock and large woody debris.
- Cable/rock anchoring of whole tree revetment system.
- Bio-engineering of exposed surfaces.

Access to the stream was limited from the south side of the stream through Antler Beach Provincial Park.

A Hitachi Ex-120 excavator was used for all removal and placement of material. The excavator was chosen because it was small enough to work around and not damage the existing streambank vegetation, and was large enough to handle some of the large rock pieces.

Rehabilitation Work
The instream works for this project were conducted over four days between August 11 and 14 during the established fisheries window for the stream.

The instream works started from the low end of the stream (Highway Bridge) and progressed upstream to Renfrew Bridge.

The rock stack wall was removed from the south side. The rock wall limits fish habitat and deflects stream flows to the opposite bank. All usable rock was stockpiled for use in other components of the project, and all deleterious material (concrete, re-bar) was transported to a local landfill.

The rock weirs were constructed from rock blasted from a local quarry. The weirs were constructed in "wet" conditions, which made establishment of a footing difficult. Equi-dimensional rocks with flat surfaces were selected for use to facilitate easy placement in the stream. Rock sizes ranged from 0.125 m^3 to 1 m^3. The rock weir required a row of footer rocks, underlying an upper row of scour rocks. The rocks were positioned in an upstream "V" to deflect flows to the center of the channel (Fig. 3-21).

Bank armouring of the north side required the removal of a utility shed before an acceptable footing could be established. The bank armouring consisted of a row of rootwads sandwiched between a row of footer and header rocks. The rocks were lined with a geo-textile, backfilled and then bio-engineered.

Whole trees were positioned on the north side of the stream with the rootwads facing stream flows. The trees (2) were secured into place using cables attached to a system of large rock "dumbbells" anchored into the channel bed.

All streambank surfaces exposed during the instream works were revegetated to promote vegetation and soil stabilization. Bio-engineering techniques of live staking and fascines using cottonwood and willow were used to promote erosion and soil stabilization on the exposed soils.

Cost Summary

Professional	$ 3,500
Labour, supervision	$ 6,200
Materials, equipment	$ 9,700
Total	$ 19,400

Expected Results

The project completed works on approximately 130 m of stream and it is expected that the instream works will significantly reduce the amount of erosion on the streambanks and will provide much needed habitat for the valuable fisheries resource.

Upon completion of the project, the rock weirs were effectively diverting stream flows towards the center of the channel and reducing bank erosion. Observations from fisheries personnel indicate that the other instream works were soon being utilized by returning kokanee.

Monitoring and further assessment of the sites will be undertaken in March or early April 1999, following this year's freshet to determine the overall effectiveness of the project.

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Figure 3-21. Boulder weir to create scour pool and central thalweg.

Shingle Creek - A Pilot Study to Address Sediment Input and Transport Within a Dry-belt Watershed

Objectives
The objectives of this project were to:
- reduce the input and transport of sediment downstream throughout; and
- (where possible) provide overwintering/ rearing habitat for rainbow trout within the Shingle Creek watershed.

FRBC Region / MELP Region / MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Author
Jan den Dulk

Proponent
First Nations of the Okanagan and Similkameen Environmental Protection Society, Penticton, B.C.

Partners
Penticton Indian Band, Ministry of Environment, Lands and Parks.

Watershed
Shingle Creek

Location
Parallel to the Shingle Creek Road approximately 10 km west of Penticton, B.C.

Introduction
The Shingle Creek watershed drains an area of approximately 150 km^2. It lies within the Bunchgrass (lower), Ponderosa Pine (middle) and Interior Douglas-fir (upper) biogeoclimatic zones. The mainstem flows from west to east and enters the Okanagan Channel at Penticton. This area adjacent to the restoration works is primarily used for livestock free-ranging. Upstream factors affecting the overall hydrology of the watershed include agriculture and timber harvest activities.

Rainbow trout are resident within the watershed while the lower reaches support Okanagan and Skaha Lake adfluvial rainbow trout and kokanee populations. Habitat features have been limited by a combination of the loss of LWD input to the channel, low summer flows and excessive sediment transport and deposition throughout the watershed (Fig. 3-22). The primary goals of this project were to stabilize the eroding bed and banks; limit the input of sediment to the channel; and restore instream fish habitat where possible.

Assessments and Prescriptions
Preliminary assessments identified existing habitat conditions and provided potential areas for restoration projects. Due to work window timing restrictions, prescriptions were refined in the field with assistance from P. Epp and A. Crampton and then implemented.

Rehabilitation Work
Techniques used included:
- The excavation of overhanging and under cutting banks to a 1:3 slope and the placement of angular rip-rap (>0.25 m diameter) up to bankfull elevation. Above the rip-rap, live poles were installed to initiate the recovery of the riparian vegetation. This technique was applied to areas of excessive erosion.
- Live pole fences were installed in areas of moderate erosion and bank instability (Fig. 3-23). These were constructed at low flow elevation and back filled up to bankfull level. To maximize the durability of the structures, the existing bank profile was mimicked and channel constriction was minimized.
- Live pole stakes were inserted into banks which exhibited minimal erosion but lacked a riparian zone beyond grasses and herbaceous vegetation. These were spaced approximately 1 m and to a minimum depth of 0.7 m to ensure contact with groundwater.
- Bundles (>25 whips) where installed on point bars to encourage sediment deposition and establish woody vegetation. These were orientated downstream 45^o and buried into the bars.

Note that all disturbed areas were treated with an Interior erosion control seed mixture (formulated specifically for the local biogeoclimatic sub-zone). Live plantings included native and local willow and cottonwood cuttings to accelerate the riparian zone recovery. Live poles and stakes were >5 cm diameter x 1m length and fences and bundles were constructed from whips (approximately 0.5 cm x 3 m).

Equipment

Equipment and labour used included:

- Hitachi EX200 track excavator - Carcana Excavating Ltd.
- Rock trucks - West Hills Aggregates (Penticton Indian Band).
- Overall IWRP Project Coordination - Goodings Environmnetal Inc.
- Project management, technical design, environmental monitoring and reporting - EcoTec Environmental Consultants Inc.
- Bioengineering technicians and general labourers - First Nations of the Okanagan and Similkameen Environmental Protection Society.

Cost Summary

General cost breakdown:

Hitachi EX200 track excavator	$ 4,500
Rock trucks	$ 1,500
Overall IWRP project coordination	$ 1,500
Project management, technical design, environmental monitoring and reporting	$ 9,750
Bioengineering technicians (3) and general labour	$ 2,750
Materials (seed, etc.)	$ 750
Total	$ 20,750

The total project costs were $20,750 to stabilize 2500 m of channel bank and to create 48.5 person days of employment.

Production Estimates

This project initiated the restoration 2500 m of channel for rainbow trout habitat. This area has the potential to produce an estimated 855 rainbow trout juveniles annually.

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Figure 3-22. Pre-construction conditions illustrating bank slumping on Shingle Creek.

Figure 3-23. Live pole placement and bank stabilization on Shingle Creek.

Sinmax Creek Channel Rehabilitation - 1998 Works

Objectives
The main objective of the Sinmax Creek channel rehabilitation project (1998 works) was to stabilize critical channel sections and control bank erosion in lower Sinmax Creek. Channel and bank stabilization is the first phase in a multi-year restoration program planned for the Sinmax Creek watershed. Long-term objectives of future restoration works include: staging the downstream movement of accumulated sediments; rehabilitating riparian vegetation communities affected by land clearing; and, restoring the complexity of instream habitats for stream rearing salmonids in the lower mainstem channel.

FRBC Region / MELP Region / MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Author
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Silvatech Consulting Ltd.

Proponent
International Forest Products Limited,
Adams Lake Lumber Division, Chase, B.C.

Watershed
Sinmax Creek

Location
Sinmax Creek drains approximately 195 km^2 of forested and cultivated land into Skwaam Bay on Adams Lake in the Southern Interior of British Columbia. The watershed is located approximately 60 km northeast of Kamloops.

Introduction
Sinmax Creek provides spawning and/or rearing habitats for a variety of anadromous, adfluvial and fluvial salmonid species including sockeye salmon, coho salmon, kokanee salmon, rainbow trout and bull trout. Local resident accounts and spawner enumeration by the Department of Fisheries and Oceans indicate that anadromous fish numbers and the length of stream utilized by some species have been in decline since the mid-1960's.

Preliminary results of fish habitat, stream channel and riparian assessments funded by Forest Renewal BC (FRBC) indicate that declines in anadromous fish use may be closely linked to past stream management practices and agricultural land clearing adjacent to the lower mainstem of Sinmax Creek. Sediment inputs have also occurred as a result of historic mining in the vicinity of Homestake Creek at 5 km upstream on Sinmax Creek. Increased sensitivity of the mainstem below Homestake Creek and apparent channel destabilization may have been further compounded by recent high flow years and forest harvesting in the upper watershed.

The absence of sustainable inputs of large woody debris (LWD), and increased sediment loads through localized bank erosion, have led to the development of a wider, shallower, less stable channel in lower Sinmax Creek, with associated reductions in the quality and quantity of fish habitat. Reduced availability of LWD within the mainstem, and a near absence of intact riparian vegetation communities on adjacent agricultural lands, limits the potential for both short- and long-term natural recovery of the channel.

Assessments and Prescriptions
In 1997, an Interior Watershed Assessment Procedure (IWAP) was undertaken to study hydrologic conditions in the Sinmax Creek watershed. As part of the IWAP process, a roundtable committee of stakeholders was formed to discuss resource use interactions in the area. In response to recommendations resulting from the IWAP and the roundtable, overview stream channel, fish habitat and riparian assessments were conducted in 1998.

Prior to completion of the overview assessments, six extensive bank erosion sediment sources and destabilized channel sections (designated sites A through F) were identified in the lower mainstem. Field visits by a Hydrologic Engineer and a Habitat Biologist determined that rehabilitation of these sites was a critical precursor to stream channel recovery and fish habitat restoration. As it was possible to make reparations to these sites outside of the wetted area of the stream under low flow conditions, prescriptions were prepared.

To support the development of rehabilitation prescriptions, a fixed wing overview flight was completed and low-level aerial photography obtained. Selected photos were digitally scanned and used as base maps for illustrating proposed rehabilitation works at each of the six critical sites. The main purpose of these initial works was bank stabilization and sediment control. However, consideration was also given to the ultimate goal of restoring fish habitat values. Over-sized rock and rootwads were incorporated into proposed bank protection structures to act as roughness elements creating lower water velocity holding or rearing habitats for fish.

Although rehabilitation prescriptions were prepared for all six critical channel and bank stabilization sites, FRBC funding restrictions forced further prioritization of proposed works and construction was only undertaken at two sites during 1998. Letters of Agreement were signed with private landowners adjacent to each of these sites to permit machine access to the stream channel and encourage landowner cooperation with the goals and objectives of the restoration project. Specifically, an agreement was reached to provide a 20 m riparian setback from the newly established streambank with all new fencing to be maintained by the private landowners.

Rehabilitation Works

Rehabilitation works were initiated on October 13 and completed on October 21, 1998. Two rock toe key revetments were constructed at critical sites A and E along the right bank of Sinmax Creek (Figs. 3-24 and 3-25). Sites A and E are located approximately 350 m and 1700 m upstream of Adams Lake, respectively.

The construction of the rock toe key revetments proceeded as follows:

- Rip-rap was keyed into the channel bottom a minimum of 0.5 m below the existing low water level (PWL) to prevent under-scouring of the completed structure.
- Filter cloth was laid under and behind the rip-rap to prevent the flushing of fines.
- Cedar rootwads were incorporated into the rock revetment at a 5m spacing, with the root balls protruding into the stream. In some cases two or three smaller boles were placed together to form a larger rootwad. Some birch (*Betula spp.*) and fir boles were also added. Where required, rootwads were cabled to log deadmen.
- Rip-rap was placed to a minimum height of 1 m above PWL to complete the revetment.
- Revetments were backfilled with stream bank materials in 1 m lifts to the surrounding natural bank height. Brush layers consisting of live cottonwood cuttings were placed between each lift.

Upon completion, all disturbed areas were live staked with cottonwood cuttings, seeded with low growing grasses and mulched with hay to reduce surface erosion.

In addition to the completion of two revetments, materials (rock and rootwads) were stockpiled at rehabilitation sites A and D for future use.

Cost Summary

Professional fees / supervision	$ 7,985
Labour	$ 7,620
Equipment	$ 18,928
Materials	$ 11,090
Total	$ 45,623

Restoration Results

A total of 170 m of rock toe key revetment was constructed at two critical bank erosion sites on lower Sinmax Creek. The completed structures incorporated 65 pieces of LWD (rootwads) as roughness elements along the face of the revetments. Additional materials were stockpiled at remaining channel rehabilitation work sites.

Remaining restoration activities include completion of the six critical channel and bank stabilization sites, staging the downstream movement of accumulated sediments through channel bar revegetation, rehabilitation of riparian vegetation communities in areas affected by land clearing and restoring the complexity of fish habitat through instream works in lower Sinmax Creek.

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Figure 3-24. Site A on Sinmax Creek. Upstream view of channel rehabilitation.

Figure 3-25. Site E on Sinmax Creek. Downstream view of channel rehabilitation.

Trout Creek Bank and Channel Stabilization

Objectives
The primary objective of this project was to reduce sediment transport in Trout Creek for improved water quality by reducing streambank erosion and stabilizing gravel bars. A secondary objective was to improve fish habitat.

FRBC Region/ MELP Region/ MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Authors
Michael Zimmer and Phil Epp.

Proponent
The Corporation of the District of Summerland

Watershed
Trout Creek

Location
Trout Creek flows into Okanagan Lake at Summerland. The project area is located on the mainstem of Trout Creek approximately 27 km upstream (west) of Summerland.

Introduction
The 74,000 ha Trout Creek watershed is designated as a community watershed and is used as a domestic and irrigation water supply by the District of Summerland. Numerous water storage reservoirs are in place on Trout Creek and its tributaries.

Resident rainbow trout occur throughout most of the watershed with Eastern brook trout in some lakes and reaches. Kokanee spawn in the lower reach adjacent to Okanagan Lake and adfluvial rainbow trout spawn in the lower to mid-reaches of Trout Creek.

Timber harvesting activities have been conducted in the Trout Creek watershed over the past 60 years. Early logging tended to selective cutting in the lower elevations while recent logging has tended towards clearcuts at mid- and higher elevations. The current ECA is approximately 17%. Agricultural and urban land use are also prevalent along the lower reaches of Trout Creek.

Assessments and Prescriptions
Level 1 Fish Habitat Assessments and Present Functioning Condition Assessments were previously completed for Trout Creek and it's major tributaries. Various impacts were identified relating to eroding streambanks, poor riparian vegetation and limited fish habitat. A number of reaches within the Trout Creek watershed were identified as high priority for restoration.

Reach 7 was identified in the assessments as a significant sediment source with several km of streambank logged and cleared for agriculture. There is poor riparian vegetation, particularly in unfenced areas, with actively eroding streambanks and a recent channel avulsion. Restoration potential was high due to easy access and willing participation from the current landowner. Mr. Redicop has recently changed the grazing management practices in Reach 7 by fencing to reduce cattle access to many areas and reducing overall herd size. Slow natural recovery of riparian areas was beginning.

Reach 7 was surveyed during the prescription phase to identify and delineate specific problem sites. Sites were typically eroding banks of fine alluvium on outside bends and expansive unvegetated bars on the inside points. The greatest impacts were associated with the avulsion and the immediate downstream area.

Rehabilitation Work
Eroding banks were stabilized at eight sites within an 1800 m length of creek and point bars were planted at two sites within this length.

Bankside river spur structures were constructed at six of the sites. Structures were comprised of large wood, thinned trees, rootwads and boulders (Fig. 3-26). Anchoring of structures was by boulders, cable and epoxy or by buried deadman logs and cables. A blanket layer of thinned pine and fir trees was placed against the eroding bank. Large wood debris with rootwads attached were placed on top of the brush layer. Large wood pieces were spaced out along the subject bank at 6-8 m intervals, with rootwads facing upstream (Fig. 3-27). Thinned trees were then positioned on top of the structures. All thinned trees were secured to the LWD with spikes.

Deadman logs were used to anchor the structures at two sites. T-trenches were excavated 2.5-3 m back from the eroding bank to just below creek bed elevation. Cable was cinched and clamped around LWD pieces against the bank so cable was as low to the water as possible. The other end of the cable was wrapped around the deadman log and secured with clamps. The excavator was used to pull on the deadman to tighten the cable (Fig. 3-28). The deadman was then lowered into the T-trench when the cable was as tight as possible and the LWD against the bank was snug. The cables were attached and tightened in order to resist both bouyant and vector forces during high flow events. The T-trench was then infilled and compacted. Trench scars and exposed soil (Fig. 3-26) were also planted with willow stakes to promote riparian recovery.

The remaining four river spur structures were anchored by boulders and the HILTI epoxy and cable system.

At the remaining two bank protection sites, subject banks were pulled back to a more natural configuration and alignment and armored with graded rip-rap to above the bankfull height. The banks were further stabilized with supplemental planting of willow stakes to promote the establishment of riparian vegetation (Fig. 3-29).

Willow stakes were also planted on two large point bars using the excavator. The excavator was used to dig a vertical walled pit up to 1 m deep. Three or four willow stakes were placed into each pit and then infilled (Fig. 3-30).

The ground crew for all restoration components of this project were members of the Penticton Indian Band arranged through the First Nations of the Okanagan Similkameen Environmental Protections Society (FNOSEPS). The Penticton Indian Band has a special interest in land management within the Trout Creek watershed as this area falls within their traditional lands. Band members actively participated in this restoration process by providing local knowledge and restoration ideas.

Equipment

Equipment used included:

- Hitachi EX100 excavator.
- Rock truck.
- Farm tractor/loader.
- 4 X 4 pick-up truck.
- Chainsaw, rock drill, wood drill, hammers, cable cutters.

Materials

Material used included:

- 190 m of 3/8” steel-rope cable.
- 78 3/8” Crosby clamps.
- 10 tubes of HILTI HY150 epoxy.
- 1100 6” and 8” spikes.

Raw materials used at the eight sites included:

- 68 large wood pieces with rootwads attached.
- 552 thinned pine and fir trees.
- 24 rootwads.
- 21 deadman logs.
- 110 boulders.
- 135 m^3 rip-rap.
- 1456 willow stakes.

Cost Summary

Prescription development	$ 3,188
Heavy equipment and operator	$ 9,817
Labour	$ 8,268
Materials and rentals	$ 3,007
Project mgt. and on-site supervision	$ 18,722
Total	$ 43,002

Production Estimates

The primary purpose of the project was to stabilize eroding banks and revegetate gravel bars to reduce sediment movement in the creek, thereby improving water quality. Fish production estimates are not available, but the features installed are expected to create more complex habitat for resident rainbow trout and an increase in rainbow trout populations at this site is expected.

Monitoring / Future Work

All sites will be monitored post-freshet in 1999 to determine functionality and stability of structures. Willow plantings will also be monitored to determine success rate. Sites not addressed in 1998 may be prioritized for work in 1999 pending the directives of the principle proponent.

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Figure 3-28. Excavator used to tighten and place deadman logs into T-trenches.

Figure 3-26. Typical river spur structure using large wood pieces, thinned trees, rootwads and boulders; supplemented by planting willow stakes.

Figure 3-29. Channel manipulation using graded rip-rap and supplemented with planting willow stakes.

Figure 3-27. Typical river spur on outside bend. Note: large wood pieces, thinned trees and extensive bar planting with willow stakes.

Figure 3-30. Bar planting using excavator. Willow stakes (3-4) were planted per bucket, up to 1 m deep.

Granite Creek Stream Restoration Project

Objectives
The objectives of this project were to:
- stabilize two eroding banks in Granite Creek;
- reroute flow through a log jam and into the main channel of Granite Creek;
- dismantle a second log jam so as to concentrate low flows in the main channel of Granite Creek; and
- revegetate barren cobble/ gravel bars with black cottonwood nursery trees.

FRBC Region/ MELP Region/ MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Author
Christina Annand

Proponent
Ministry of Environment, Lands and Parks, Penticton.

Watershed
Tulameen River Watershed / Granite Creek

Location
The primary project site was located at 8.3 km on the Arrastra Creek Forest Service Road, from the Blakeburn Creek Forest Service Road (6 km) south of Coalmont, B.C. A second site (log jam manipulation) was located at 7.5 km on the Arrastra Creek Forest Service Road.

Introduction
The Granite Creek watershed, which includes Frenchy Creek and Arrastra Creek, drains in a northerly direction into the Tulameen River southeast of Coalmont, B.C. The Granite Creek watershed has previously been heavily logged, and in many areas cut blocks extended to the streambank. Other uses of the watershed have included placer mining, tourism, recreational camping, hunting and fishing.

In spite of the detrimental impacts resulting from historical logging and mining activities, and the 1:200 year flood event in 1995, the 1996 fish survey indicated the presence of rainbow trout throughout the Granite Creek watershed.

Assessments and Prescriptions
The 1996 Tulameen River Watershed Stream Assessment assessed fish habitat and indicated fish species distribution in the Tulameen River and eleven tributaries (IRC 1997). The 1996 report identified habitat restoration priority ratings (low, medium, or high) and indicated restoration/enhancement opportunities for each creek assessed in the Tulameen River watershed. In 1997, a log jam was fortified, three rootwads were anchored to deadmen and five bank sections were protected with LWD in Granite Creek, as well as riparian vegetation was restored in the headwaters of Frenchy Creek. In 1998, maintenance was conducted on the log jam fortified in 1997, a second log jam was manipulated, two bank sections were stabilized, and black cottonwood nursery trees were planted on cobble bars barren of vegetation.

Rehabilitation Work
The work included:
- Five large rootwads were placed into a void in the log jam (8.3 km Arrastra Creek Road) adjacent to the east bank to fortify the east portion of the log jam so that flows would be encouraged to pass under the log jam at the west portion of the log jam (Fig. 3-31). Three large logs in the west portion of the log jam were cut and placed along the east bank immediately upstream for bank protection. Branches were removed from the logs which spanned the flow in the western portion of the log jam to allow flows to pass through and to minimize entrapment of woody debris.
- The branches and small woody debris were removed from the log jam (7.5 km Arrastra Creek Road) to allow low flows to concentrate in the main channel and to minimize the volume of water deflected to the side channel which flowed adjacent to the eroding east bank. At the downstream end of the log jam, a large log was cut and angled into the creek bed to create and maintain a scour pool. A log which was located high on top of a point bar was relocated and imbedded into the point bar so that it extended into the creek at an angle which directed flows into the main channel and away from the side channel.

- A total of 130 boulders (approx. 1 m dia.) were used to construct four Bendway Rock Weirs and to protect the toe of the eroding bank between, and upstream of, the base of the four weirs (Figs. 3-32, 3-33). The Bendway Weirs were designed to divert high flows away from the toe of the slope and into the middle of the channel. Four trenches, approx. 0.8 - 1.2 m deep and 6 - 7 m long, were excavated in the creek at an upstream angle of 10 - 15^o from perpendicular to the eroding bank. Six to eight boulders were placed within the trench contiguously and the trench was back filled with previously excavated substrate. The next two parallel rows of six boulders each were placed on the creek bed contiguous to, and on either side of, the first row. The last row of boulders was placed on top of the two parallel rows.
- Each of the four Bendway Rock Weirs consisted of 25- 30 boulders approximately 1 m in diameter. The four rock weirs were placed at intervals ranging from 10.9 - 11.3 m and extended into the creek 6.7 - 8.7 m. Undersized boulders (approx. 0.5 m) were placed along the bank upstream of the weirs to provide additional protection to the eroding bank.
- A total of 400 willow branches were cut into 0.5 - 1.0 m lengths (min. of 3 nodes), and installed into two eroding banks manually at approximately 1- 1.5 m intervals from the toe of the slope to a height of 1- 2 m. Willow whips were planted along moisture veins whenever possible. Approximately 150 willow whips were planted in the eroding bank above the Bendway Rock Weirs.
- Eighteen black cottonwood nursery trees were planted in trenches 0.4 m deep and 2 - 4 m long in the cobble/gravel bars barren of vegetation in Granite Creek (Fig. 3-34). The trenches were backfilled and the point bars were regraded.
- A rootwad and deadman were placed by the excavator into two holes approximately 1.5 m deep in the cobble/gravel bar between the rootwads and deadmen which had been placed in the bank in 1997. The holes were back filled with cobble and gravel and the deadman and rootwad were cabled together with 1/2 inch galvanized steel cable.

Equipment

Equipment and labour used included:

- Excavator - Lower Nicola Backhoe Ltd.
- Rock trucks - Sanders & Company Ltd.
- Chainsaws - Valley Rentals Ltd.

Cost Summary

General Cost Breakdown:

PC 200 excavator	$ 4,096
Rock trucks	$ 2,000
Chainsaws	$ 400
Materials (rocks)	$ 2,895
Labour	$ 3,750
Site supervision	$ 5,880
Accommodation / subsistence	$ 1,500
Fish salvage equipment	$ 175
Anchoring crew and equipment	$ 1,500
Administration / reporting	$ 5,700
Total	$ 27,896

Production Estimates

The primary purpose of the project was to stabilize an eroding bank by rerouting high flows away from the toe of the bank and into the center of the channel using four Bendway Rock Weirs. Indirectly, the features installed are expected to create more complex habitat for resident rainbow trout. An increase in rainbow trout populations at this site is expected. Fish population data, as well as length and weight data, was collected during a fish salvage at the work site prior to instream works. We recommend conducting a fish population survey as part of the ongoing monitoring program.

Proposed Work for 1999

Monitoring of the 1998 rehabilitation works, a fish population survey, and modifications to structures, if necessary.

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Figure 3-31. View in a northerly direction of Granite Creek at the log jam at 8.3 km Arrastra Cr. Road. Note: partial clearing (west) and fortification (east). (24 September, 1998).

Figure 3-32. View in a northerly direction of Granite Creek facing downstream before installation of the Bendway Rock Weirs (21 July, 1998).

Figure 3-33. View in a northerly direction of Granite Creek facing downstream after installation of the Bendway Rock Weirs (24 September, 1998).

Figure 3-34. View in a northerly direction of the excavator digging a trench into which the black cottonwood nursery trees were planted (24 February, 1998).

Trapping Creek Stream Rehabilitation Project

Objectives

The objectives of this project are to:

- over a three year period (1997-1999), restore productive trout habitat and channel stability in a 15 km stretch of Trapping Creek;
- in 1998, conduct routine monitoring of structures installed in Trapping Creek in 1997, and adapt prescriptions to improve stability and function;
- in 1998, conduct maintenance of previously built structures as required;
- in 1998, initiate riparian restoration in a 1.5 km stretch of Trapping Creek;
- in 1998, use more manpower intensive options, such as horse loggers, rather than helicopters, to move logs from road to stream;
- in 1998, install signs to create on-site opportunities for visitors to learn about stream restoration.

FRBC Region / MELP Region / MOF Region

Thompson-Okanagan / Southern Interior / Kamloops

Author

Richard McCleary, Timberland Consultants Ltd. Selected photographs (Figs. 3-35 to 3-39) by Bob Verigin.

Proponent

Pope and Talbot Ltd.,
Boundary Timber Division.

Watershed

Trapping Creek, tributary to the West Kettle River.

Location

Sixteen km north of Beaverdell or 65 km southeast of Kelowna on Highway 33. Turn east on Trapping Creek Forest Service Road. The 1997 project area is lower 13 km of stream.

Introduction

Prior to forest development, Kelowna residents traveled to Trapping Creek to fish for rainbow trout. They reported numerous pools and good habitat supporting an abundance of fish. Logging, initiated in the 1970's, targeted the valley bottom spruce forests. Buffer strips were not retained along Trapping Creek. In the 1980's logging activities moved up onto adjacent slopes. Corresponding to forest development, fishermen observed a decrease in fish abundance and habitat quality. Today sport fishing is limited to stocked headwater lakes and larger rivers downstream of Trapping Creek.

In 1996, Ministry of Environment personnel identified Trapping Creek as a candidate for assessment and restoration work.

In 1997, a major effort to restore productive trout habitat in Trapping Creek was initiated. The project continued in 1998 and is scheduled for completion in 1999.

Assessments and Prescriptions

In 1996, preliminary assessments indicated sections of Trapping Creek lack important fish habitat attributes such as pools and cover.

In 1997, detailed assessments revealed that, Trapping Creek has low productivity, and with overall abundance of 3.9 trout per 100 m^2 in the 1997 treatment area. In contrast, Wilkinson Creek, the watershed established for an experimental control, has an overall abundance of 14.3 trout per 100 m^2. Signs of impact to habitat include very few pools, minimal cover, extensive bank erosion, and channel widening.

Due to low stream gradient, impacted reaches were well suited for restoration work including large woody debris placement. Restoration prescriptions were developed with assistance from Duane Kloes of the USFS.

In 1998, post-freshet routine structure monitoring was completed for all structures built in 1997. The most successful structures were lateral debris jams and boulder vortex weirs (Figs. 3-35 to 3-37). Single log structures such as diagonal LWD weirs were the least successful structures (Fig. 3-38). In 1998, structure design was modified to:

- use several shorter logs rather than a single full length log (i.e., full length logs were often cut in half);
- minimize the length of each piece of cable used in order to tightly secure logs to ballast;
- use more than one piece of cable to anchor logs subject to large forces; and
- use additional ballast.

Rehabilitation Work

During 1998, work on the Trapping Creek restoration project included:

- Riparian planting in moist growing sites along the streambanks and floodplain. A total of 2000 alder seedlings and 2000 willow cuttings were planted by hand over a 1.5 km distance.
- Falling and skidding of 2 loads (52.63 m^3) of pulpwood in the Upper Granby River watershed.
- Hauling the two loads to Trapping Creek and relocating another 2 loads that were previously hauled.
- Skidding logs into upper reaches using horses on approved skid-trails (Fig. 3-39).
- Undertaking maintenance of 1997 structures over a 1 km distance with a "spider" style excavator.
- Using an excavator for installation of new structures over a 3 km distance in upper Trapping Creek.
- Training a new anchoring crew with the help of WRP staff, Mark Potyrala.
- Completing anchoring of all structures built during the maintenance and construction phases (Fig. 3-40).
- Riparian planting using an excavator over a 3 km distance (2000 willow cuttings planted).
- Designing and constructing three interpretative trails trailhead signage and an interpretative trail brochure.

Equipment

- Log truck with self-loader.
- Yutani 200 excavator.
- John Deere 200 excavator.
- Two teams of horses for skidding logs.
- RYOBI ER382K 1.5" gas powered rotary hammer drill.
- ATOM 2000 drill attachment for STIHL 044A chainsaw.
- Cable sheers for up to 3/4" metal cable.

Materials

- 5,000 feet of cable.
- 200 Crosby clamps.
- 100 tubes of HY150 epoxy.
- 25 carbide tip rock drill bits.
- 6 wood auger bits (28"x5/8").

Cost Summary (1998)

Labour	$ 43,000
Equipment (excavators, logging equipment)	$ 28,000
Materials	$ 8,200
Monitoring	$ 6,450
Project management / supervision	$ 31,500
Signage production / installation	$ 5,500
Total	$122,650

Production Estimates

Similar projects have resulted in 2.7-fold increases in rainbow trout abundance, on average, based on biostandards (Koning and Keeley 1997).

Proposed Work for 1999

- Monitor existing structures during high flows and complete required maintenance.
- Install remaining structures in 3 km of stream.
- Evaluate riparian restoration efforts in July after freshet and one month of growing season.
- Conduct biological effectiveness monitoring of areas that were treated with LWD placement in 1997.

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Figure 3-35. Properly functioning lateral debris jam, installed in 1997.

Figure 3-36. Properly functioning boulder vortex weir, installed in 1997.

Figure 3-37. Properly functioning diagonal LWD weir, installed in 1997.

Figure 3-38. Failed diagonal LWD weir. Inadequate ballast/anchoring on left side, installed in 1997.

Figure 3-39. Horse logging team moving LWD from road through 25 year old regenerating forest for use in stream restoration.

Figure 3-40. Using a rotary hammer to drill holes in a boulder.

West Kettle River Restoration Demonstration Site

Objectives
The objectives of this project are to:

- provide demonstration of a variety of fish habitat rehabilitation techniques appropriate to large streams of the Interior for training courses;
- provide opportunities for community-based employment, mentoring and stewardship; and
- restore and protect fisheries and aquatic resources in a 1 km section of the West Kettle River.

FRBC Region / MELP Region / MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Authors
Pat Slaney and Wendell Koning.

Proponent
Ministry of Environment, Lands and Parks.

Partners
B.C. Conservation Foundation, and
Pope and Talbot Ltd., Midway Division.

Watershed
West Kettle River

Location
The West Kettle River parallels Highway 33, approximately 65 km southeast of Kelowna. The demonstration site containing the installed instream and bank structures is located upstream and downstream of the confluence with Little Goat Creek, or by highway 16 km south of the town of Beaverdell.

Introduction
The West Kettle River (mean monthly discharge May-August, 57.9, 36.9, 12.0 and 3.91 $m^3 \cdot s^{-1}$ respectively; max. daily discharge, in May 135 $m^3 \cdot s^{-1}$; drainage area, 1870 km^2; bankfull channel width, approximately 30-40 m) has been affected or impacted by past logging activities, agriculture, road construction (Highway 33), and by the now defunct, Kettle Valley Railroad (Fig. 3-41).

Previous studies have provided estimates of resident rainbow trout population numbers and habitat characteristics/capability in the West Kettle River and some of its tributaries. Historical data indicates low fish populations and limited fish habitat characteristics (lack of LWD and pools) due to past logging and other human impacts. For the past five years, the trout fishery has been largely managed under catch and release regulations, with potential for 40 cm fish in prime habitats.

Rehabilitation Work
Nine lateral log jams were installed within an 800 m section of the river in 1996-97 (see 1997-1998 Compendium for details). These were a triangular design to resist drag forces (Slaney et al. 1997) (Fig. 3-42) and are designed to replicate natural lateral jam templates in trout rivers, to provide cover for fish, and to create scour-pools. Each structure utilized a minimum of 3 large logs (hemlock, 0.4 - 1 m dia., 10 - 15 m length) with sufficient boulders (approx. 1 m^3 boulder volume, 2650 kg boulder mass per log) for ballast. This provided a safety factor of 2-3 over that provided in D'Aoust and Millar (1999) to account for debris accumulation.

In September, 1998 eleven additional structures were installed at the site, namely, one additional lateral log jam was added, plus 2 sets of 3 bank stabilization structures and 4 log box groins. The bank stabilization structures (designed and installed by R. Finnigan, BCCF) are comprised of logs secured to the bank and with boulder ballasting to prevent floatation (Fig. 3-43). The logs are designed as a ramp to catch woody debris and armour the bank, similar to natural templates. They are meant to be a softer solution for bank erosion protection, replacing the more conventional rock rip-rap. The box groins adapted from a European design described by Donat (1995) function to generate pool scour, plus provide cover for adult fish. They consist of 4 logs secured in a slot near the top of the streambank and sloping downwards at an upstream angle to the streamflow (Fig. 3-44).

There are now a total of 20 habitat and bank stabilization structures in the 800 m treated section including the 9 structures installed in 1996-97.

Physical and biological monitoring was carried out to assess the performance of the structures installed in 1996-97. In July 1998 a standardized snorkel census was used to count fish in the treated (9 structures) and control sites. Preliminary results are encouraging; in the treated section we counted 114 rainbow trout (at parr stage and larger) within or near the constructed lateral log jam structures (range, 0 - 25 rainbow trout per structure), and only 9 rainbow trout away from the structures in open water. In comparing the treated and control sections, swim counts revealed a density of 154 rainbow trout/km in the treated section, and 23 rainbow trout/km in the control section. More than 50% of the rainbow trout were between 10 - 20 cm in length, and about 15% were between 20-30 cm. One rainbow trout greater than 30 cm was counted, and the remainder were under 10 cm. We also observed and counted mountain whitefish and redside shiners (*Richardsonius balteatus*) at the installed log jams.

Physical stability monitoring of the lateral jams installed in summer 1997 was carried out to test for condition and durability. The structures were surveyed both prior to and post-flood in 1998. The results indicate that all structures to date are functional, although four had experienced minor lateral movement (D'Aoust and Millar 1999). One triangular structure did cause bank erosion illustrating the need to pre-fill or armour the bank at the upstream log at erodable sites (see D'Aoust and Millar 1999).

Finally, in November 1998 a limited program of riparian planting was initiated. This program consisted of willow whip and juvenile conifer planting at structure and bank stabilization sites.

Cost Summary

Construction of eleven new instream structures (including preparation, labour, materials, transport and machinery)	$ 26,500
Physical and biological monitoring	$ 3,000
Riparian planting	$ 2,000
Total cost in 1998	$ 31,500

Production Estimates

Based on the snorkel count results, the lateral log jam structures are likely capable of supporting 5 - 10 catchable- sized rainbow trout each for a total of 45 - 90 fish. At 2 "angler-days" per fish, 45 - 90 additional catchable fish are therefore estimated to provide 90 - 180 angler-days. This equates to an increase much greater than average biostandard values, but trout habitat was largely lacking and this is a large interior stream. One angler day is estimated to provide an economic return of $40 (Scarfe 1997) and thus it is probable that this type of project is economically viable. These predictions of carrying capacity will continue to be tested by more intensive effectiveness monitoring in the summer of 1999.

Proposed Work

In the summer-fall months of 1999 additional, diverse pool forming structures will be added to the West Kettle River to support WRP training courses in the Okanagan sub-region. Plans are to complete the 1.1 km demonstration section with the addition of riffle-pool work similar to that described in Newbury and Gaboury (1983). A more rigorous riparian assessment-restoration phase will be initiated to demonstrate treatment of some of the longer term watershed restoration issues. Monitoring will be continued to assess condition and durability of structures, and to obtain more detailed data on fish abundance.

Anecdotal field observations suggest pools associated with these lateral structures are now being fished relatively heavily by trout anglers. However, as the area is within a catch-and-release zone on the river, the removal of fish should be low. During the summer months of 1999, a creel census will be carried out to survey the number of fishers and "catch per unit effort" within the treated and control sections. This will assist in economic evaluation of this restoration demonstration.

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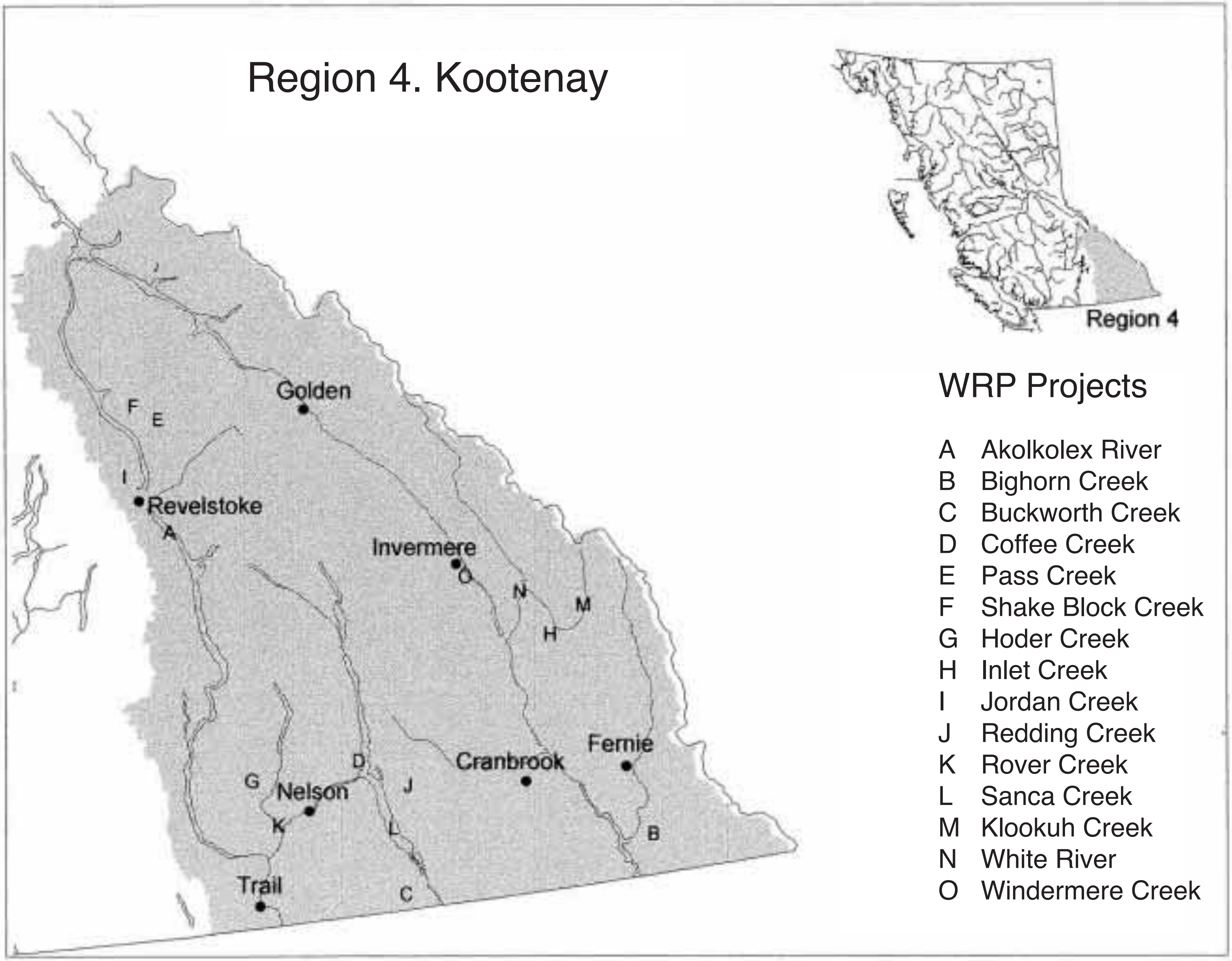
Figure 3-41. West Kettle River, revealing impacts from past logging, agriculture and highway development.

Figure 3- 42. A lateral log jam structure installed in the West Kettle River in 1997. The triangular structure accumulated debris during the spring flood.

Figure 3- 43. Bank stabilization structures (before ballasting) installed in the West Kettle River as an alternative to the use of rock rip-rap for erosion control.

Figure 3- 44. A box groin structure, one of four installed in the West Kettle River in 1998 to provide fish habitat cover and promote pool formation. (During construction, one log to be placed.)

Kootenay Region


Region 4. Kootenay
Region 4
Golden
Revelstoke
Invermere
Fernie
Cranbrook
Nelson
Trail
A
B
C
D
E
F
G
H
I
J
K
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M
N
O
WRP Projects
A Akolkolex River
B Bighorn Creek
C Buckworth Creek
D Coffee Creek
E Pass Creek
F Shake Block Creek
G Hoder Creek
H Inlet Creek
I Jordan Creek
J Redding Creek
K Rover Creek
L Sanca Creek
M Klookuh Creek
N White River
O Windermere Creek

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 4, Kootenay.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
A	**Kootenay**	Akolkolex River	Akolkolex River	11	5630729	427454	300-741700	00000UARL
B		Bighorn Creek	Bighorn Creek	11	5449832	648633	349-248100-04900-37900	00000ELKR
C		Buckworth Creek	Buckworth Creek	11	5435718	522101	340-434800-20400-38800	00000KOTL
D		Coffee Creek	Coffee Creek	11	5504952	506698	340-213100	00000KOTL
E		Downie Creek	Pass Creek	11	5697360	421045	300-784900-64300	00000REVL
F		Downie Creek	Shake Block Creek	11	5699539	420735	300-784900-59900	00000REVL
G		Hoder Creek	Hoder Creek	11	5501775	452101	340-047200-23300-58400	00000SLOC
H		Inlet Creek	Inlet Creek	11	5555843	610104	349-666200-32000-34500	00000KOTR
I		Jordan River	Jordan River	11	5651872	413211	300-754800	00000REVL
J		Redding Creek	Redding Creek	11	5489503	529458	349-411700-55000	00000SMAR
K		Rover Creek	Rover Creek	11	5477865	462899	340-062200	00000KOTL
L		Sanca Creek	Sanca Creek	11	5469143	519615	340-317400	00000KOTL
M		White River	Klookuh Creek	11	5568220	628345	349-666200-63100	00000KOTR
N		White River	White River	11	5578748	597810	349-666200	00000KOTR
O		Windermere Creek	Windermere Creek	11	5589719	571877	300-979100	00000COLR

Akolkolex River Fish and Wildlife Habitat Complex – Addition of Supplemental Water

Objectives

The objectives of this project were:

- to provide additional water to the off-channel habitat complex constructed during 1997 for westslope cutthroat trout (*O. clarki lewisi*);
- to increase cover within the main pond;
- to re-build the log vortex weirs constructed in 1997 within the main pond outlet channel and reduce the channels gradient to ensure access by juveniles;
- to construct a triangular lateral log jam structure within the outlet channel; and
- to improve water quality within the lower pond.

FRBC Region/ MELP Region/ MOF Region

Kootenay-Boundary / Kootenay / Nelson

Author

Cory S. Legebokow

Proponent

Ministry of Environment, Lands, and Parks implemented this project on behalf of Downie Street Sawmills Ltd. of Revelstoke, B.C.

Watershed

Akolkolex River

Location

The Akolkolex River is located within the Columbia Forest District approximately 25 km southeast of Revelstoke, B.C. It flows southwest for approximately 31 km from its glacial headwaters in the Duncan Ranges of the Selkirk Mountains to its confluence with the Columbia River.

The watershed restoration project is located at approximately 23.5 km on the Akolkolex River Mainline FSR at which point it is clearly visible from the road. Foot access to the groundwater channel portion of the project is gained from approximately 23.8 km (Standfast Creek) by a short walk of approximately 200 m. The intake box for the supplemental water line is located on the upstream side of the Standfast Creek culvert along the mainline FSR.

Introduction

The Akolkolex River watershed (Northern Columbia Mountains eco-region; Interior Cedar-Hemlock biogeoclimatic zone) was one of the first valleys to be harvested within the Revelstoke TSA and had 29 cutblocks harvested prior to 1987. Harvesting occurred primarily along the mainstem valley bottom and lower reaches of the main tributaries. During the winter of 1996, there was an avalanche, apparently induced by a lack of vegetative cover from forest harvesting activities. This resulted in the destruction of riparian and off-channel rearing habitats adjacent to the Akolkolex River mainstem.

The Akolkolex watershed contains westslope cutthroat and slimy sculpins (*Cottus cognatus*). The population of westslope cutthroat is of particular interest because it has not experienced any degree of introgressive hybridization with introduced rainbow trout as has occurred in many other watersheds (DeDominicis and Boag 1996a). The combination of previous forest harvesting practices and historical angling pressure is thought to have caused a decline of this provincially significant, endemic population of westslope cutthroat trout.

As a result, a mitigation project in 1997 developed off-channel winter rearing and spring high flow refuge habitat (refer to the Annual Compendium of Aquatic Rehabilitation Projects for the Watershed Restoration Program 1997 - 1998).

Assessments and Prescriptions

After completion of the project in the fall of 1997, flow contributions to the main pond were sufficient to maintain its connection with the Akolkolex mainstem. Monitoring in February 1998 revealed that flows had substantially reduced and that the main pond connection no longer existed. Spring melt increased flows significantly and the connection was regained. Fish began to access the main pond. As the freshet subsided, it became apparent that flows would not be adequate to maintain connection. By the end of July 1998, the main pond level had dropped to approximately 1 m below the invert of its outlet channel. Fish that had entered the main pond during a freshet became isolated. The lower pond maintained connection with the mainstem due to separate groundwater inputs. As a result, a supplemental water source was required to provide the necessary flow inputs to the main pond during winter and low flow summers. A reconnaissance determined that groundwater flows were inadequate to allow collection by perforated pipe. It was then decided that diversion of surface water from a nearby stream would be required. An engineering firm was retained to complete a detailed design for an intake box and associated pipeline. The detailed design was based on recommendations provided by a Fisheries Habitat Engineer. Calculations predicted the flow rate to be about 40 litres per second. This significant increase in flow combined with high pond levels during freshet resulted in the design of an emergency spillway near the main pond outlet.

Visual monitoring during 1998 suggested that the log vortex weirs within the main pond outlet channel were a barrier to juvenile fish. Fish observed in the main pond were all greater than 10 cm while the lower pond (which still had mainstem connection) contained numerous fish that were less than 10 cm. Based on the above, it was decided that a reduction in the outlet channel gradient and reconstruction of the log vortex weirs using rock would allow juvenile fish to access the main pond.

A small bay within the lower pond was found to be collecting iron leachate from the base of the main pond containment berm. This iron leachate was adversely affecting water quality within the lower pond. Removal of the small peninsula which created the bay would allow for the main pond outlet channel water to flush this area out and maintain acceptable water quality.

The outlet channel between the lower pond and the Akolkolex mainstem was void of adequate cover. As a result, a triangular lateral log jam structure was prescribed.

Rehabilitation Work

Works were initiated in late October 1998 and took approximately 12 days to complete. The construction involved the following sequence of activities:

- An intake box was constructed using a purchased polyethylene box tank (3.75' wide x 2.5' deep x 7' high). The front face of the box was removed and replaced with 2 x 6 boards and a sub-surface intake slot (Fig. 4-1). The slot could be moved up or down to accommodate various flow conditions. The lowest slot position was placed approximately 0.6 m above the bottom of the box in order to form a sediment trap within the box. The outlet hole was set to the same elevation as the lowest intake slot.
- A ditch 2 m deep x 240 m long was excavated from the headpond of the groundwater channel (which feeds the main pond) to the upstream end of the Standfast Creek culvert. Groundwater flows increased as the ditch approached Standfast Creek. As a result, "socked" perforated pipe was ordered to collect this groundwater (Fig. 4-1).
- A berm was built within Standfast Creek to divert water away from the intake box during installation (Fig. 4-1).
- The intake box was installed so that its lowest intake position would be 0.3 m below the invert of the culvert to ensure continuous flow. The box was tilted back so its exposed face was at the same angle as the streambank (Fig. 4-1).
- 240 m of 6" PVC Schedule 80 gasketted pipe was installed in the excavated ditch. 240 m of 4" socked "Big-O" pipe was placed adjacent to the PVC pipe to collect the groundwater encountered (Fig. 4-1).
- A 6" gate valve was installed at the groundwater channel end of the pipe.
- The headpond of the groundwater channel was deepened by 1.5 m to allow for a 1.0 m thick layer of rip-rap. The PVC and perforated pipe was placed within the rip-rap so that the water would percolate upwards.
- A 6' high metal box sleeve with a locking lid was placed over the valve. The valve was backfilled such that the metal box just protruded from the ground. A 6' long valve stem provides access to the valve.
- The diversion berm in Standfast Creek was removed and a rock vortex weir was constructed within the creek immediately upstream of the intake box. The weir promotes scour in order to keep the intake area clean (Fig. 4-2).

- An emergency spillway was constructed near the outlet of the main pond. The spillway is 3 m wide, is armoured with rip-rap and has a 2% gradient towards the main pond outlet channel.
- The material excavated for the spillway was added to the main pond outlet channel to increase its length, thereby reducing its gradient (Figs. 4-3 and 4-4).
- Rock vortex weirs were constructed in the new main pond outlet channel at approximately every 5 channel widths (Fig. 4-4).
- A portion of the small peninsula within the lower pond was removed to allow for the flushing of iron leachate collecting within the bay (Fig. 4-5). In effect, this turned the peninsula into an island (Fig. 4-6).
- Within 12 hours after opening the valve, the main pond level had risen to the point where water was again flowing down its outlet channel (Fig. 4-3).
- Large rootwads were secured to boulders using the cable/epoxy method and subsequently placed in the main pond to increase cover. A total of 10 rootwads were assembled but inclement weather only permitted the placement of 4 of them. The remaining 6 will be placed in 1999.
- A triangular lateral log jam structure was built within the outlet channel between the lower pond and the Akolkolex mainstem to provide cover for fish accessing the project area.
- All disturbed soils were grass seeded and planted with willow, red osier dogwood, and cottonwood whips. Fill planting was conducted in areas originally planted during 1997 to increase densities.

Equipment

Most of the work was accomplished by a Caterpiller 318 rubber tired excavator. Dump trucks hauled rip-rap to the site and a front end loader moved the rip-rap and stumps as well as backfilled the pipeline.

Cost Summary

Engineering	$ 8,000
Supervision	$ 7,000
Labour (4 displaced forest workers)	$ 6,200
Equipment	$ 10,300
Materials	$ 12,000
Total	$ 43,500

Production Estimates

Monitoring of the works completed in 1997 was initiated in February 1998. Minnow traps were set for 4 hours during water quality monitoring activities. No fish were captured.

In May 1998 several cutthroat trout were observed within the main pond. Sizes ranged from 10 - 20 cm based on visual observations. The lower pond had substantially more fish, most of which were less than 5 cm and were likely 1+ in age. Minnow traps were unsuccessful at capturing any of these fish. The lack of smaller sized fish within the main pond was likely a result of the v-log weirs creating a barrier during freshet flows. The subsequent isolation of the main pond due to dropping water levels prevented the complex from reaching its full capacity. Fish have not been observed within the groundwater channel or the diverted surface water source to date.

A post-freshet float is planned for 1999 in order to obtain quantitative data on fish use and age class distributions.

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Figure 4-1. Intake box and pipeline installation.

Figure 4-2. Completed intake box and vortex weir.

Figure 4-4. Main pond outlet channel after supplemental water and new vortex weirs.

Figure 4-3. Main pond outlet channel prior to supplemental water and new vortex weirs.

Figure 4-5. Lower pond prior to works. Note iron leachate (foreground) and main pond outlet channel (upper left).

Figure 4-6. Lower pond after removal of peninsula. Note clean water and longer outlet channel with increased flow from main pond.

Bighorn Creek - Reach 1 Slump Rehabilitation

Objectives
The Bighorn Creek Reach 1 rotational slump rehabilitation project objectives were to:

- prevent further undermining of the slump by moving the thalweg away from the toe of the slope;
- re-contour and stabilize the hillslope; and
- minimize further contributions of fine sediment to the stream.

FRBC Region / MELP Region / MOF Region
Kootenay-Boundary / Kootenay / Nelson

Author
Herb Tepper

Proponent
Ministry of Environment, Lands and Parks

Watershed
Bighorn Creek

Location
Reach 1 of Bighorn Creek is located at the 47 km mark on the Ram Creek Forest Service Road in the Cranbrook Forest District. The rehabilitation site is located at the top of Reach 1, approximately 600 m upstream of the Wigwam mainline road crossing of Bighorn Creek.

Introduction
Bighorn Creek is located in the southeast corner of British Columbia in the MacDonald Ranges of the Rocky Mountains, approximately 35 km south of Fernie. Bighorn Creek is a tributary to the Wigwam River which flows into the Elk River. Bighorn Creek is a fourth-order stream with a mainstem length of approximately 25 km and a drainage area of approximately 139 km^2. The watershed has an extensive history of disturbances, which include significant wildfires in the 1930's, bug infestations and subsequent large scale clear-cut logging in the headwaters. Three species of sportfish including westslope cutthroat trout, bull trout, and Rocky Mountain whitefish have been identified in the watershed. However, recent studies in the watershed only indicate the capture of westslope cutthroat trout and bull trout. As is the case in many interior watersheds, the Bighorn Creek watershed lacks historical data on fish distribution and population size, thus direct evidence of harvesting impacts in this watershed is not available.

Assessments and Prescriptions
The glaciolacustrine rotational slump was determined to have been caused by sub-surface piping of water and saturation of glaciolacustrine silts and clays. In combination with the lateral instability of the Bighorn Creek channel in the vicinity of the rotational slump (Babakaiff et al. 1998 c), columns of exposed glaciolacustrine deposits subject to physical weathering have continued to topple and accumulate at the toe of the slide. Erosion and undermining of the toe by fluvial processes, particularly during spring freshets, have elevated fine sediment delivery to the channel over the past eight years (Oliver 1998 b). Figures 4-7 and 4-8 illustrate the condition of the site prior to rehabilitation commencing.

Oliver's 1998 Level 2 Prescription Report prescribed a plan to rehabilitate both the channel adjacent to the slump as well as the slump itself. The rehabilitation plan included the following:

- redistribution of gravel from a mid-channel bar to help stabilize the toe of the slump;
- construction of two groynes intended to stabilize the reconstructed bar, encourage local scour at their streamward edge and provide additional cover for bull trout and westslope cutthroat trout;
- construction of two log jams intended to dissipate stream energy of expected critical flow lines during freshet and provide refuge for fish during high flow conditions;
- construction of a log deflector intended to train flood flows away from the south bank of the stream channel; and,
- re-contouring and bio-engineering of the slump.

Rehabilitation Work
Work was initiated at the beginning of August 1998 and the following steps were taken:

- All material (i.e., purchased logs, railway rails and cable) were trucked to a landing near the rehabilitation site and then flown to the site via a Lama helicopter.

- Gravel was redistributed, with an excavator, from the mid-channel bar to the base of the slump toe, at a 2% grade away from the slump.
- Two log groynes were then constructed in the newly formed gravel bar adjacent to the slump. The groynes were constructed in the following manner:
  - A trench (approximately 1.5 m below design grade) was dug with the excavator approximately perpendicular to the direction of stream flow.
  - Railway rails were driven vertically into the streambed (at the downstream side of the trench) to design height using a vibrator compactor attached to an excavator.
  - Logs were then placed against the rails and stacked on top of each other to design height. Cable (3/4") was wrapped around the bundle of logs and secured to the rails.
  - Finally the groyne was back-filled to the design elevation with cobble-sized material.
- As seen in Figures 4-9 and 4-10, each groyne had whole tree deflectors incorporated into their streamward edge to provide additional cover habitat.
- Log jams were constructed at the downstream end of the slump (Fig. 4-11) and at the upstream end of the slump (Fig. 4-12). The jams were secured through the use of railway rails, 3/4" cable and clamps. As well, several logs in the jams were partially buried in the substrate for additional security.
- A log defector was constructed at the start of the gravel bar seen in Figure 4-12 (just upstream of the picture).
- The slump hillslope was recontoured with an excavator to an angle of approximately 26°. The hillslope was then grass seeded and fertilized immediately following re-contouring. Following the first frost in the fall the hillslope was live stalked with willow cuttings.

Cost Summary

Project management and supervision	$ 5,150
Technical and unskilled labour	$ 16,750
Material and equipment purchase/rental	$ 23,132
Total	$ 45,032
Cost per structure	$ 7,505

Rehabilitation Results

This project rehabilitated approximately 1600 m^2 of stream channel (0.1 km) and 600 m^2 of hillslope, which should result in improved spawning, rearing and overwintering habitat for adfluvial bull trout and westslope cutthroat trout.

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Figure 4-7. A downstream view of the rotational slump.

Figure 4-8. Downstream view of the rotational slump. Note that the slump is composed of two distinctive levels/layers. The prescription only focused on the lower level as there is a terrace between the two levels, thus preventing material from the upper level reaching the creek.

Figure 4-9. The lower groyne with a whole tree deflector incorporated into it's streamward edge.

Figure 4-10. The upper groyne. Note the re-contoured hillslope in the background with grass seed starting to become established.

Figure 4-11. The lower log jam situated at the downstream end of the slump.

Figure 4-12. The upper log jam situated at the upstream end of the slump, seen on the left hand side of the photo. Also, seen in the background is the re-contoured revegetated hillslope.

Buckworth Creek Restoration

Objectives
The objectives of this project were threefold:
- to rehabilitate fish habitat in Buckworth Creek;
- to prepare the riparian area for planting next spring; and
- to provide employment for well trained First Nation workers.

FRBC Region / MELP Region / MOF Region
Kootenay-Boundary / Kootenay / Nelson

Author
Terry Anderson, Norm Deverney, and
Gerry Oliver.

Proponent
Ktunaxa Kinbasket Development Corporation

Watershed
Buckworth Creek

Location
Buckworth Creek is a third-order watershed which flows east into Corn Creek approximately 30 km west of the town of Creston.

Introduction
A wildfire in 1973 and the subsequent salvage logging in the riparian area of Reach 3 of Buckworth Creek are in part responsible for the stream channel lacking in structural elements such as large woody debris (LWD). Other impacts to the system are related to a failed stream crossing (wood box culverts) and road-related sediment sources. Restoration in this reach incorporated the immediate need for instream restoration and the long-term, future supply of LWD and overhead cover by beginning riparian treatments.

Assessments and Prescriptions
Results of Kokanee Forests Consulting Ltd. FHAP report indicated that forestry-related activities have had an impact on fish habitat within Reaches 3 and 5 of Buckworth Creek. The existing fish habitat can begin to be restored through immediate instream rehabilitation. The focus for the instream restoration was to increase pool habitat, LWD complexing and spawning areas. Instream restoration work comprised of removing barriers to upstream migration, constructing LWD structures, increasing pool habitat, protecting eroding banks and improving spawning habitat.

In 1997 some minor instream work was completed to better prepare for the restoration work in 1998. The work conducted in 1997 consisted of the partial removal of two fish barrier jams and the manipulation of channel spanning logs to allow the passage of juvenile fish and allow for better sediment transport downstream.

Results of the Riparian Assessment Procedure (RAP) by T. Johnson and Associates indicated that the riparian zone along the lower portion of Reach 3 was not sufficiently restocked. The prescription recommended to mound the soil to create plantable spots with subsequent planting of conifers the following spring. The mounding was not accomplished this fall due to inclement weather but will proceed in the spring of 1999.

Rehabilitation Work
To ensure upstream fish passage two more channel spanning log jams were manipulated in 1998. One in Reach 3 and one in Reach 5. An old log skid bridge which was failing and impairing sediment transport was also removed.

A total of 15 structures were placed in Reach 3 (Figs. 4-13 to 4-16). The structures were comprised of single and multiple log/rootwad placements comprised of triangular log structures and LWD bank revetments. These structures are designed to dissipate energy, promote scour in certain locations, increase habitat complexity and maintain bank stability. In all 49 logs, 38 rootwads, 32 boulders, 4 whole trees and 47m of cable were incorporated into the 15 structures.

Cost Summary

Labour/supervision	$ 19,500
Supplies	$ 3,500
Machine time costs	$ 7,000
Total	$ 30,000

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Figure 4-13. Structure #8 on Buckworth Creek, a revetment designed to minimize further undercutting of the stream bank and provide instream cover.

Figure 4-14. A log/rootwad structure on Buckworth Creek.

Figure 4-15. A log/rootwad structure on Buckworth Creek provides instream cover and protection to the stream bank.

Figure 4-16. A stoplog/rootwad structure on Buckworth Creek.

Coffee Creek Watershed Restoration

Objectives
The objective of this project was to increase spawning habitat by improving bedload migration and sorting by manipulating the over abundant large woody debris in Coffee Creek.

FRBC Region / MELP Region / MOF Region
Kootenay-Boundary / Kootenay / Nelson

Author
Michael Zimmer

Proponent
Meadow Creek Cedar Ltd. (MCC)

Watershed
Coffee Creek, Kootenay Lake, Kootenay River.

Location
The project area was a 1.1 km stretch on the mainstem of Coffee Creek located approximately 10 km upstream of Kootenay Lake.

Introduction
Historical timber harvest activities in the vicinity of the project area involved logging to the banks of Coffee Creek. This process effectively reduced available riparian vegetation while overloading the creek with lost or unsalvageable wood. The result has been extensive aggradation and lateral channel movement. The unsorted bedload conditions are thought to be limiting for mainstem spawning by the resident westslope cutthroat trout population.

Since timber harvest activities, Kokanee Glacier Provincial Park was extended and now includes the project area. Through the Watershed Restoration Program of FRBC, MCC was able to revisit the historically logged area to improve fish habitat.

The Queen's Bay Community Group (QBCG) has been active in watershed stewardship in this portion of the Kootenay Lake watershed and was involved in the delivery of this project. The restoration field crew was made up of two individuals from the QBCG.

Assessments and Prescriptions
Background fish habitat and riparian assessments were completed which had identified specific reaches of Coffee Creek as candidates for restoration. Restoration sites were chosen using habitat unit data from previous studies. Units that had high values for large wood debris (LWD) per m were targeted for detailed field investigation. Units with high LWD were prescribed restoration only if the LWD was limiting bedload transport (Fig. 4-17). Target habitat units were prescribed notch log or manipulation treatments dependent upon their limitations to bedload migration.

Attention was given to prescription concepts which did not require any engineering by way of cabling or other mechanical anchoring strategies. Structures were to conform to the Provincial Park mandate of maintaining a wilderness setting. Terrain and attention to the biological sensitivity of the area limited heavy equipment use and only hand tools were used.

Rehabilitation Work
Notch log structures were created where LWD spanned across the creek and perpendicular to flow (Fig. 4-18). Typically large sediment wedges were present upstream of these features. A minimum of one third of the log was removed, usually mid-channel (Fig. 4-19). This feature allowed for unrestricted bedload movement as well as maintaining instream cover.

LWD manipulation involved redistribution of wood within the channel where it was found to be limiting to bedload movement. Problematic LWD pieces were removed to the channel margins and complexed with existing lateral log jams. Log jams were also created in units with excessive LWD. Log jams were constructed by overlapping logs into a random matrix along a given bank. Large anchor logs were used to weigh down the log jam. Portions of the anchor logs were embedded into the creek bank for added stability. LWD manipulation also involved the partial removal of an on-line relic beaver dam (Figs. 4-20, 4-21).

The following restoration was completed to improve the capacity of Coffee Creek to transport and sort bedload:

- Two notch log and one LWD manipulation monitoring sites were set up.

- Manipulation of LWD was done by chainsaw winch and hand tools.
- Pool, riffle and glide habitat units (34) over 1100 m of creek were restored.
- Notch logs (58) were constructed.
- Large wood pieces (203) were manipulated.
- Lateral log jams (6) were constructed.
- One relic beaver dam was partially removed.

Equipment

Equipment used included:

- Chainsaw winch (Fig. 4-22).
- Multiple pulley system.
- Chainsaws.
- Hand saws, peaveys, shovels and polaskis.
- Canoe.
- 4 X 4 pick up truck.

Materials

Material used included:

- Mixed chainsaw fuel.
- Sunflower seed base bar and chain lubricant.

Monitoring

Channel form and substrate composition were monitored two months after restoration work at the three stations. Although at base flow conditions, some response in channel form was apparent. The three sites will be revisited post freshet in spring, 1999 to determine response after true channel forming flows.

Cost Summary

Queen's Bay Community Group	
(labour)	$ 8,125
Equipment rentals	$ 4,953
Monitoring	$ 5,967
Project management, prescription design,	
on-site supervision	$ 5,538
Total	$ 24,583

Production Estimates

It is anticipated that improved gravel sorting will occur now that the treated area of Coffee Creek can move bedload more effectively. Sorted gravel will then be available to resident westslope cutthroat trout for spawning. The mainstem of Coffee Creek should be able to support increased spawner numbers and ultimately increase recruitment.

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Figure 4-17. Typical perpendicular LWD limiting substrate migration, existing conditions.

Figure 4-18. Perpendicular LWD post-notch log prescription. Note: increased local velocity and active down-cutting under base flow conditions.

Figure 4-19. Notch log prescription. Work crew removing mid-portion of problem LWD.

Figure 4-20. Relic beaver dam across channel, existing conditions.

Figure 4-21. Relic beaver dam after partial removal. Note: channel down-cutting, shifted substrate and newly exposed LWD.

Figure 4-22. Chainsaw winch set up. Note: use of pulley, cable attachment to log and direction of pull for fail safe operation.

Pass Creek Channel Stabilization and Culvert Replacement

Objectives
To minimize dewatering of bull trout spawning and rearing habitats in the main channel of Pass Creek through minimizing enlargement of a natural avulsion channel as a mitigation action for forest development impacts elsewhere in the Downie Creek watershed. To remove two partially embedded culverts and replace these with a clear span bridge stream crossing to restore suitable upstream passage conditions for bull trout.

FRBC Region/MELP Region/MOF Region
Kootenay-Boundary / Kootenay / Nelson

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Proponent
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Watershed
Downie Creek

Location
Downie Creek is located on the east side of Lake Revelstoke, approximately 60 km north of Revelstoke, B.C. This watershed drains an area of approximately 610 km^2 and extends nearly 40 km into the Selkirk Mountains.

The Pass Creek culvert replacement work site is located at approximately 25 km on the Downie Forest Service Road (FSR). The channel stabilization work site is accessed via a blazed trail located at approximately 24.8 km on the FSR.

Introduction
Fish species known to occur in the Downie Creek watershed include bull trout, rainbow trout, kokanee salmon, mountain whitefish, largescale sucker (*Catostomus macrocheilus*) and various sculpins (*Cottus spp.*). The upstream distribution of these species is limited by a series of bedrock cascades at 16.5 km upstream on the Downie Creek main channel. Obligate resident populations of bull trout and mountain whitefish are the only fish known to occur above this point. Fish distributions in tributaries to Downie Creek are generally limited to the lowermost reaches by successive, permanent obstructions, steep stream gradients and unfavorable channel conditions upstream. These areas frequently coincide with past forest harvesting or road building activities.

Assessments and Prescriptions
An Overview Fish Habitat Assessment Procedure was completed for the Downie Creek watershed during 1996. The Fish Distribution Assessment for Pass Creek determined that bull trout were present to a distance of 6 km upstream and that as much as 2 km of additional stream length was potentially accessible to fish. Extensive main channel and side channel spawning and rearing habitats were also identified below the FSR crossing at 500 m upstream on Pass Creek. The Fish Habitat Condition Assessment noted that the twin-culvert FSR crossing of this stream formed a potential obstruction to the free movement of fish but suggested that some individuals were likely able to pass upstream under base flow conditions. The Preliminary Fish Habitat Evaluation determined that the combination of extensive fish distributions and high quality spawning and rearing habitats found in Pass Creek was unique amongst tributaries to the upper Downie Creek watershed. A Level 1 Fish Habitat Assessment was recommended for the lowermost reaches of this stream to support the development of regionally specific diagnostics of salmonid habitat condition.

An integrated program of Level 1 and 2 Fish Habitat and Riparian Assessment and Prescription Procedures was completed for the Downie Creek watershed during 1997. During the course of these assessments, a Hydrologic Engineer and a Habitat Biologist revisited the FSR crossing of Pass Creek to assess fish passage conditions under base stream flows. The assessment team determined that estimated water velocities of 1.4 m·s^{-1} and 1.5 m·s^{-1} through the twin 1600 mm x 9.2 m FSR culverts combined with cascading outlet flows to exceed the swimming capacity of resident bull trout. The assessment team also visited a site at 326 m upstream on Pass Creek where a naturally undercut spruce tree of 0.6 m diameter had recently toppled across the channel. The combined effect of flow attenuation by the trunk and a streambank breach caused by the lifting of the 3.5 m rootwad had been a partial right bank channel avulsion. At the time of the assessment, approximately one third of total stream flows were being diverted from active bull trout spawning redds in Pass Creek to a beaver dam complex located approximately 200 m to the north. Further enlargement of the avulsion channel was considered likely if it were left untreated. The assessment team concluded that this would reduce the capacity of all downstream fish habitats in Pass Creek due to partial or complete channel dewatering.

Fish habitat restoration prescriptions were subsequently prepared for Pass Creek to:

- Minimize dewatering of bull trout spawning and rearing habitats through stabilization of the channel avulsion site as a mitigation action for forest development impacts elsewhere in the Downie Creek watershed.
- Replace the partially embedded culverts at the FSR stream crossing with a clear span bridge to restore suitable upstream passage conditions for bull trout. Consultation with regional fish and fish habitat specialists of the Ministry of Environment, Lands and Parks determined that channel stabilization works were best accomplished manually so as to minimize any potential for the disturbance of adjacent riparian vegetation and high value fish habitats.

Rehabilitation Work

Channel stabilization works were initiated on August 15 and completed on August 19, 1998. The sequence of individual tasks was as follows:

- A three-person fish salvage crew erected 6 mm mesh stop nets to isolate lengths of the main and avulsion channel proposed for stabilization. Multiple pass electroshocking was then conducted to remove all fish present within the work site. Stop nets were maintained for the duration of instream works.
- A chainsaw was used to cut the toppled 0.6 m diameter spruce tree at a height of approximately 1.8 m above the root collar.
- A five-person hand crew reoriented the rootwad into an upright position at the head of the right bank avulsion channel using a 1814 kg lift capacity manual cable winch.
- A 10 m section of bole was cut from the remaining trunk of the toppled spruce and winched into position as a tilt log/flow deflector across the head of the right bank avulsion channel (Figs. 4-23 and 4-24). The bank end of the tilt log was attached to a sound spruce tree of 0.7 m diameter with 5/8” galvanized steel cable and cable clamps. The wetted end of the tilt log was weighted with 4 x 0.5 m diameter ballast boulders. These were attached to one another with 5/8” galvanized steel cable fed through augered holes in the tilt log and fastened with Hilti HY-150 epoxy as detailed in Chapter 9 of Watershed Restoration Technical Circular No. 9 (Slaney et al. 1997).
- A deflecting wall was constructed from 3 pieces of locally available, sound large woody debris (LWD) so as to closely fit the gap remaining at the head of the avulsion channel beneath the tilt log. The deflecting wall was reinforced with 2 pieces of 16 mm rebar driven through augered holes in its 3 component parts. It was then fastened in place with an additional 3 pieces of 16 mm rebar driven through augered holes in the tilt log and the deflecting wall and into the stream substrates.
- Additional pieces of 16 mm rebar were driven through augered holes in the tilt log to create a trash rack spanning minor gaps at the margins of the deflecting wall. These were backfilled with locally available LWD and large cobbles to complete closure of the avulsion channel.

Culvert replacement works were initiated on August 29 and completed on August 30, 1998. During this time the twin culverts of the FSR stream crossing were replaced with a clear span bridge deck of 40’ in length resting on pre-cast concrete lock-block abutments (Figs. 4-25 and 4-26). Heavy equipment requirements included a CAT 235B backhoe to position lock blocks, a gravel truck to provide backfill and a Komatsu 100 excavator to remove the embedded culverts and position the bridge deck.

Cost Summary

<u>Channel Stabilization Work Site</u>	
Pre-construction field review	$ 408
Site supervision	$ 1,879
Technical support (fish salvage)	$ 2,798
Technical support (labour)	$ 2,314
Materials	$ 180
Light equipment (cable winch)	$ 57
Sub-total	$ 7,636

<u>Culvert Replacement Work Site</u>	
Site survey	$ 756
Site plan	$ 1,775
Site supervision	$ 640
Materials	$ 25,492
Heavy equipment	$ 7,296
Sub-total	$ 35,959
Total cost	$ 43,595

Restoration Benefits

Completed channel stabilization works minimized the dewatering effects of a natural channel avulsion on 314 m of high quality bull trout spawning and rearing habitats in lower Pass Creek. The potential for enlargement of the avulsion channel was also reduced. Culvert replacement works reduced average base flow water velocities at the FSR crossing of Pass Creek from between 1.5 $m \cdot s^{-1}$ and 1.6 $m \cdot s^{-1}$ through twin steel culverts to less than 1.0 $m \cdot s^{-1}$ over a natural stream bed. Fish access to as much as 8 km of upstream habitats was thus assured.

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Figure 4-23. Pre-work downstream view of rootwad and bole of toppled spruce and right bank avulsion channel on Pass Creek.

Figure 4-24. Post-work downstream view of spruce tilt log, re-oriented rootwad and re-established stream course on Pass Creek.

Figure 4-25. Pre-work view of partially embedded culverts posing a velocity barrier to the upstream movement of bull trout in Pass Creek.

Figure 4-26. Post-work view of clear span bridge stream crossing of Pass Creek.

"Shake Block Creek" Fish Access Improvement, Channel Stabilization and Sediment Control

Objectives
To increase fish access past a natural but impermanent falls and reinforce a naturally low streambank as mitigation actions for forest development impacts elsewhere in the Downie Creek watershed. To replace a development-related debris jam and sediment wedge with log drop structures to stabilize the stream channel and increase the area of accessible spawning and rearing habitats for resident bull trout. To restore riparian vegetation communities and construct a "safe-fail" stream crossing to minimize potential sediment sources and encourage lateral channel stability.

FRBC Region/MELP Region/MOF Region
Kootenay-Boundary / Kootenay / Nelson

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Watershed
Downie Creek

Location
Downie Creek is located on the east side of Lake Revelstoke, approximately 60 km north of Revelstoke, B.C. This watershed drains an area of approximately 610 km^2 and extends nearly 40 km into the Selkirk Mountains.

The "Shake Block Creek" watershed restoration project is located at approximately 22.7 km on the North Downie Forest Service Road (FSR). A portion of the works completed are directly accessible from the FSR. Two additional work sites may be accessed by walking downstream for distances of 64 m and 175 m, respectively.

Introduction
Fish species known to occur in the Downie Creek watershed include bull trout, rainbow trout, kokanee salmon, mountain whitefish, largescale sucker and various sculpins. The upstream distribution of these species is limited by a series of bedrock cascades at 16.5 km upstream on the Downie Creek main channel. Obligate resident populations of bull trout and mountain whitefish are the only fish known to occur above this point. Fish distributions in tributaries to Downie Creek are generally limited to the lowermost reaches by successive, permanent obstructions, steep stream gradients and unfavorable channel conditions upstream. These areas frequently coincide with past forest harvesting or road building activities.

Assessments and Prescriptions
An Overview Fish Habitat Assessment Procedure was completed for the Downie Creek watershed during 1996. The Fish Distribution Assessment for "Shake Block Creek" determined that bull trout were present above a 0.8 m falls at 75 m upstream. The Fish Habitat Condition Assessment identified a debris jam consisting of logging debris and side cast road material at 220 m upstream and this was characterized as a development-related obstruction to the upstream movement of fish. The Preliminary Fish Habitat Evaluation recommended that a restoration prescription be developed to remove the development-related debris jam.

An integrated program of Level 1 and 2 Fish Habitat and Riparian Assessment and Prescription Procedures was completed for the Downie Creek watershed during 1997. A Level 2 Fish Habitat Assessment was completed for "Shake Block Creek" by an interdisciplinary team consisting of a Hydrologic Engineer and a Habitat Biologist. The assessment team determined that headcutting of natural clay deposits perched over boulders and large woody debris (LWD) had formed the 0.8 m falls at 75 m upstream. The presence of bull trout upstream of these falls was attributed to occasional fish access from Downie Creek to "Shake Block Creek" through adjacent flood channels or occasional channel downcutting through the restrictive clay layer. A low right streambank was identified at 186 m upstream on "Shake Block Creek" as a potential avulsion site should upstream sediment wedges related to forest development be released. The backfilled debris jam at 220 m upstream was confirmed as an obstruction to fish passage and as a threat to downstream fish habitats if the jam was breached and its accumulated sediments released. Cut logs and cedar blocks incorporated into the jam confirmed that it had originated with logging or road building activities. Additional logging debris and side cast road material had inhibited the recovery of adjacent riparian vegetation and maintained active sediment sources between the debris jam and the FSR at 250 m upstream. Lastly, a high point in the FSR at the crossing of "Shake Block Creek" and an incomplete right bank levee immediately upstream represented a potential avulsion site and sediment source should the culvert become blocked.

A fish habitat restoration prescription was subsequently prepared for "Shake Block Creek" to:

- Increase fish access past the natural falls at 75 m upstream and reinforce the naturally low stream bank at 186 m upstream by hand as mitigation actions for forest development impacts elsewhere in the Downie Creek watershed.
- Rehabilitate the development-related debris jam and sediment wedge at 220 m upstream by replacement with log drop structures at regular intervals to stabilize the stream channel and increase the area of accessible spawning and rearing habitats for resident bull trout.
- Pull back and scatter side cast logging debris, revegetate exposed soils with local brush species, construct a shallow, armored swale at the FSR stream crossing and complete the FSR levee to minimize potential sediment sources and encourage lateral channel stability. Log drop structures were prescribed based on natural templates and functional habitat units observed downstream.

Rehabilitation Work

Channel rehabilitation works were initiated on August 18 and completed on August 24, 1998. Riparian revegetation was completed on October 21, 1998. The sequence of individual tasks was as follows:

- A two person hand crew used spades and pry bars to excavate channel substrates at 75 m upstream to encourage downcutting through the perched clay layer and eliminate the 0.8 m falls (Figs. 4-27 and 4-28).
- The same two person hand crew used the largest of locally available cobbles and boulders to reinforce the low right stream bank at 186 m upstream.
- A two person fish salvage crew erected 6 mm mesh stop nets at 200 m upstream and above the FSR stream crossing to isolate the stream length proposed for debris jam removal and channel stabilization. Multiple pass electroshocking was then conducted to remove all fish present within the work site. A straw bale check dam was constructed immediately upstream of the lower stop net to trap fine sediment generated by instream activities. Individual straw bales were secured in place with 0.8 m lengths of 16 mm rebar driven into the stream substrates. Both stop nets and the straw check dam were maintained for the duration of instream works. In addition, a sheet of 1/2" plywood lined with plastic sheeting was placed over the culvert inlet at the FSR to create a sump and water pumps totaling 108 $L \cdot s^{-1}$ capacity were used to divert between one third and one half of stream flows around the site while works were in progress.
- A Komatsu 100 excavator pulled back and piled logging debris and side cast road material to create a 10 m working width on both streambanks adjacent to the debris jam work site. The sediment wedge behind the debris jam was then excavated to create a stream bed of approximately 10% grade between the jam and the FSR; excavated sediments consisted almost entirely of fine mineral soils and decaying organic matter rather that the alluvial material that had been expected. The jam itself was removed next. The excavator and a two person hand crew then constructed a series of 5 log drop structures between the previous location of the debris jam and the FSR. These structures were upstream v-weirs designed and installed in accordance with Chapter 11 of Watershed Restoration Technical Circular No. 9 (Allan and Lowe 1997). Structural members were 0.4 m diameter cedar logs keyed a minimum of 2 m into adjacent stream banks and 0.4 m

into stream substrates. These were lined with filter cloth on their upstream side and backfilled with clean cobble and gravel substrates to create stable vertical drops at a minimum spacing of 4 m. Streambanks within the work site were then out-sloped to a 1:1 angle of repose and available LWD was dispersed to stabilize disturbed soils (Figs. 4-29 and 4-30).

- A shallow, armored swale was constructed directly over the culverted FSR stream crossing. The swale was excavated to a maximum depth of 0.4 m and lined with clean cobble to provide flood relief while maintaining lateral channel stability should the culvert become blocked. The right bank levee upstream of the FSR crossing was then reinforced sufficiently to redirect channel overflows to the swale (Figs. 4-31 and 4-32).
- Riparian vegetation was re-established through grass seeding and live stake planting of local brush species at a spacing of 1 m. Devil's Club (*Oplopanax horridus*) and red osier dogwood cuttings were treated with rooting hormone and planted only within 2.5 m of the wetted stream margin while black cottonwood live stakes were planted over all disturbed soils.

Cost Summary

Pre-construction field review	$ 408
Site supervision	$ 5,099
Technical support (fish salvage)	$ 830
Technical support (labour)	$ 5,188
Materials	$ 4,741
Light equipment (water pumps)	$ 1,962
Heavy equipment	$ 4,579
Total	$ 22,807
Cost per structure (9)	$ 2,851

Production Estimates

Chapter 3 of Watershed Restoration Technical Circular No. 9 (Koning and Keely 1997) provides little information regarding biostandards for mainstem complexing in small bull trout streams. However, based on past sampling in the watershed, it is anticipated that plunge pools downstream of the 5 completed log drop structures will provide spawning and rearing habitat for a total of 8 to 12 fish. In addition, fish access improvement, channel stabilization and sediment control works have safeguarded approximately 250 m of natural instream habitats in "Shake Block Creek".

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Figure 4-27. Pre-work of 0.8 m falls at 75 m upstream "Shake Block Creek".

Figure 4-28. Post-work view of excavated channel at 75 m upstream on "Shake Block Creek".

Figure 4-29. Pre-work view of development-related debris jam at 220 m upstream of "Shake Block Creek".

Figure 4-30. Post-work view of upstream v-wiers at 220 m upstream on "Shake Block Creek".

Figure 4-31. Pre-work view of the North Downie FSR crossing of "Shake Block Creek".

Figure 4-32. Post-work view of cobble swale and ditch block levee at the North Downie FSR crossing of "Shake Block Creek".

Hoder Creek Large Woody Debris Placement

Objectives
The objectives of this project were to increase pool frequency, wood cover in pools and channel stability in order to increase bull trout productivity in a section of stream impacted by previous forest harvesting.

FRBC Region / MELP Region / MOF Region
Kootenay-Boundary / Kootenay / Nelson

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Proponent
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Watershed
Hoder Creek

Location
Hoder Creek is located on the southeastern portion of the Valhalla Mountain Range. This range is located on the western slope of the Slocan Valley, in the South Columbia Mountains of British Columbia. Hoder Creek flows into Little Slocan Lakes, the source of the Little Slocan River. The Little Slocan River flows into the Slocan River near the village of Vallican.

Introduction
The mainstem of Hoder Creek is 20 km long. Waterfalls block the upstream migration of fish from Little Slocan Lakes and a resident population of bull trout inhabits most of Hoder Creek. The valley receives abundant precipitation and cedar/hemlock forests occur along much of the stream. In the early 1970's, logging roads were constructed into the back end of Hoder Creek valley. To date, 35% of the streamside forests have been harvested. These areas are at various stages of regeneration.

Bull trout are a sensitive fish that are adapted to cold water temperatures, frequent pools, and abundant LWD for cover. These habitat elements can be compromised during streamside logging. Bull trout are also vulnerable to over-harvest from angling. A natural bedrock plunge pool located at a bridge crossing has been a popular fishing spot for more than one generation.

As is many areas of it's range, the bull trout in Hoder Creek have been subject to habitat loss and heavy fishing pressure.

Assessments and Prescriptions
In 1997, Slocan Forest Products initiated Overview Fish Habitat Assessments within Tree Farm Licence #3. Hoder Creek was found to support the only resident bull trout population within the TFL. Potential impacts from streamside logging were apparent along low gradient areas. A Level 1 survey conducted in 1998 indicated that these logged areas had fewer pools, a wider channel and less abundant LWD. Areas of eroding streambanks were also noted. The reaches with streamside logging also supported fewer fish. Mean length of bull trout captured was also less in logged areas.

Prescriptions using LWD placement were developed to restore fish habitat and stabilize eroding streambanks. Prescriptions were also developed to restore slope stability and vegetation on two landslides into Hoder Creek.

Rehabilitation Work
Two loads of dry cedar logs were obtained from nearby road construction. Skid corridors, approved by the Forest Service and Slocan Forest Products were used by a local logging contractor for skidding logs from the road to the stream. An excavator was used to distribute the logs along the stream channel throughout the project area.

Structures built included: lateral debris jams (Fig. 4-33); debris catchers to promote bar stabilization and channel narrowing (Fig. 4-34); boulder vortex weirs (Fig. 4-35); lateral debris jams incorporated into bank revetments (Fig. 4-36); and structures intended to improve bank-side cover for fish (Figs. 4-37). Anchors included ballast boulders, as well as logs pushed vertically or horizontally into areas with softer substrate.

Bioengineering was also completed on a single landslide. The range of techniques used included wattle fences, modified brush layers, smiles, and buried live pole in gullies (Fig. 4-38).

Cost Summary

Materials and equipment purchase	$ 7,500
Labour	$ 16,000
Equipment	$ 20,000
Assessments / prescriptions	$ 21,700
Construction supervision	$ 4,000
Total	$ 69,200

Monitoring / Future Work

Baseline fish and fish habitat information has been collected. In addition detailed topographic surveys of all structures at two reference sites have been completed. This information should be used to evaluate project success in future years. Routine structure monitoring and a re-survey of reference sites should be completed after the 1999 freshet in order to determine project success and determine maintenance requirements. The findings from these evaluations should be incorporated into the design of other stream restoration projects planned for the TFL in 1999.

One of the restoration sites is located at an ideal viewing point along the Hoder Creek Forest Service Road. This road is the most popular access route for visitors to Valhalla Provincial Park. A kiosk is planned for this location. The kiosk will support a two-sided sign to provide a message about the Hoder Creek bull trout. The first side of the sign will describe the threats to bull trout from over-fishing and the new fishing regulations that are intended to conserve existing stocks. The second sign will explain bull trout habitat requirements and describe the stream restoration efforts. This sign should be constructed and installed in late spring or early summer in 1999.

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Figure 4-33. Lateral debris jam to provide additional cover in side channel.

Figure 4-34. Debris catcher at the top end of a meander bend intended to promote bar stabilization and channel narrowing.

Figure 4-35. Boulder vortex weir and lateral debris jam to enhance existing deep pool habitat with additional depth and cover.

Figure 4-36. Bank revetment with rootwads and lateral debris jam to stabilize toe of slope and increase cover.

Figure 4-37. Cover log to increase cover, anchored to large boulders in existing pool.

Figure 4-38. Landslide stabilization using wattle fences, live smiles and buried live pole drains (in gullies).

Inlet Creek Restoration

Objectives
To complete a variety of creek and channel restoration techniques to restore critical fish habitat features for a regionally significant rainbow trout population, including:

- debris removals with gradient control to allow fish passage;
- revegetation of streambanks and adjacent riparian edge;
- stabilization of point bars and streambanks;
- promoting single channel and pool development; and
- providing sediment and erosion control.

FRBC Region / MELP Region / MOF Region
Kootenay-Boundary / Kootenay / Nelson

Author
Sue Crowley

Proponent
Crestbrook Forest Industry Ltd. in partnership with the B.C. Ministry of Environment, Lands and Parks (MELP).

Watershed
Inlet Creek, tributary to Whiteswan Lake.

Location
Inlet Creek originates in the Van Nostrand Range of the Rocky Mountains in southeastern B.C. and flows to its confluence with Whiteswan Lake. The lower two reaches lie within Whiteswan Lake Provincial Park. The project area is located approximately 34 km southeast of Canal Flats, B.C.

Introduction
Inlet Creek is a third-order stream with a mainstem length of approximately 10 km, and total drainage basin area of approximately 3056 ha. The mainstem has eight identified reaches up to 3300 m in length.

The lower reaches are located in the Dry Cool Montane Spruce Subzone (MSdk) at an elevation of 1150 m. The channel slope remains constant at 1 to 3% over the project area, with stream bankfull width ranging from 4.5 to 5.5 m and the bankfull depth 0.3 to 0.8 m.

Approximately 61% of the operable forest area of the watershed has been cut through harvesting operations, mostly concentrated on the hillslopes above the Inlet Creek mainstem and headwater tributary drainages.

Inlet Creek is a regionally significant fish stream for the Ministry of Environment due to its excellent rearing potential and valuable spawning habitat for rainbow trout, resident to Whiteswan Lake. As a result, the creek is closed to angling to protect the juvenile rearing and adult spawning population. Rainbow trout spawning each spring primarily utilize the lower reaches of the mainstem channel, where restoration efforts have been focused.

Assessments and Prescriptions
Fish Inventory data (FHIIP, l993; Amos et al. l997) documents exclusive rainbow trout presence within Inlet Creek.

In l998, a water quality monitoring station was established within Reach 1 of Inlet Creek for site specific water quality objective monitoring and representative core data collection.

Overview and Level 1 Fish Habitat Assessment Procedures (FHAP) were conducted in 1997 to determine the location, nature and extent of the impacts within the Inlet Creek watershed, and assess the feasibility of restoration within each reach. Based on these results, preliminary restoration concepts were developed for 6 high priority sites in Reaches 1 and 2 and presented through a Level 2 FHAP detailed design in l998 (Agra Earth and Environmental Nov. 1998).

Prescriptions were developed to address specific habitat requirements and identified limitations for the rainbow trout, including lack of streambank LWD and vegetation, scarcity of pools, fish passage obstructions, sediment and erosion concerns, and aggraded channel conditions. Low site impact methodology was prescribed due to the fisheries importance of Inlet Creek, and its location in the Whiteswan Provincial Park with the associated high recreational exposure.

Rehabilitation Work
Field work was initiated in November 1998 to ensure project completion during an October to

April fisheries work window, and was successfully accomplished early in this time frame. Horse logging was effectively utilized for movement and placement of all large materials, and resulted in minimal site disturbance (Fig. 4-39).

Specific site works included:

- A rootwad tree revetment was placed to stabilize an eroding streambank, with log wall armoring upstream to prevent erosion and to secure the upstream end of the works (Fig. 4-40). Live dogwood and willow fascines and cuttings were placed at the opposite bank toe to provide erosion protection, bank stabilization and revegetation. The rootwad and log materials were locally salvaged and skidded to the restoration site using the horses. They were placed in hand excavated trenches and secured with 5/8 inch cable through deadman logs and rebar. The facines and cuttings were also cut and prepared on site.
- Pool development will be promoted by placement of two log spurs (oriented upstream) with a triangular lateral log jam on the adjacent bank. The log spurs were buried at the upstream end, with the exposed bank end secured with 5/8 inch cable to boulders and existing LWD.
- To improve fish passage and promote pool development, a cross-channel debris jam of cut logs was removed and replaced with two log V-weirs which will maintain gradient control. Hand excavated trenches were prepared in the creek bed for the logs to slope down to the center of the weir, directing the flow to the middle of the stream. The apex logs were bevel cut and pinned, with the streambank ends buried approx. 1.5 m and secured with existing and supplemented LWD.
- Point bar stabilization and vegetation will prevent fish entrapment and promote a single narrow channel with a deep pool development. A log spur was placed at the upstream end of the point bar, ballasted with boulders and oriented upstream. Willow and dogwood brush traverses were placed in trenches on the bar, anchored with fascines and live stakes prepared on site (Fig. 4-41).
- Two sites involved the partial removal of debris jams consisting of logging slash and encroaching snow-pressed birch, with the revegetation and stabilization of the exposed bar and streambank. At one of the sites, two upstream log spurs were also placed to promote pool development.

Comments

There was a good local supply of dogwood and willow, as well as windfall and LWD material which was suitable for project use. Several days of site preparation was completed by hand crews to maximize the efficiency of the horse logging crew. Natural examples of typical pool and diagonal log spurs were observed on Inlet Creek which were used as templates for the field crew during a pre-construction walk through. The use of horse logging for restoration activities proved successful in providing low site impact and cost effective methodology.

Cost Summary

Project planning, management and supervision	$ 23,400
Technical and crew labour	$ 10,700
Horse logging crew	$ 11,400
Material and equipment purchase/rental	$ 6,500
Total	$ 52,000

Rehabilitation Results

This project rehabilitated approximately 1000 m^2 of stream channel, incorporating 10 structures which should result in high quality spawning, rearing and overwintering habitat for rainbow trout in the lower reaches of Inlet Creek.

Post-construction Monitoring

Site monitoring and evaluation will be conducted post-freshet 1999. Continued site restoration is scheduled for additional high priority sites during the 1999 fisheries work window. The monitoring program will incorporate fluvial geomorphic, fish abundance and cost breakdown.

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Figure 4-39. Manual labor and horse logging techniques were effective in minimizing impacts to Inlet Creek and adjacent habitat.

Figure 4-40. Works in progress: streambank stabilization on Inlet Creek incorporating rootwad revetment and log wall armoring.

Figure 4-41. Bar stabilization using brush traverses.

Jordan River Mainstem Habitat Complexing

Objectives
To increase habitat complexity within Reach 3 of the Jordan River mainstem by providing rearing cover for resident bull trout, westslope cutthroat trout and rainbow trout through the placement of boulder clusters and triangular lateral log jams.

FRBC Region/ MELP Region/ MOF Region
Kootenay-Boundary / Kootenay / Nelson

Author
Cory S. Legebokow

Proponent
MELP was the lead proponent for this project.

Watershed
Jordan River

Location
The Jordan River is located within the Columbia Forest District approximately 3 km northwest of Revelstoke, B.C., and flows southeast for approximately 39 km from its glacial headwaters in the Jordan Range of the Monashee Mountains to its confluence with the Columbia River. The watershed has an area of 342 km^2.

The watershed restoration project is located at approximately 9 km adjacent to the Jordan River Mainline FSR.

Introduction
The Jordan River watershed (Northern Columbia Mountains eco-region; Interior Cedar-Hemlock, Engelmann Spruce-Subalpine, and Alpine Tundra biogeoclimatic zones) was among the first valleys to be harvested within the Revelstoke TSA and has had 15 cutblocks harvested within the riparian management area (DeDominicis and Duane 1998).

Reach 1 of the Jordan River is accessible by adfluvial populations of bull trout, kokanee, rainbow trout and mountain whitefish. The remainder of the watershed contains resident populations of bull trout, rainbow trout, westslope cutthroat trout as well as rainbow-westslope cutthroat hybrids and slimy sculpins (DeDominicis and Beers 1998). One of the systems main tributaries contains an endemic population of westslope cutthroat trout (Bennett and Corbett 1994).

Assessments and Prescriptions
The Fish Habitat Assessment conducted during 1996/97 identified Reach 3 as lacking in instream cover. This reach has experienced the highest level of forest development with more than half of the riparian areas harvested to both banks. Large woody debris is rare throughout the reach with occasional boulders providing intermittent cover. Acceptable spawning areas are limited to "pockets" of material between cobbles and behind boulders where they exist. The mainline FSR is often within 10 m of the mainstem throughout the reach. The reach has an average gradient of 2%. Substrate in this reach is primarily cobble-gravel and is moderately embedded (DeDominicis and Boag 1996 b).

Initial restoration prescriptions ranked boulder placement at 3 locations within Reach 3 as a high priority (DeDominicis and Beers 1998). A detailed prescription was developed by MELP staff during the spring of 1998 for one of these sites which is approximately 200 m long (Fig. 4-42). Based on the lack of large woody debris within this reach, the prescription also included the design of 3 triangular lateral log jam structures.

Rehabilitation Work
Works were initiated in August 1998 and took 10 days to complete. The construction involved the following sequence of activities:

- A large talus slope within 100 m of the restoration site was accessed through the construction of a 30 m long road. The material here ranged in size from 0.5 - 4.0 m^3 and provided an excellent source for boulders.
- Suitable boulders (between 1.0 and 1.5 m^3) were aggressively sorted by an excavator, transported with a dump truck to the restoration site, and placed along the mainline FSR.
- The boulders were then drilled and 5/8" diameter eye bolts secured with epoxy. The excavator then lowered the boulders to the river using a long chain attached to the eye bolts.

- A “spider” hoe then placed the boulders in their final location using a chain attached to the eye bolts. The “spider” hoe did not have the lift capacity to move the boulders with its thumb. A total of 18 boulders clusters of 3 - 5 boulders each were constructed (Figs. 4-43 and 4-44);
- Eight western red cedar logs, each 10 m long by 50 cm diameter, were purchased from a local mill and delivered to the site.
- Three triangular lateral log jam structures were constructed along the opposite bank spaced about 70 m apart (Fig. 4-45). Ballast for the structures far exceeds the guidelines provided in Technical Circular No. 9. Galvanized wire rope (1/2”) was used to secure the structures together. Cable was fed through the existing eye bolts in the boulders and then through holes drilled in the logs. The “spider” hoe pulled the cable tight while cable clamps were secured in place.
- The boulder source access road was deactivated and all disturbed soils seeded.

Equipment
Boulder sorting was done with a Linkbelt 2800 excavator. A 5000 TA Menzi-Muck “spider” hoe was used for boulder placement and log structure construction. Additional equipment used involved a dump truck to haul boulders and a self-loading logging truck to deliver logs.

Cost Summary

Design, supervision	$ 8,000
Labour	$ 23,600
Equipment	$ 20,100
Materials	$ 9,600
Total	$ 61,300

Production Estimates
Pre- and post-project monitoring could not be conducted due to unusually high turbidity levels.

However, Table 3-4 in the Watershed Restoration Technical Circular No. 9 provides an estimate of resident salmonid production for mainstem habitat complexing (Koning and Keeley 1997). The table suggests a 2.3-fold increase in the total numbers of cutthroat trout and a 2.7-fold increase in total numbers of rainbow trout. Based on results from the West Kettle River, an 5-fold increase in rainbow trout numbers may occur. Technical Circular No. 9 does not provide such biostandards for bull trout.

Monitoring will be conducted post-freshet to determine fish use as well as structure integrity. A float of the project area will be compared with a float conducted in an area with similar pre-project habitat features.

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Figure 4-42. Pre-project conditions. Note the lack of complexity and instream cover.

Figure 4-43. “Spider” hoe placing boulder clusters.

Figure 4-45. Triangular lateral log jam.

Figure 4-44. Post-project conditions. Note boulder clusters and three lateral log jams.

Redding Creek - Reach 16 Rehabilitation

Objectives
The Redding Creek Reach 16 project objectives were to increase habitat complexity while reducing width to depth ratios and retaining meander pattern. Prescriptions focused on holding and spawning habitat requirements of adfluvial bull trout, as well as, rearing and overwintering habitat needs of resident westslope cutthroat trout.

FRBC Region / MELP Region / MOF Region
Kootenay-Boundary / Kootenay / Nelson

Author
Herb Tepper

Proponent
Ministry of Environment, Lands and Parks

Watershed
Redding Creek

Location
Reach 16 of Redding Creek is located approximately 30 km up the Redding Creek Forest Service Road in the Cranbrook Forest District.

Introduction
Redding Creek originates in the Purcell Mountains and flows east to join the St. Mary River, a major tributary of the upper Kootenay River drainage. The confluence of Redding Creek and the St. Mary River is located approximated 26 km west of Kimberley, B.C. Redding Creek is a fifth-order stream with a mainstem length of approximately 50 km and a drainage area of approximately 38,000 ha. The Redding Creek watershed is overlapped by three biogeoclimatic zones (ICH, ESSF and AT). The watershed has an extensive logging history that dates back as early as the 1950's for the lower reaches and the 1970's for the upper reaches. Six species of sportfish including westslope cutthroat trout, bull trout, Rocky Mountain whitefish, eastern brook trout, kokanee and burbot (*Lota lota*) were identified in the watershed during a recent biophysical inventory (Amos and Oliver 1997). All six species were captured or visually observed in Reach 1 of the mainstem, but only cutthroat trout and bull trout were captured as far upstream as Reach 22. As is the case in many interior watersheds, the Redding Creek watershed lacks historical data on fish distribution and population size, thus direct evidence of harvesting impacts in this watershed is not available.

Assessments and Prescriptions
Reach 16 was characterized as a wide (12.3 m), low gradient (1.5%), riffle-pool channel type (Cope and Oliver 1998). The specific rehabilitation site was section one of Reach 16, which extends upstream approximately 400 m. Section one of Reach 16 was logged to the west streambank providing limited riparian cover (Fig. 4-46). Fish habitat was limited by extensive, shallow, riffle areas, and a lack of cover in the form of large woody debris (LWD) or depth.

Cope and Oliver's 1998 Level 2 Prescription Report prescribed twenty rehabilitation structures for the treatment section of Reach 16. Prescriptions incorporated geomorphic principles to establish target riffle-pool spacing, width to depth ratios, and meander pattern. Structures were also designed to address habitat requirements and limitations of adfluvial bull trout and resident westslope cutthroat trout. The types of structures prescribed included: boulder clusters, LWD windfalls, vortex rock weirs, opposing wing deflectors, log bank spurs, native material bank revetments, triangular lateral log jams, lateral log jams, "W" Weir, and "Newbury" rock riffles.

Pre-construction Monitoring
Cope and Oliver's 1998 Level 2 Prescription Report also included pre-construction monitoring data. Data collected included cross-sectional transects at 2 m intervals through the "zone of influence" of each proposed rehabilitation structure. One to six transects were established for each structure (n=75). Across each transect, elevation (depth) and velocity were measured at a maximum of 1 m intervals. Fish abundance monitoring was completed in the summer of 1998 prior to structure installation, which included a snorkel survey, as well as, a three-

pass removal electroshocking method at six closed sites. Sample sites were selected to represent two riffle, two glide and two pool habitat types. Also, sample sites were selected to be representative of distinct prescription structures such that the fish density data could be utilized for future cost-benefit analysis.

Rehabilitation Work

Work was initiated at the end of July 1998 and the following steps were taken:

- Purchased logs (45 m^3) and salvaged bridge stringers (35 m^3), a total of 131 logs, were collected and delivered to the site with a self-loading logging truck (two truckloads). A loader (Caterpillar 965) then skidded the logs to three on-site locations readily accessible by an excavator (John Deer 590D) with minimal streambank disturbance.
- All rootwads (n=90) were salvaged from nearby cutblocks. Rootwads were extracted from skid trail margins using an excavator and a rock truck (Volvo BM 6x4) distributed rootwads to structure locations.
- Rock (n=400) was excavated from a nearby location and transported to the site using a gravel truck with an end dump plus a rock truck. The rock truck then transported the rock to three on-site locations readily accessible by an excavator. The high surface to weight ratio of the oversized tires of the rock truck allowed the instream transport of materials with minimal substrate disturbance.
- In total, 33 structures were constructed within the treatment area. Two structures were considered interim and will require future modifications.
- Structures constructed included: boulder clusters, LWD windfalls, vortex rock weirs, opposing wing deflectors, log bank spurs, native material bank revetments, triangular lateral log jams, lateral log jams, "turning" logs, and "Newbury" rock riffles (Figs. 4-47, to 4-50). The "W" weir proposed in the Cope and Oliver 1998 report was considered too manufactured and thus was replaced with three large "turning" logs (Fig. 4-51).
- All exposed soil on skid trails, used for access, were grass seeded and small pieces of woody debris were placed on the trails with an excavator to reduce future erosion.

Cost Summary

Project management and supervision	$ 11,025
Technical and unskilled labour	$ 40,090
Material and equipment purchase/rental	$ 14,450
Total	$ 65,565
Cost/Structure	$ 1,987

Average Cost Per Structure Type

Type of Structure	# of Stuctures	Average Cost
Boulder Clusters	3	$ 178
Single & Double LWD Deflectors	6	$ 561
J-LWD/Rock Veins	3	$ 710
LWD/Rock Veins	7	$ 475
Trianglar Log Jams	3	$1,375
Natural Bank Revetments	5	$4,318
Bar Stabilization	1	$7,746
Newbury Type Riffles	2	$3,253
Vortex Weir	1	$1,109
Lateral Log Jams	2	$1,912
Road Deactivation (Access Rd.)		$1,130

Note: Additional costs not included in above averages were:

Vehicle/Travel	$6,247
Equipment Rental	$2,333
Misc. Materials/Safety	$1,538

Rehabilitation Results

This project rehabilitated approximately 5000 m^2 of stream channel (0.45 km), which should result in high quality spawning, rearing and overwintering habitat for adfluvial bull trout and westslope cutthroat trout.

Post-construction Monitoring

A post-construction monitoring program is planned for the 1999/2000 fiscal year and then repeated 5 and 15 years post-construction. The monitoring program would incorporate fluvial geomorphic, fish abundance and cost breakdown data for the rehabilitated section of Reach 16. The pre- and post-rehabilitation data would allow an assessment of geomorphic objectives (i.e., scour, deposition). The pre- and post-fish assessment data would allow an assessment of fish utilization and production benefits. Finally, an integration of the above components would enable a structure specific cost-benefit analysis that would provide insight to the most cost-effective fish habitat rehabilitation structures.

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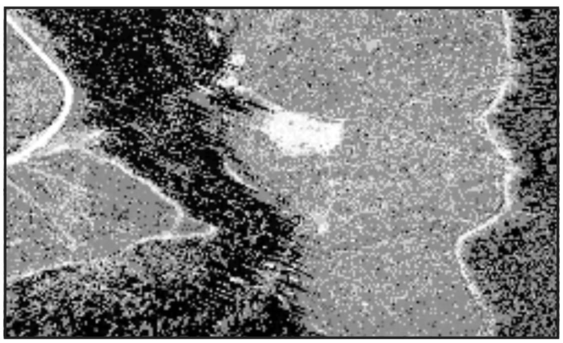

Figure 4-46. Aerial photograph (1:2,500) illustrating the rehabilitation section of Reach 16 in relation to historic logging activities.

Figure 4-47. Spur log/rock weirs in the foreground with opposing natural material bank revetment in the background.

Figure 4-48. Newbury type riffle and natural material bank revetment at a deactivated bridge crossing.

Figure 4-49. Upstream view of vortex type weir.

Figure 4-50. A triangular lateral log jam built in a residual pool within a minor bend of Redding Creek.

Figure 4-51. A series of three large turning logs placed at 20 upstream angle to transfer the thalweg towards the center of the channel. Note the mid-channel bar stabilization structures in the background.

Rover Creek Hillslope Rehabilitation

Objective
The objective of this project was to use bio-engineering techniques to establish vegetation on unstable slopes to minimize the amount of deleterious sediment being delivered to Rover Creek.

FRBC Region / MELP Region / MOF Region
Kootenay-Boundary / Kootenay / Nelson

Authors
Terry Anderson, Jamie Stirling, Pierre Raymond.

Proponent
Kalesnikoff Lumber Company Ltd.

Watershed
Rover Creek

Location
Rover Creek flows into the Kootenay River 15 km west of the city of Nelson.

Introduction
Rover Creek is a third-order watershed that has seen industrial use since the turn of the century. It supports a population of rainbow trout and is licensed for domestic water use. The watershed was extensively burned in 1905 for prospecting and the subsequent development of mines. Logging in the watershed was been ongoing since the early 1980's. A CCPA determined that landslides represent the most severe and common sediment sources, comprising 14 of the 36 sediment sources noted. Debris flows and slope failures generally originate from road cut and fill slopes.

Assessments and Prescriptions
The watershed has been the focus of previous assessments including a Sediment Source Survey, a SWAP and a Level 2 Road/ Hillslope/ Gully Rehabilitation Assessment and Prescriptions. The CCPA recommended that one of the highest and three medium priority sites be stabilized. Other sites were either not a significant source of sediment or considered cost effective.

Rehabilitation Work
The focus of the prescriptions was toward controlling the sediment sources rather than creating instream structures for fish habitat. They were based on stabilizing the four largest sediment sources using a combination of seeding and bio-engineering with live willow stakes. The various techniques included live staking and the construction of brushlayers, modified brush layers, wattle fences, live smiles and live gully breaks (Figs. 4-52 to 4-54). The structures function as a slope break and a silt fence while creating an environment to establish vegetation.

Approximate Cost Summary

Labour/supervision	$ 4,500
Overhead	$ 900
Total	$ 5,400

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Figure 4-52. Live gully breaks and brush layers on Rover Creek.

Figure 4-53. Live gully breaks and live smiles on Rover Creek.

Figure 4-54. Two wattle fences completed on a large raveling slope above Rover Creek. For scale note the worker sitting at the base of the tree.

Sanca Creek Partial Log Jam and Blowdown Removal

Objectives
The objectives of this project were to partially remove a large log jam at one site and blowdown from another site in the Sanca Creek watershed. The partial removal, rather than full removal, was done to maintain high quality fish habitat while minimizing the probability of catastrophic movement of large woody debris which could have significant impacts on water quality for the community watershed.

FRBC Region / MELP Region / MOF Region
Kootenay-Boundary / Kootenay / Nelson

Authors
Terry Anderson, Norm Deverney and Trisha Merriman.

Proponent
Wynndel Box and Lumber Company Ltd.

Watershed
Sanca Creek

Location
Sanca Creek is a community watershed which flows west into Kootenay Lake approximately 36 km north of the town of Creston.

Introduction
In 1996 a debris torrent started below a spur road and traveled nearly a km before entering Sanca Creek which created a debris jam across the channel. Two km upstream of this site a portion of riparian timber “blew down” at the edge of a cutblock. Large woody debris (LWD) jams developed from the accumulated blowdown LWD (Fig. 4-55). The debris accumulation in the debris jam and blowdown jam presented a high risk of channel blockage which if released suddenly during high peak flows could create significant downstream impacts to water quality and fish habitat.

Assessments and Prescriptions
Assessments in the watershed began with a Level 1 Road and Hillslope Assessment in 1994. An IWAP and Detailed Road Assessment and Prescriptions followed two years later. Road deactivation and hillslope restoration was conducted in the following year. An Overview FHAP was completed in 1997 to identify potential restoration opportunities in the watershed. The Overview FHAP recommended a CCPA (conducted in 1997) be conducted as the majority of the disturbances were primarily channel and geomorphic in nature. The prescriptions and restoration works were conducted at the two sites in August, 1998. All assessments and prescriptions were prepared by Kokanee Forests Consulting Ltd., Nelson, B.C.

Rehabilitation Work
Considerable attention was given to the restoration works because of the significance of Sanca Creek being a community watershed. All work conducted was done utilizing hand tools and hand labour to minimize sediment and disturbance to reduce any risks to water quality. Geotextile fabric was placed across the channel at both sites to trap debris and sediment to reduce any water quality impacts. Most of the bucking of the LWD occurred over and/or directly adjacent to water therefore work crews replaced the regular chainsaw oil with canola oil. The crew reported that the conversion to canola oil did not have an adverse effect on the machinery and on performance.

The partial log jam removal was accomplished in two days with chainsaws and hand labour (Figs. 5-56 to 4-58). Caution was used to ensure the stability of the jam throughout the dismantling process. The jam was removed layer by layer starting in the middle and working towards the edges. The logs were bucked into manageable pieces, carried to the streambank and were scattered throughout the floodplain. The middle section of the jam was removed to the streambed. A few large logs were strategically felled into a pool slightly upstream of the jam which were immediately used by westslope cutthroat trout. A portion of the jam was enhanced on the left bank to maintain complex habitat, maintain scouring and provide quality pool cover.

Large numbers of cutthroat trout and rainbow trout were observed throughout the 90 m section of blowdown. Every attempt was made to leave as much wood as possible instream while reducing the risk of channel blockage and subsequent massive failure (Fig. 4-59). Embedded logs were left in place to ensure some level of stability to jam. Cross spanning logs were cut in different positions and styles depending on their orientation but all were cut to leave the channel open. Trees with rootwads were used to stabilize some of the smaller LWD and used as bank protection. Come-alongs were used to strategically place pieces of LWD in key locations and increase the structural integrity of the jam.

Figure 4-55. Blowdown completely covering Sanca Creek.

Approximate Cost Summary

Labour/supervision	$ 4,500
Overhead	$ 900
Total	$ 5,400

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Figure 4-56. The beginning of removal of the debris jam on Sanca Creek.

Figure 4-57. The Sanca Creek channel opened at the site of the debris jam.

Figure 4-58. The partial removal of blowdown on Sanca Creek has been completed.

Figure 4-59. The channel of Sanca Creek is opened but logs were left in and above the pool to provide cover for trout.

Klookuh Creek Restoration

Objectives
The Klookuh Creek restoration project objectives were to increase habitat complexity (primarily creating pool habitat), reduce sediment input sources and restore full passage past an unnatural barrier. Prescriptions focused on holding and spawning habitat requirements of bull trout, as well as, rearing and overwintering habitat needs of resident westslope cutthroat trout.

FRBC Region / MELP Region / MOF Region
Kootenay-Boundary / Kootenay / Nelson

Author
Rob Baldwin

Proponent
Slocan Forest Products Ltd., Radium Division.

Watershed
Klookuh Creek, North White River Middle Fork (MF).

Location
Klookuh Creek is located approximately 60 km up the White River and Middle Fork Forest Service Road in the Invermere Forest District.

Introduction
Klookuh Creek is a tributary of the upper White River (Middle Fork) which originates in the Rocky Mountains and eventually flows south into the Kootenay River. Klookuh Creek is approximately 50 km east of Canal Flats, B.C. Klookuh Creek is primarily in the ESSFdk biogeoclimatic zone. The MF White River watershed has an extensive logging history that encompasses a large portion of the Klookuh Creek watershed. A significant portion of the lower watershed's riparian zone was harvested resulting in bank instability and loss of recruitment of LWD. Bull trout are the target species for restoration efforts although it is surmised that westslope cutthroat presently use and/or historically used the watershed. There are no barriers or restrictions to cutthroat trout into the system. Therefore, all restoration efforts would also be of benefit to cutthroat trout. As is the case in many interior watersheds, the Klookuh Creek watershed lacks historical data on fish distribution and population size, thus direct evidence of harvesting impacts on fish populations in this watershed is not available. Impacts on fish habitat resulting from harvesting are evident throughout the lower watershed (i.e., eroding banks, no mature riparian zone).

Assessments and Prescriptions
The lower reaches of Klookuh are characterized by a single, narrow (<4.0 m), irregular wandering, moderately confined stream channel with gradients ranging around 2-3%. The channel type is riffle-pool with a cobble dominated substrate. There is very little functional LWD and there are several high eroding and unstable banks (Baxter et al. 1997). The specific restoration area was a section of Reach 1, which extends downstream approximately 400 m from the MF White mainline road bridge crossing. The entire riparian zone in this area was harvested providing limited riparian cover. Fish habitat is limited by extensive, shallow, riffle areas, and a lack of cover in the form of large woody debris (LWD) or depth.

Prescriptions were developed to target two primary impacts. There were two large eroding banks that were very unstable and producing a large amount of deleterious sediment (Fig. 4-60). This sediment was resulting in long homogeneous riffles and poor pool habitat as well was of concern during/after rain events during bull trout spawning. The second primary impact to be targeted was the lack of primary pools. Two historic pool locations were identified in two bends of the creek. Rootwad structures were prescribed for these two locations and were also designed to function during various flow regimes. A secondary restoration site also had prescriptions developed to remove/alter a potential fish barrier and actual sediment barrier. Two blowdown trees fell perpendicular to the channel and collected a significant amount of SWD and logging slash resulting in sediment being accumulated forming a sediment wedge/ barrier and potential channel avulsion location.

Rehabilitation Work
Work was conducted during the August fisheries

work window. The following bullets are a brief description for each of the five restoration sites rehabilitated:

Site 1

- A large eroding bank with a distinct overhang was re-sloped to an approximate 1:1 angle. Any boulders encountered during the re-sloping were used to help armour the toe of the slope. The slope was then raked and seeded. A coconut fibre Terra-Mat was then installed over the slope and pinned down with wood stakes (Fig. 4-61). The area was then staked with willow stakes. Areas above and below the site were used as templates; they had significant willow cover and a reduced bank angle.

Sites 2 and 4

- Both sites 2 and 4 were identified during the prescription development as being historic and/or potential pool sites located on bends. At both locations the bank was being undermined from the breakdown of rootwads from harvested trees. In both cases a trench was dug approximately 5 m long to an estimated 0.5 m below the existing streambed profile. Large rootwads with at least 4 m stem were placed in the trench. These pieces of LWD were than covered with LWD perpendicular which were then backfilled with earth and rock to the edge of the rootwad and stream (Fig. 4-62). A small portion of the stream bed was excavated to induce pool scour.

Site 4

- A potential fish barrier and definite sediment barrier was altered to allow for consistent fish passage and allow for improved bedload migration. Two channel spanning blowdown trees were bucked off close to the streambank to maintain the rootwad within the bank. The accumulation of logging slash and SWD was removed. Just above the barrier was an area where the risk of channel avulsion was high. Although the channel had not avulsed to date evidence of sediment being deposited during high flows resulting from the barrier was visible. This area was reinforced with a LWD revetment. There should not be a high risk to avulsion after the stream begins to downcut after barrier removal.

Site 5

- This site is very similar to Site 1 with a large eroding bank and was re-sloped and covered in the same fashion. The cause of this eroding bank was from the accumulation of logging slash on an existing jam deflecting flows during higher water stages against the bank causing erosion. A LWD revetment was also built as a fail-safe against further erosion at this site to ensure that lateral stream erosion is eliminated. The revetment is buried and cannot be seen. The existing log jam was also manipulated to try and reduce the intensity of any flow deflection during higher water stages.

Approximate Cost Summary

Prescriptions, preparation, report	$ 4,960
Project management and supervision	$ 4,120
Material and equipment purchase /rental	$ 4,420
Total	$ 13,500

Rehabilitation Results

This project rehabilitated approximately 1600 m^2 of stream channel, which should result in high quality spawning, rearing and overwintering habitat for bull trout and potentially westslope cutthroat trout.

Post-construction Monitoring

A post-construction monitoring program planned for the 1999/2000 fiscal year is of a low intensity type. All five sites will be checked for performance and any maintenance issues. Quality of the vegetative growth will also be reviewed to determine if further work is required. No fish usage monitoring is being considered due to the small size of the project and reductions in funding creating higher priorities elsewhere.

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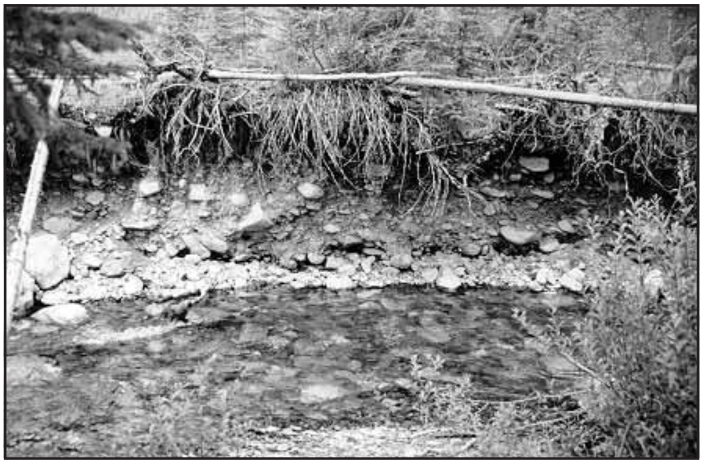

Figure 4-60. Large eroding bank with overhang prior to re-sloping.

Figure 4-61. Eroding bank re-sloped, toe partially armored and covered with coconut fibre matting.

Figure 4-62. Rootwad structure to protect bank and induce pool scour.

Middle Fork of the White River Restoration

Objectives
The Middle Fork of the White River (MF White) restoration project objectives were to increase habitat complexity by placing large wood debris (LWD) complexes to accelerate the recovery of a heavily logged watershed. Prescriptions focused on holding and spawning habitat requirements of bull trout and westslope cutthroat trout in their various life history stages.

FRBC Region / MELP Region / MOF Region
Kootenay-Boundary / Kootenay / Nelson

Author
Rob Baldwin

Proponent
Slocan Forest Products Ltd., Radium Division.

Watershed
Middle Fork of the White River.

Location
Middle Fork White is located approximately 40 km up the White River and Middle Fork Forest Service Road in the Invermere Forest District.

Introduction
The Middle Fork White River which originates in the Rocky Mountains and eventually flows south into the Kootenay River is approximately 40 km east of Canal Flats, B.C. Elevation in the basin ranges from 3000 m at the height of land, to 1350 m at the confluence of the White River. The MF White River watershed has an extensive logging history that encompasses valley bottom, hillslope and riparian harvesting. A significant portion of the watershed's riparian zone was harvested resulting in bank instability and loss of recruitment of LWD. Bull trout and westslope cutthroat are the target species for restoration efforts. The MF White is a high value fishery and restoration efforts are targeted at minimum to maintain populations and habitat for cutthroat trout in the system. The watershed is considered to be geomorphicaly stable with the headwaters of the system being protected by a provincial park. Two areas were chosen for restoration works in the first year. They were chosen for two primary reasons. The first is both sites on one side of the system have had the riparian zone completely harvested resulting in some bank erosion and loss of recruitment of LWD and poor habitat. The second reason for the site selection was ease of access in light of limited project funds.

Assessments and Prescriptions
The two reaches chosen for the first phase of the restoration project are characterized by a single, irregular wandering, wide (approx. 21.9 m) stream channel with gradients lower than 1%. The channel type is riffle-pool with a gravel dominated substrate. There are numerous elevated bars and extensive riffle and glide areas with few primary and very few secondary pools. There is very little functional LWD and there are several eroding and unstable banks (Baxter et al. 1997). The entire riparian zone on one side of the stream at each location was harvested completely providing limited riparian cover.

Prescriptions were developed to target two primary objectives. They were to increase habitat and pool complexity at the two locations and stabilize one large eroding bank that was at risk of catastrophic failure. The objectives at Site 1 were to build three large triangular lateral log jams (Fig. 4-63) and a large LWD revetment to stabilize the eroding bank. Two large triangular lateral log jams were constructed at Site 2. Placement of the five structures was to encourage scour, create pool habitat associated with overhead cover for sub-adult and adult trout (Oliver 1998 a). Recruitment of natural LWD at both sites would not occur for at least 30-40 years.

Rehabilitation Work
Work was conducted during the August fisheries work window. The LWD used for the key structural members was salvaged from a bridge replacement in the same watershed. Other LWD was collected from blowdown in areas adjacent to the restoration sites. A permit from Ministry of Forests was obtained to salvage some blowdown with rootwads. Ballast boulders were collected from the surrounding area. Quality boulders are very difficult to obtain and are expensive to purchase in the east Kootenays due

to the rock types found in the Rocky Mountains. To reduce the amount of boulders used, and cost, metal railway line was used as “stakes” or “piers” to anchor the bank ends of the structures (Fig. 4-64). These “stakes” are pounded into the bank a minimum of 3 m leaving at maximum 30 cm of the stake exposed. The exposed part of the “stake” has holes to allow for cabling.

All five structures are very large in size to withstand the high flows in this system as well as to mimic the natural occurring log jams that occur in the system. All five jams are located on the outside of large bends and will not extend further than one third of the way into the channel. The design and orientation of each structure is such that that they should collect river transported debris to further complex the structures. As much as possible the salvaged blowdown trees were collected to keep the rootwads intact. These pieces of LWD were used as additional structural support and further complexing of the structures (Fig. 4-65). Ballasting was completed using 1/2” stainless cable and the Hilti‰ system as well as clamps and stapling.

The whole tree revetment was incorporated into one of the triangular log jams at Site 1. The revetment is intended to reduce near-bank velocities and stabilize the unstable bank (Fig. 4-66). The revetment will also provide excellent cover for juvenile, sub-adult and adult trout. The revetment was built in two layers. The first layer was constructed with the salvaged bridge stringers. The stringers are placed parallel to the bank with their butt ends overlapping at the downstream ends to prevent endcutting. The logs are ballasted with boulders in the stream and tied into the bank using the steel “piers”. The second layer was comprised of the salvaged blowdown wood collected. Care was taken by the excavator operator to minimize the breaking of tree limbs and roots. These were than tied into the existing logs and also ballasted. These natural logs provide for more energy dissipation, better habitat and potential to collect more debris.

Approximate Cost Summary

Prescriptions and as-built report	$ 11,000
Material acquisition, prep.	$ 7,600
Installation (equip, etc.)	$ 21,400
Total	$ 40,000

Rehabilitation Results

This project rehabilitated approximately 0.5 km of stream channel, which should result in high quality spawning, rearing and overwintering habitat for bull trout and westslope cutthroat trout. Within one week adult bull trout and westslope cutthroat were observed utilizing the newly created habitat at Site 1.

Post-construction Monitoring

A post-construction monitoring program planned for the 1999/2000 fiscal year is of a medium intensity type. Both restoration sites will be checked for performance and any maintenance issues. Fish usage assessment will be limited to snorkeling surveys, visual observation and angling during different seasons. Both locations will be re-surveyed for geomorphic information if funding is available.

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Figure 4-63. One of the large LWD structures constructed and also illustrates the impacts from harvesting on the riparian zone.

Figure 4-64. Typical placement of anchor “piers” used to supplement boulder ballasting.

Figure 4-65. Large LWD structure. Note the use of a variety of sized LWD and rootwads for added complexity and strength.

Figure 4-66. Whole tree revetment to protect eroding bank. Note energy dissipation along bank margin.

Windermere Creek - Instream Restoration

Objectives
To complete a range of creek and channel restoration techniques on 7 high priority sites on the lower reaches of Windermere Creek, including streambank stabilization and revegetation, applying bioengineering techniques; streambank revetment and sediment control utilizing native materials; fish passage barrier removals and gradient controls; and construction of an inlet catch basin and drain system for diversion of a spring-fed discharge.

FRBC Region / MELP Region / MOF Region
Kootenay-Boundary / Kootenay / Nelson

Author
Sue Crowley

Proponent
Slocan Forest Products, Radium Division (SFP) in partnership with the Ministry of Environment, Lands and Parks (MELP).

Watershed
Windermere Creek, tributary of the Columbia River.

Location
Windermere Creek is a fifth-order tributary of the Columbia River located within southeastern British Columbia. The mainstem flows 27 km from its origin in the Stanford Range of the Columbia Mountains to its confluence with Windermere Lake. Windermere Creek is the largest tributary to the lake. The watershed encompasses approximately 10,500 ha and includes 11 tributary streams.

Introduction
The Windermere Creek Watershed is located within the Columbia Mountains Ecoregion of southern British Columbia. Three biogeoclimatic zones are represented within the area: Montane Spruce at the lower elevations, and Englemann Spruce - Subalpine Fir and Alpine tundra zones at higher elevations. The watershed has an extensive resource development history, including crown land forest harvesting, open pit gypsum mining, gravel pit, recreational and residential development, access development (highway, secondary and forest roads) and agricultural uses. The lower reach of Windermere Creek flows through the town of Windermere and Columbia Lake Indian Reservation #3 where the native community is located.

Windermere Creek is a regionally significant fish stream for MELP. Its outlet provides spawning habitat for kokanee salmon as well as rearing and spawning habitat for bull, eastern brook, rainbow, and westslope cutthroat trout. Slimy sculpin and juvenile mountain whitefish have been observed in reaches 1 and 2 of the creek.

Resource extraction and developments in the Windermere Creek watershed have impacted the water, habitat and channel conditions of the creek, as well as the lake which is an extremely important water supply, recreation and fisheries water body.

Assessments and Prescriptions
Overview Interior Watershed and Fish Habitat Assessment Procedures (IWAP and FHAP) were conducted in 1997 to provide a preliminary assessment on the location, nature and extent of the effects of human impacts on the watershed and affected habitat. Based on the results of the overview studies, a Level 1 FHAP was then undertaken concurrently with a Channel Condition and Assessment Procedure (CCPA), to provide more detailed information on the watershed, and identify specific restoration opportunities. Twenty-three sites were identified for restoration through these processes. Detailed prescriptions were completed for the 7 highest priority sites. Prescriptions were developed to address habitat requirements and limitations on the resident fish species as well as to enable spawning kokanee access to prime upstream habitat.

Fish abundance monitoring (electroshocking method) was completed in the summer of 1998 at each of the seven sites prior to restoration activities, to allow for future cost benefit analysis and baseline fish monitoring data.

All proposed restoration activities were developed in consultation with the large number of stakeholders for the watershed.

Rehabilitation Work

Restoration works were initiated in August 1998 and took 10 days to complete. Activities and objectives for each of the sites include:

- Removal of a 1 m high dam composed of sediment and debris which was a barrier for upstream passage of spawning kokanee. A Menzi Muck 5000T1 "spider" hoe excavator removed and repositioned suitable LWD from the dam, accompanied by a hand crew of 5 displaced forestry workers (Fig. 4-67). Materials were deadman trenched 2-3 m back from the streambank and secured by cable to provide streambank stability and provide cover for fish. Small machine excavation provided a smooth and gradual transition to the stream bed and banks. Spoil material was placed outside the channel and floodplain.
- A large piece of LWD spanning the channel resulted in a 1 m high waterfall barrier. To allow for fish passage, the LWD was removed and replaced with 2 log V-weirs to maintain the existing gradient and upstream pool (Fig. 4-68). Four sound, straight logs, 5 m long x 0.6 m dia. obtained and prepared on site (delimbed and debarked) were set into pre-excavated trenches in the stream bed. The trench was sloped down and toward the middle of the weir to concentrate flow midstream. Log ends were angle-cut to form the apex of the weir and pinned together using rebar drift pins. Outside ends were buried in the stream bank 2 m and backfilled.
- A 12 m long undercut streambank adjacent to the road was subject to channel erosion and lacked streambank and riparian vegetation. Steambank stabilization and restored fish habitat was achieved through tree revetment construction utilizing 3 on-site rootwads 5 m long x 0.6 m dia (Fig. 4-69). These were secured into the streambank 5 m apart, using rock rip-rap over-topped with bedding gravel and granular fill.
- A 16 m long undercut streambank was stabilized and restored as described above using 4 rootwads 5 m long x 0.6 m dia.; in addition, rock rip-rap was placed at the toe of the eroding bank upstream.
- A 170 m section of eroding streambank at the toe of a valley contributed significant sediment to the stream. Rehabilitation included 1 m diameter boulder placement in cluster patterns to reduce stream flow rates, (minimizing erosion) and to provide fish habitat. The boulders were placed in pre-excavated holes which set them a maximum of 0.3 m above the stream bed. They were spaced 0.8 to 1.5 m apart, with clusters a minimum of 5 m apart. LWD placement and live willow staking provided additional bank stabilization.
- A 20 m eroding streambank at the toe of a road fill was a sediment source to the stream. The streambank was partially stabilized through construction of a 0.7 m log wall slope break, which was hand-trenched in place and supported by rebar. Live willow staking was also completed (Fig. 4-70).
- The interception of a spring by a road ditch adjacent to Windermere Creek resulted in reduced instream discharge to the creek, and was contributing ditch sediment through erosion. An inlet catch basin was constructed consisting of a perforated culvert placed vertically and surrounded by drain rock. The culvert and a downstream outlet pipe consisted of a round 450 mm dia. PVC pipe.

Comments:

- The "spider" hoe was utilized on the first 5 of the 7 sites described, and was well complimented by a hand crew.
- The use of the walking excavator allowed easy access to the work sites with minimal disturbance.
- Live willow stake cuttings and native shrub cuttings were planted in all disturbed stream banks, angle-cut at the basal end and tamped into the ground at right angles to the slope.
- Topsoil was replaced and seeded with erosion control grass mix at all disturbed areas.

Cost Summary

Materials	$ 7,500
Equipment	$ 24,500
Design, supervision	$ 13,800
Labourers	$ 7,700
Total	$ 53,500

Rehabilitation Results

This project rehabilitated approximately 2000 m^2 of stream channel, which should result in high quality fish spawning, rearing and overwintering habitat. Spring-fed discharge now directly entering Windermere Creek provides a significant portion (in the order of 30-40%) of the total flow. The fall 1998 kokanee run were able to spawn upstream over an additional 0.8 km of prime habitat.

Monitoring will be conducted post-freshet to review fish presence and population estimates, debris jam buildup, scour and streambank structure integrity, and potential channel impacts associated with restoration activities.

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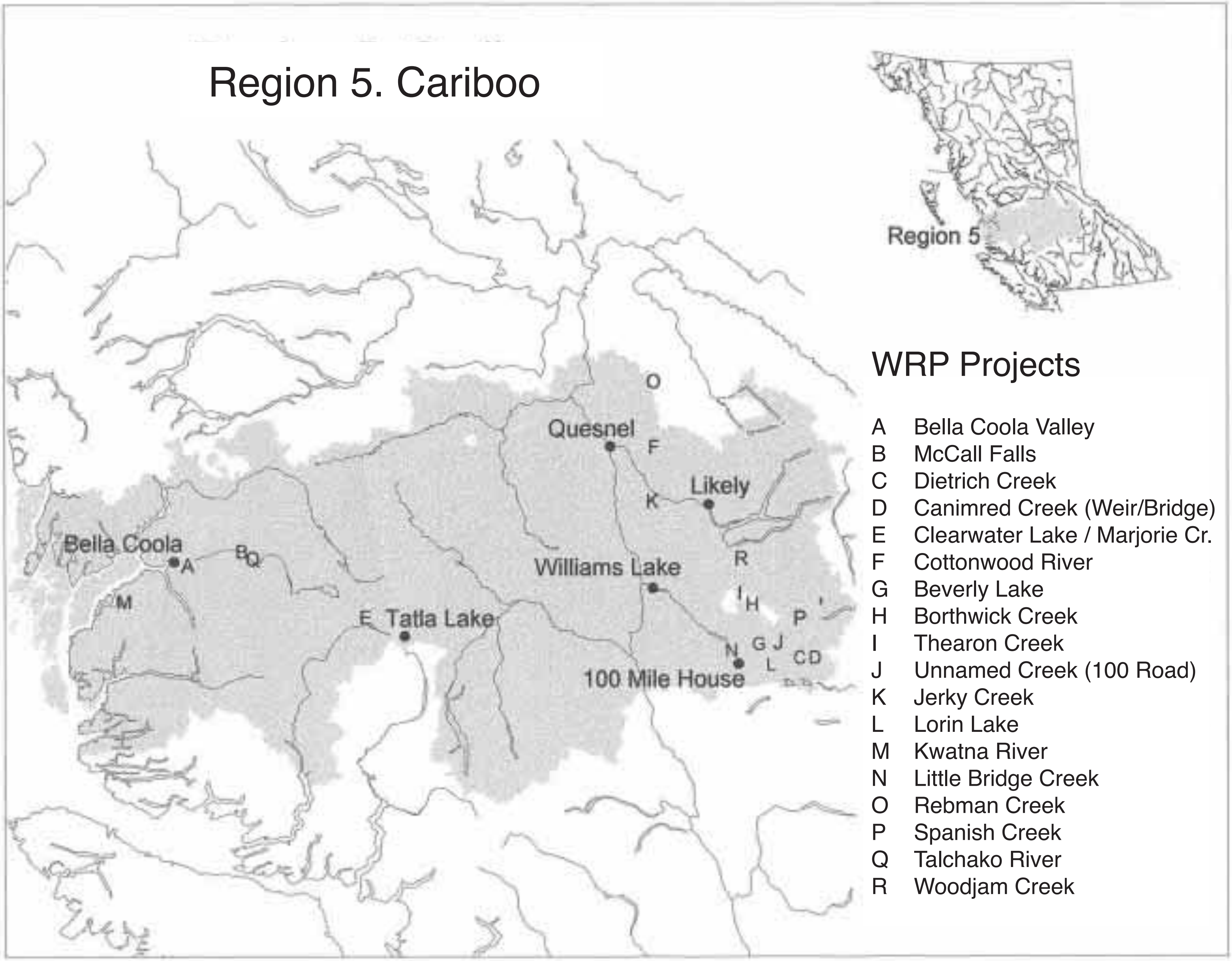
Figure 4-67. Effective use of a "spider" hoe provided low site impact during restoration activities.

Figure 4-68. Placement of a log V-weir will provide gradient control following debris removal.

Figure 4-69. Rootwad LWD placement will provide bank stability and create habitat.

Figure 4-70. Eroding bank stabilization using displaced forest workers.

Cariboo Region


Region 5. Cariboo
Region 5
Quesnel
Likely
Bella Coola
Williams Lake
Tatla Lake
100 Mile House
WRP Projects
A Bella Coola Valley
B McCall Falls
C Dietrich Creek
D Canimred Creek (Weir/Bridge)
E Clearwater Lake / Marjorie Cr.
F Cottonwood River
G Beverly Lake
H Borthwick Creek
I Thearon Creek
J Unnamed Creek (100 Road)
K Jerky Creek
L Lorin Lake
M Kwatna River
N Little Bridge Creek
O Rebman Creek
P Spanish Creek
Q Talchako River
R Woodjam Creek

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 5, Cariboo.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
A	**Cariboo**	Bella Coola River	Bella Coola Valley	9	5805455	651723	910-290700	00455BELA
B		Bella Coola River	McCall Flats	10	5812500	281550	Non gazetted trib to 910-290700	00000BELA
C		Boss Creek	Dietrich Creek	10	5750681	661322	129-360400-23900-98400-3430	00000MAHD
D		Canimred Creek	Canimred Cr. (Weir and Bridge)	10	5748500	662550	129-360400-23900-98400-3280	00000MAHD
E		Clearwater Lake/Marjorie Creek	Clearwater Lk./Marjorie Cr.	10	5764886	363254	900-592700-70700-08900	00455KLIN
F		Cottonwood River	Cottonwood River	10	5870517	562176	100-481100-43400	00000COTR
G		Eagle Creek	Beverly Lake	10	5746049	648806	129-360400-23900-98400-7260	00000MAHD
H		Eagle Creek	Borthwick Creek	10	5762886	623525	129-360004-23900-98400-7260-4940-141	00000MAHD
I		Eagle Creek	Thearon Creek	10	5770429	615216	129-360400-23900-98400-7260-6190	00000MAHD
J		Eagle Creek	Unnamed Stream (100 Road)	10	5747583	647452	129-360400-23900-98400-7260	00000MAHD
K		Jerky Creek	Jerky Creek	10	5834502	559791	160-274600-11400-03600	00000QUES
L		Jim Creek	Lorin Lake	10	5733683	663059	129-360400-23900-98400-4800-3000	01824MAHD
M		Kwatna River	Kwatna River	9	5774308	611315	910-246500	00000NIEL
N		Little Bridge Creek	Little Bridge Creek	10	5723798	619395	129-360400-23900-98400-9950-4650	00000BRID
O		Rebman Creek	Rebman Creek	10	5914623	564053	100-596500-64100	00000WILL
P		Spanish Creek	Spanish Creek	10	5760917	667031	129-360400-23900-86400-3130	00000MAHD
Q		Talchako River	Talchako River	9	5806891	697596	910-290700-99800	00000BELA
R		Woodjam Creek	Woodjam Creek	10	5793777	617648	160-635400-29700	00000HORS

Bella Coola Valley Restoration

Objectives
To demonstrate a variety of restoration techniques that would benefit a variety of salmonids at various life stages.

FRBC Region/ MELP Region/ MOF Region
Pacific / Cariboo / Vancouver

Author
Michael A. Parker

Proponent
Ministry of Environment, with support of a Community Partnership Group including, Department of Fisheries and Oceans, Central Coast Regional District, International Forest Products, Central Coast Fisherman's Protective Association.

Watershed
Bella Coola River

Location
The Bella Coola River watershed is located in the Mid-Coast Forest District approximately 450 km west of the city of Williams Lake.

Introduction
This project is the continuation of activities begun on the ground in 1997. Through the participation of a local partnership group, small systems that feed the Bella Coola River were selected for restoration activities. MELP staff has completed most of the instream prescriptions that are then constructed by a variety of local firms and groups. Works have been intentionally kept as primarily hand works when possible. The project created over 400 person days of work.

Assessments and Prescriptions
An Overview Fish Habitat Assessment was completed for the Bella Coola Valley in 1996. Level 1 FHAPs were completed on six different tributaries in 1997, and prescriptions have been ongoing.

Rehabilitation Work
<u>Site 1: Anne Creek</u>
Fencing was erected approximately 8 m back from the creek for 700 m to eliminate cattle access. An alcove pond in a corralled and graveled area provides a watering location to the cattle away from the main channel. Hand crews removed all small organic debris under 15 cm diameter and 2 m in length within the channel for 1100 m. Rakes were used to remove water parsnip that had choked the degraded channel. Finally, 846 spruce and cedar trees were planted within the newly fenced riparian areas.

<u>Site 2: Dump Creek</u>
Dump Creek has historically been used as a spawning and rearing area for coho and cutthroat. However, ongoing problems with beaver and scour at a culvert placement on Highway 20 through which the creek flows limited access into and out of the upper pond and channel portions of this creek (Fig. 5-1). A beaver box was constructed and installed on the upstream end of the culvert to prevent beavers from damming the entrance, and a series of riffles were constructed below the culvert to improve access to the culvert and the habitat above (Fig. 5-2). In the fall of 1998 adult coho were observed in the pond above the culvert having successfully negotiated the riffles and beaver box.

<u>Site 3: Epp Creek</u>
Epp Creek is a small channel primarily used for coho rearing. However, late summer low flows often stranded fish in a few small pockets of water. A refuge pond of approximately 0.025 ha was excavated to a depth of 2 m (Fig. 5-3), and complexed with rootwads, artificial cutbanks, and other LWD placements. As well, a 0.005 ha pond was excavated adjacent to a year-round cool water spring that augments water flows in the creek during low flow periods. These two ponds will provide stable rearing and refugia area for juvenile fish of many species that seek stability from the waters of the Bella Coola mainstem some 300 m downstream.

<u>Site 4: Tuck Creek</u>
Tuck Creek was originally excavated as a 250 m drainage ditch through an old cutblock and agricultural land. Due to the high quality of water it picked up, it has been highly utilized by pink, chum, coho, and cutthroat, and to a lesser degree, other species of fish. However, it is undersized

for its high flows, and has minimal habitat features. As the first step in redesigning this channel, excavation has begun on a channel that will bring more stable year-round flows from a spring to the ditchline. This 275 m channel, to be built during early 1999, will have a repeatable riffle/pool morphology and be complexed with LWD and boulder placements to target steelhead and cutthroat. In 1999, this work will be connected to the spring and ditchline, and the ditchline will be redesigned to handle all flows, complexed with structures, and morphologically altered to provide a combination of riffle and pool habitats. In total, 500 m of new and existing channel will be reworked and complexed.

Site 5: Hagensborg Slough

Work on the Hagensborg Slough was a follow up to restoration activities that had taken place during the summer of 1997. A couple of days were spent checking the 47 structures placed in 1997, and making any adjustments to these hand placements, as was necessary. In addition a pond and channel habitat from one of the source springs was excavated to a depth of 2 m, with four pockets in an existing pond brought to a depth of 3 m during 1998. This 0.04 ha area was complexed with LWD placements and the streamside planted with 120 conifers. Coho, cutthroat and other species were counted through the fish fence being operated as part of an ongoing monitoring program on the slough (Fig. 5-4). Over 400 spawning adult coho were counted within the slough during the fall of 1998. By far the largest numbers observed in recent years, these fish were found almost exclusively within the reach restored during the past two years.

Site 6: George Hall Creek

George Hall Creek was set to receive 35 full-spanning log structures to promote scour of primary pool habitat within 500 m of stream. Due to late funding approvals the instream window for this activity was missed. However, all logs and rock materials have been placed on site and are ready for installation in 1999.

Cost Summary

Labour (NFOL)	$ 30,000
Labour (non-NFOL)	$ 40,000
Expenses	$ 18,500
Materials	$ 19,000
Total	$107,500

Proposed Work

Thirty-five full-spanning log placements will be installed in George Hall Creek. Six large structures have been designed for a 180 m section of Nuhalk Creek. Activities will continue in Anne Creek, George Hall Creek, Tuck Creek, Epp Creek, and Hagensborg Slough. New activities will be undertaken in Fish Creek, and Molly Walker Creek.

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Figure 5-1. Culvert before beaver box installation on Dump Creek.

Figure 5-2. Culvert after beaver box installation on Dump Creek.

Figure 5-3. Overwinter pond excavation on Epp Creek prior to wood complexing.

Figure 5-4. Fish counting fence constructed on lower Hagensborg Slough.

McCall Flats Groundwater Channel

Objectives
Restoration objectives were to provide improved rearing habitat for salmonids, particularly coho and cutthroat.

FRBC Region/ MELP Region/ MOF Region
Pacific / Cariboo / Vancouver

Author
Michael Parker

Proponent
International Forest Products,
Mid-Coast Division, Hagensborg, B.C.

Watershed
Bella Coola River

Location
McCall Flats is a few kilometers downstream of where the Atnarko and Talchako Rivers join to form the Bella Coola River. The flats were an area approximately 55 km east of the community of Bella Coola that were logged many years ago and have regrown with mature cottonwood being the dominant species.

Introduction
McCall Flats Creek has a drainage area of approximately 1 km^2. The project activities are to focus on the lower 700 m of this small channel, where the gradient is slightly less than 1%. Late winter dewatering of the shallow pools in the channel has caused mortality of juvenile fish.

Assessments and Prescriptions
The area was included in Overview and Level 1 Assessments completed by Summit Environmental in 1996. LGL Ltd. completed prescriptive work and Level 2 assessment of McCall Flats Creek in the fall of 1998.

Rehabilitation Work
Small organic debris (SOD) was removed from the lower 500 m of the system to promote flow and scour. Past logging debris and SOD from the regenerated cottonwood stand had clogged the channel and promoted catchment of sediment and in-filling of habitat features. This work was completed by hand.

Prescriptions call for the excavation of a groundwater channel along the toe of a hillslope for approximately 180 m above the top of the existing channel. It is expected that additional groundwater will be picked up through the lower alluvial fan to stabilize year-round flows. As well, five alcove ponds have been prescribed to provide refuge in low flow conditions. Rock riffles near the outlet of these alcoves will maintain a minimum water depth of 0.7 m.

Cost Summary

Machine	$ 9,000
Labour	$14,000
Total	$23,000*

*These costs are estimates as work was not completed at time of writing.

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Dietrich Creek Culvert Replacement 6500 Road

Objectives
To replace two culverts acting as barriers to fish passage.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Ken MacKenzie

Watershed
Boss Creek

Proponent
Weldwood of Canada Ltd.,
100 Mile House Operations.

Location
The site is located at 9 km on the 6500 Road in the Boss Creek watershed.

Introduction
Dietrich Creek is the main tributary to Hendrix Lake and therefore acts as the headwaters for the Hendrix Creek watershed. Rainbow trout are found in the stream.

Assessments and Prescriptions
This site was listed as the highest priority for restoration in the Boss/Deception fish passage-culvert inspection report. Two culverts at the crossing had high water velocities (1.5 $m \cdot s^{-1}$) and outfall drops (15 and 48 cm) (Fig. 5-5). The stream channel is 4.5 m wide requiring that a clear span structure be used to provide for fish passage.

Rehabilitation Work
Water was diverted into the smaller of the two existing culverts while the larger one was removed and the channel reconstructed (Fig. 5-6). Silt fences were placed downstream during all phases of construction to maintain water quality during installation.

Structure Details
- Eleven meter concrete deck bridge (Fig. 5-7).
- Two percent slope to bridge deck.
- Pre-cast concrete footings.
- Reconstructed stream channel approximately 5 m wide.

Cost Summary

Bridge design, supply and install	$ 47,841
Rip-rap, site plans and supervision	$ 5,990
Total	$ 53,831

Environmental Benefits
An additional 2.6 km of stream is now accessible to rainbow trout.

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Figure 5-5. Culverts prior to replacement.

Figure 5-6. Channel bypass.

Figure 5-7. Completed installation.

Canimred Creek Tributaries Bridge Construction

Objectives
The primary objective of this project was to replace a small culvert with a bridge to allow fish passage.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo /Cariboo

Author
Ken MacKenzie

Proponent
Weldwood of Canada Ltd.,
100 Mile House Operations.

Watershed
Canimred Creek

Location
The crossing is located 2.0 km down a side road at 17 km on the Bowers FSR at an unnamed stream that flows into Canimred Creek.

Introduction
Canimred Creek has high densities of rainbow trout and may be an important spawning stream for Canim Lake. The streams affected by this project have high spawning and rearing habitat potential.

Assessments and Prescriptions
This barrier to fish was identified during a field inspection by Weldwood. The culvert was undersized for Q100 flows, was quite long (25 m), at a gradient that prohibited fish passage and had a small outfall drop (Fig. 5-8). A clear span structure was determined to be the best option for restoring fish passage.

Rehabilitation Work
To minimize environmental impacts during the weir construction, the following steps were taken:

- A bypass channel was constructed adjacent to the culvert that was armored with clean rock prior to stream diversion (Fig. 5-9).
- Rip-rap was placed at the upstream bend in the creek to eliminate erosion and potential sediment inputs to the stream.
- Sediment traps of hay bales and filter cloth were placed downstream to maintain water quality during channel reconstruction work.
- An environmental monitor was on site for all phases of construction.

Structure Details
- Fifteen meter concrete slab deck (Fig. 5-10).
- 30¥ skewed approaches.
- Eight inch steel posts on pre-cast concrete footings.
- Reconstructed channel width 4 to 5 m.

Cost Summary

Site plan preparation	$ 2,000
Bridge design, supply and install	$ 54,800
Rip-rap supply, supervision	$ 6,500
Total	$ 62,800

Environmental Benefits
An additional 2.4 km of habitat is now available to fish.

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Figure 5-8. Outfall of culvert.

Figure 5-9. Construction of the bypass channel.

Figure 5-10. Completed installation.

Canimred Tributary Weir Construction 535 Road

Objectives
The primary objective of this project was to construct a weir to allow fish passage through existing culverts increasing the quantity of available habitat.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Ken MacKenzie

Proponent
Weldwood of Canada Ltd.,
100 Mile House Operations.

Watershed
Canimred Creek

Location
The crossing is located 0.5 km down a side road at 17 km on the Bowers FSR at an unnamed stream that flows into Canimred Creek.

Introduction
Canimred Creek has high densities of rainbow trout and may be an important spawning stream for Canim Lake. The streams affected by this project have high spawning and rearing habitat potential.

Assessments and Prescriptions
This barrier to fish was identified during a field inspection by Weldwood staff. It was determined during the site plan preparation that the existing culverts were sufficiently large to accommodate the Q100 flows. The primary barrier to fish was caused by the 20 cm outfall at the downstream end of the culverts and increased water velocity during high flow periods (Fig. 5-11). Constructing weirs to eliminate the outfall drop barrier was determined to be the most cost effective solution.

Rehabilitation Work
To minimize environmental impacts during the weir construction, the following steps were taken:

- Only clean rock was used for construction of the weir to reduce sediment input into the stream.
- An environmental monitor was on site for all phases of construction.

Structure Details
Two weirs were built to eliminate the outfall drop from the culverts. The first weir raised water levels by approximately 30 cm slowing water velocities through the culverts and eliminating the outfall drop (Fig. 5-12). An additional benefit from the weir construction is the significant deepening of the plunge pool for overwintering habitat. A second smaller weir was built downstream from the first to reduce the gradient of the stream and provide better fish passage.

Cost Summary

Site plan preparation	$ 2,000
Rip-rap supply	$ 4,500
Supervision	$ 2,000
Machine time	$ 1,500
Total	$ 10,000

Environmental Benefits
An additional 6.2 km of habitat is now available to migrating rainbow trout.

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Figure 5-11. Culverts prior to weir construction.

Figure 5-12. Culverts backflooded after weir installation.

Clearwater Lake LWD Placements

Objectives
There are several objectives of the Marjorie Creek Restoration Project and they are outlined below:

- To increase the rainbow trout carrying capacity (rearing and spawning habitat) through the addition of LWD instream structures in reaches DA1 and DA2.
- To document and present the structures that were placed in Marjorie Creek.
- To calculate the anticipated increase in rainbow trout productivity using established biostandards.
- To calculate the cost per structure site given labour and materials costs.
- To provide stream restoration training through on-ground works to select local individuals.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Michael A. Parker with excerpts from report by Peter Nicklin, Bioterra Consulting.

Proponent
Kleena Kleene Resource Association

Watershed
Clearwater Lake / Marjorie Creek

Location
The project area is located within the Chilcotin Forest District of the Cariboo Region, some 230 km west of the city of Williams Lake.

Introduction
With an active community group as proponent, all levels of fish habitat, riparian, and upslope assessments have been completed for this watershed. MOF is working with the proponent to complete road deactivation and upslope works. Three key fish habitat issues guided restoration options in the Clearwater Lake watershed.

Marjorie Creek is the major source of recruitment for rainbow trout in the watershed (specifically the stream below the bridge crossing at the Big Stick FSR).

The carrying capacity of Marjorie Creek (presently limited to the lower four reaches, approximately 1.9 km) is a major factor in determining the status of the rainbow trout population in the Clearwater Lake watershed.

Fish habitat impacts to Marjorie Creek are attributed to stream debris clearance, very low summer flows, sedimentation of spawning gravel and low quantity of spawning gravel. The removal of LWD in the Marjorie Creek system has resulted in the degradation and loss of spawning habitat. The loss of spawner holding pools and cover has probably further reduced the suitability of a number of historic spawning sites. Removal of LWD has increased the habitat favored by longnose suckers. The suckers are competing with the rainbow trout for spawning sites in the spring high flows. Increasing the complexity of Marjorie Creek will enable the rainbow trout to compete more successfully against the suckers for spawning habitat.

Assessments and Prescriptions
The Kleena Kleene Resource Association (KKRA), through Forest Renewal BC and in coordination with the Ministry of Environment (Watershed Restoration Program) and Ministry of Forests, Cariboo Region have completed an Overview and Level 1 Fish Habitat Assessment, Sediment Source Survey, Interior Watershed Assessment, Level 2 Fish Habitat Assessment and Prescriptions Procedure (FHAP), Riparian Assessment and an Integrated Watershed Restoration Plan on the Clearwater Lake watershed.

The target species for restoration in the Clearwater Lake watershed is rainbow trout. The Marjorie Creek system (downstream of the Big Stick FSR bridge) is the primary source of recruitment for rainbow trout (spawning and rearing) to Clearwater Lake and is thus the focus of instream restoration. Lack of LWD in reaches DA1 and DA2 was determined by the Level 2 FHAP to be limiting rainbow trout habitat.

Rehabilitation Work
Seven types of LWD structures (21 in total) were placed over a 1.4 km length of stream. The seven types of structures included: single log deflector, double log deflector, bar stabilization

with rootwad LWD, boulder/cobble weir, deflector/digger log, full-spanning digger log and angled LWD.

All work was completed by a hand crew of three people, with hand tools and a chainsaw. The breakdown of each structure type is as follows:

- 6 angled/anchored LWD structures;
- 2 deflector/digger log structures;
- 1 downstream boulder/cobble weir;
- 6 full-spanning digger logs;
- 2 single log deflectors;
- 6 buried LWD rootwad structures; and
- 1 double log/boulder deflector.

Formation of local scour pools and increased cover via log deflectors, digger logs, angled/anchored LWD, bar stabilization with rootwad LWD and rock weir placements should increase the carrying capacity of the stream by increasing the rainbow trout rearing and spawning habitat through increased stream complexity. Formation of scour pools will help retain more water during periods of low flow and potentially increase juvenile survival (Fig. 5-13).

Twelve person days of labour were created by the Marjorie Creek rehabilitation project.

Cost Summary

The instream structures were completed in 24 hours. Man hours of employment created by this project are calculated by the following breakdown. Three people were used for 24 hours. An additional 2 people were used for the first 12 hours of labour. Twelve person days (based on 8 hour days) of labour were created by this project.

Labour	$ 2,952
Equipment rental and supplies	$ 800
Total	$ 3,752

Each structure has an estimated average cost of $178.67.

Restoration Results

Twelve pieces of LWD were added to Reach DA2, thus exceeding the total pieces of wood recommended for addition in the Level 2 FHAP. The expected increase in rainbow trout population (using established biostandards) is 2.7 -fold for total rainbow trout numbers and a 1.3-fold increase for catchable sized trout (>= 15 cm) per unit length of mainstem.

Proposed Work

No further works are proposed for the Clearwater Lake watershed.

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Figure 5-13. Site 8 on Marjorie Creek at extreme low flows during August 1998 installation (above) and approaching bankfull conditions on November 12, 1998 (below).

Cottonwood River Fish Access Restoration

Objectives
To restore fish passage at identified high priority sites along the 1300 Road of the Cottonwood River watershed.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Michael Parker

Proponent
West Fraser Timber Ltd.,
Quesnel Division.

Watershed
Cottonwood River

Location
The Cottonwood River is located in the Quesnel Forest District. This system flows northwest for 151 km before entering the Fraser River just north of the city of Quesnel.

Introduction
As part of a Level 1 FHAP completed in 1998 by Carmanah Research Ltd., a fish passage culvert inspection was conducted on a portion of the watershed. Twenty seven sites were assessed with 20 being rated as high priority, and representing more than 34 km of habitat that was inaccessible above these sites. Four sites were identified for installation of a downstream weir to backflood the culvert (Fig. 5-14), and another two were identified for bridge replacements. All sites were along tributaries feeding the Sovereign Creek system that flows into the Cottonwood River.

Assessments and Prescriptions
Overview and Level 1 Fish Habitat Assessments were completed in early 1998, and G3 Consulting completed Level 2 prescriptions for some project areas during 1998. Two sites were earlier identified in a Fish Habitat Inventory of the Swift River Watershed (Imhof and Sutherland 1996).

Rehabilitation Work
The four culverts that were backflooded made accessible a total of 17 km of stream for a cost of $12,000. Three of these sites were flooded by creating a rock riffle downstream of the culvert, thus eliminating outfall drops of 25-60 cm, and in culvert velocities up to 1.06 $m{\cdot}s^{-1}$ (Fig. 5-15). One site was used to test an alternative approach, by rebuilding the riffle directly from the downstream lip of the culvert by filling in the existing plunge pool. Pool habitat was not limited in the reach, and this type of approach allowed us to place substrate within the culvert itself to further slow velocities. Large “key” angular boulders were placed at the culvert outlet lip such that they extended 15cm above the culvert lip. It is anticipated that these key stones will help hold substrate in the culvert. All weirs were constructed with clean angular rock of assorted sizes up to 1 m^3.

Two bridges were installed at sites where existing culverts were undersized, and had created outfall drop barriers. One was on a tributary to Little Swift Creek, and installation gained access to over 2.5 km of high value bull trout spawning habitat. The other was on Horan Creek and provided access to 1.7 km of habitat on a first-order rearing stream.

Cost Summary

Materials	$100,000
Labour	$ 20,000
Machinery	$ 56,000
Total	$176,000

Restoration Results
In total more than 21.5 km of stream habitat is once again accessible to fish in six different Cottonwood tributary systems. This is a combination of spawning and rearing habitat for target species of rainbow trout and bull trout.

In addition materials have been stockpiled at a project site on a tributary to Sovereign Creek in anticipation of instream works during 1999.

Proposed Work
Level 2 prescriptions were completed by G3 Consulting Ltd. for instream works on Sovereign Creek, Horan Creek and Fontaine Creek of the Cottonwood River watershed. These LWD/

boulder complexing type projects are scheduled to take place in 1999. Additional crossings will be examined for works based on FRBC eligibility criteria that are yet to be confirmed.

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Figure 5-14. Culvert site at 19 km - 1300 Road, Cottonwood River watershed limiting fish access to 1.75 km of habitat. The outfall drop of 30 cm was followed by a cascade of 80 cm height.

Figure 5-15. Culvert site at 19 km - 1300 Road, Cottonwood River watershed after construction of a downstream riffle.

Beverly Lake Elliptical Culvert Site 641 Road

Objectives
To replace a culvert barrier with a crossing structure that could accommodate spring flows and allow fish passage at all times of the year.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Ken MacKenzie

Proponent
Weldwood of Canada Ltd.,
100 Mile House Operations.

Watershed
Eagle Creek

Location
The site is located at 1 km on the 641 Road in the Eagle Creek drainage. The stream is the main inflow to Beverly Lake.

Introduction
The site is located upstream from Susan Lake which has a Forest Service recreation site and receives moderate fishing pressure. The stream has good spawning and rearing fish habitat potential.

Assessments and Prescriptions
This site was not ranked in the Eagle-Bradley fish passage-culvert inspection report because work to replace it had already been initiated. However, based upon the quantity and quality of habitat gained and the barrier that existed prior to replacement this site would have ranked third or fourth.

The existing culvert was undersized to accommodate high spring flows (Fig. 5-16) and acted as a barrier to fish by increasing water velocity and having a 25 cm outfall drop. As the stream width was relatively small (around 1.7 m) an elliptical culvert was determined to be a viable option to restore fish passage.

Rehabilitation Work
Low flows at the time of replacement allowed the stream to be pumped around the work area during installation (Fig. 5-17). Silt fences were installed downstream for all phases of construction. An environmental monitor was on site during all phases of construction.

Structure Details
- 2540 mm wide by 1630 mm high by 15,850 mm long elliptical culvert.
- Culvert was embedded 20% (320 mm) of height into the reconstructed streambed (Fig. 5-18).

Cost Summary

Site plan and culvert	$ 19,000
Installation, rip-rap and road resurfacing	$ 19,427
Total	$ 38,427

Environmental Benefits
An additional 5.1 km of habitat is now available to fish.

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Figure 5-16. Culvert prior to replacement.

Figure 5-17. Stream diversion during instream works.

Figure 5-18. Final installation.

Borthwick Creek Road Bridge Site

Objectives
To replace man-made barriers to fish with a clear span structure.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Ken MacKenzie

Proponent
Weldwood of Canada Ltd.,
100 Mile House Operations.

Watershed
Eagle Creek

Location
The site is located at 0.5 km on the Borthwick Creek road in the Eagle Creek watershed. The unnamed stream flows into Oie Creek.

Introduction
Rainbow trout are abundant in the stream as well as a variety of non-game species.

Assessments and Prescriptions
The fish passage-culvert inspection report for the Eagle Creek watershed identified this site as the highest priority for restoration for a number of reasons. Habitat potential was listed as high, the culverts were acting as a total barrier to fish passage and a large amount of upstream habitat was isolated. Two culverts at the site had water velocities of 1.5 $m{\cdot}s^{-1}$ and outfall drops of 25 cm (Fig. 5-19). The width of the stream and quantity of spring flow required that a bridge be prescribed to allow fish passage at the crossing.

Rehabilitation Work
A dry environment during stream channel reconstruction was attained by diverting the stream into one of the existing culverts using a rock and filter fabric dam. Rip-rap was placed on all embankments to prevent erosion and sediment from entering the stream. An environmental monitor was on site during all phases of construction

Structure Details
- Twelve meter concrete decked bridge (Fig. 5-20).
- Pre-cast concrete footings with steel towers.
- Stream channel reconstructed to 3.5 m.

Cost Summary

Bridge design, supply and install	$ 46,780
Rip-rap, site plan and supervision	$ 10,185
Total	$ 56,965

Environmental Benefits
An additional 3.9 km of habitat is now available to fish.

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Figure 5-19. Culvert prior to replacement.

Figure 5-20. Final installation.

Thearon Creek Bridge Site 518A Road

Objectives
To replace a culvert which was acting as a barrier to fish migration.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Ken MacKenzie

Proponent
Weldwood of Canada Ltd.,
100 Mile House Operations.

Watershed
Eagle Creek

Location
The site is located at 2 km on the 518A Road. Thearon Creek flows into Eagle Creek just upstream from Murphy Lake.

Introduction
Rainbow trout are found throughout this system and other game fish species are found in Murphy Lake including burbot, lake trout and rocky mountain whitefish. A complete barrier to fish remains in place on the Ministry of Transportation and Highways road downstream from this site.

Assessments and Prescriptions
This site was identified as the third priority in the Eagle/Bradley fish passage-culvert inspection report. Water velocity in the culvert at the time of the assessments was 0.9 $m{\cdot}s^{-1}$ with an outfall drop of 5 cm (Fig. 5-21).

Rehabilitation Work
- Water was diverted around the channel during work (Fig. 5-22).
- Silt fences were installed downstream for the duration of the work.
- An environmental monitor was on site for all phases of construction.

Structure Details
- Nine meter concrete deck bridge (Fig. 5-23).
- Pre-cast concrete footing and 8 inch steel towers.
- Reconstructed stream channel 4 m wide.

Cost Summary

Bridge design, supply and install	$ 40,000
Rip-rap, site plan and supervision	$ 12,063
Total	$ 52,063

Environmental Benefits
An additional 9.9 km of habitat is now available to fish.

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Figure 5-21. Culvert prior to replacement.

Figure 5-22. Barrel to dissipate pumped water velocity.

Figure 5-23. Bridge superstructure across reconstructed channel.

Unnamed Stream 100 Road Bridge Site

Objectives
To replace a barrier to fish passage created by two culverts with a bridge.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Ken MacKenzie

Proponent
Weldwood of Canada Ltd.,
100 Mile House Operations.

Watershed
Eagle Creek

Location
The site is located at 11.5 km on the 100 Road in the Eagle Creek watershed. The unnamed stream flows from Peach Lake into Oie Creek.

Introduction
Rainbow trout and other non-gamefish species are found in the stream.

Assessments and Prescriptions
The fish passage-culvert inspection report completed for the Eagle Creek watershed identified this site as the second priority for restoration. Water velocity through the crossing structures was 1.8 $m{\cdot}s^{-1}$ and a 15 cm outfall drop existed (Fig. 5-24). The stream width at the site (over 3.5 m) indicated that a bridge was the best option to restore fish passage.

Rehabilitation Work
A bypass channel was constructed and armoured to accommodate the stream during culvert removal and channel reconstruction (Fig. 5-25). Silt fences were installed downstream during all phases of construction to maintain water quality An environmental monitor was on site for all phases of construction.

Structure Details
- 11 m concrete decked bridge (Fig. 5-26).
- Pre-cast concrete footing and steel towers.
- Reconstructed channel width 4 m.

Cost Summary

Bridge design, supply and install	$ 46,780
Rip-rap, site plan and supervision	$ 11,688
Total	$ 58,468

Environmental Benefits
An additional 4.25 km of habitat is now available to fish.

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Figure 5-24. Culverts prior to replacement.

Figure 5-25. Preparing bypass channel.

Figure 5-26. Final installation.

Jerky Creek Fish Access Restoration

Objectives
To re-establish fish passage at two road crossings in the Jerky Creek basin while considering the expected lifespan of the roads at these crossings.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Michael Parker

Proponent
Weldwood of Canada Ltd.,
Williams Lake Division.

Watershed
Jerky Creek

Location
Jerky Creek is a tributary to Beedy Creek in the Beaver Valley watershed. The area lies some 60 km north of the city of Williams Lake in the Williams Lake Forest District.

Introduction
Two sites on the same system limited fish access of the target rainbow trout populations to the upper 3.2 km of stream. The lower crossing is only expected to be in use for approximately another 5 years, and therefore the challenge was to evaluate the costs associated with various types of structures and decide what expense could be balanced against the gain of habitat. It is expected that this lower crossing will be deactivated in the future.

Assessments and Prescriptions
Overview and Level 1 FHAP and Riparian Assessments were completed in Beedy and Freddy watersheds (of which Jerky Creek is part) during 1997-98 by Aim Ecological Consultants. There were a few riparian concerns associated with private agricultural lands, and no major habitat impacts. Two Jerky Creek crossings however were identified as limiting access to a large portion of that watershed.

Rehabilitation Work
Two Jerky Creek mainstem crossings were replaced with round culverts that were sized to accommodate the 100-year flood, and embedded 20% into the stream bed. Although, elliptical culverts are typically preferred for crossings of the size encountered to meet Q100 flows, the costs associated with the elliptical design were not felt to be justified given the anticipated deactivation of the crossings in five to seven years. Re-alignment with the natural stream, establishment of low gradient placement, armouring around the tailwater area, and embedding and loading the culvert with substrate were all factors that were employed to ensure fish passage for the life of the structures.

Cost Summary

Materials	$ 14,440
Labour	$ 2,600
Machinery	$ 10,500
Total	$ 27,540

Restoration Results
In total an additional 3.2 km of stream habitat and two small pond areas are now accessible to all lifestages of the target species rainbow trout. The first culvert gained 1.2 km to the upstream culvert, which gained an additional 2 km plus some additional uncalculated tributary habitat.

Proposed Work
No additional works are planned within this watershed based on the low priority assigned by preliminary assessment of the impacts, and confirmed by Ministry staff site visits.

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Lorin Lake Bridge 8200 Road

Objectives
The primary objective of this project was to remove man-made barriers to fish passage allowing migrating fish access to increased habitat. A second objective was to reduce the risk of sediment delivery into the stream.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Ken MacKenzie

Proponent
Weldwood of Canada Ltd.,
100 Mile House Operations.

Watershed
Jim Creek

Location
The crossing is located at 14.5 km on the Bowers Lake Forest Service Road (8200 Road) at an unnamed stream which flows from Lorin Lake into Cougar Creek.

Introduction
Both Lorin Lake and Cougar Lake are popular fishing lakes and receive moderate to high fishing pressure throughout the fishing season. Rainbow trout are the only game fish found in this system.

Assessments and Prescriptions
The Jim-Windy watershed fish passage-culvert inspection report identified this site as the top priority for restoration in this watershed for a number of reasons. The culvert at the crossing was a complete barrier to fish passage by increasing water velocity (velocity on June 6, 1998 was 1.81 $m \cdot s^{-1}$) and because of an outfall drop of 25 cm. The stream has good potential spawning substrate and is the main upstream tributary for Cougar Lake. The culvert was undersized and had the potential to become plugged which may have resulted in a serious road washout and considerable sediment delivery into the stream.

Because of the relatively steep slope of the stream at the crossing site (6.5%), the best option to restore fish passage was deemed to be a clear-span structure. A permanent, concrete decked bridge was prescribed because the Bowers Lake FSR is a well used main haul road.

Rehabilitation Work
To minimize environmental impacts during the culvert replacement work, the following steps were taken:

- Flow was blocked into the culvert using rock and filter fabric so that all work was performed in a dry environment.
- Water was pumped around the culvert into the plunge pool at the outfall using fire-fighting water pumps during installation (Fig. 5-27).
- Water was pumped into barrels to reduce water velocities to prevent scour and sediment generation in the stream.
- Sediment traps of hay bales and filter cloth were installed downstream of the pump discharge.
- An environmental monitor was on site for all phases of construction.

Structure Details

- Concrete deck composite design (9.1 m) (Fig. 5-28).
- Pre-cast concrete footing with 8 inch steel towers.
- Bridge deck at 3% slope.
- Reconstructed channel width 2.5 m.

Cost Summary

Design, supply and install bridge	$ 47,500
Rip-rap supply	$ 2,500
Supervision	$ 2,000
Total	$ 52,000

Environmental Benefits
Rainbow trout from Cougar Lake now have unrestricted access to an additional 1.5 km of spawning stream to Lorin Lake in addition to Lorin Lake itself and the small streams that drain into it. This more than doubles the available upstream habitat from Cougar Lake. The trout population in Lorin Lake is no longer isolated from the remainder of the watershed.

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Figure 5-27. Channel is constructed to route stream prior to pulling culvert on unamed creek.

Figure 5-28. Completed 8200 Road bridge installation.

Kwatna River Overwinter Pond Project - Gus Creek

Objectives
To establish rearing and high water refuge in the lower reaches of the Kwatna River for coho.

FRBC Region/ MELP Region/ MOF Region
Pacific / Cariboo / Vancouver

Authors
Niel Oborne, International Forest Products and Michael A. Parker, MELP.

Proponent
International Forest Products, Mid-Coast Division, Hagensborg, B.C.

Watershed
Kwatna River

Location
The project area is located within the Mid-Coast Forest District of the MELP Cariboo Region, some 55 km west of the community of Bella Coola.

Introduction
The Gus Creek site is an old back channel that has been in filled by silt. It is located low on the watershed (3 km from the estuary) and downstream of approximately 90 % of the spawning sites. The channel is still within tidal influence and twice a day for at least 20 days per month is enhanced by tidal flows.

Assessments and Prescriptions
This project follows 3 years of upslope watershed restoration activity in the Kwatna watershed. Fish habitat assessments indicated that rearing habitat is a limiting factor in our efforts directed toward restoration of fish populations to near historic levels. An Overview and Level 1 Fish Habitat Assessments were completed by Grizzly Holdings Ltd. on the Kwatna River in 1997. In 1998, LGL Ltd. completed Level 2 FHAP prescriptions for several sites on the Kwatna. Due to the late start in the restoration season in 1998, the Gus Creek off-channel project was undertaken as it could be constructed in the dry and connected once completed.

Rehabilitation Work
Interfor chose an EX200 excavator owned by the local Nuxalk Band with an operator adept in logging road construction, landscaping, and pond building. A Clark 668C line skidder owned by Tim Case, Hagensborg, was hired to transport large woody debris to the site. The labour crew varied from 1 to 3 persons. To account for our presence and activity in a sensitive riparian area adjacent to a major salmon producing stream, Bio Forest Consulting Services was retained to do environmental monitoring for the project.

The project began in September 1998 and continued through to November 1998. Midway through this period we finished excavating the suggested channel according to LGL's prescriptions. It was agreed between Interfor, MELP, and LGL that considering cost and the amount of pond habitat built that it would be better to double the size of the Gus Creek project than to move on to the next project which had a few unknowns built into it.

The average mid-pond depth is approximately 2 m at low tide; high tide may increase this depth by as much as 1 m (Fig. 5-29). Nearly 100 individual pieces of woody debris were anchored or placed in the pond to serve as cover. Final completion is scheduled for March 1999 when all bared soil will be seeded with a Coastal Reclamation grass mixture. Young cedar and spruce trees will be planted to increase riparian cover.

Work to date created 356 person days of labour.

Cost Summary

Machinery	$ 77,500
Materials (found on site)	nil
Labour	$ 60,300
Total	$137,800

Restoration Results
The completed overwintering pond is 420 lineal meters and is slightly over 0.5 ha (500m^2) in surface area.

Biostandards suggest that this pond should supply new habitat to 340 adult coho, and some 6000 smolts (Keely et al. 1996, and Adams and Whyte 1990 as cited in Slaney and Zaldokas

1997). An estimated 2072 salmonid fish would be expected in the 0.5 ha pond given the equation Log_{10} fish number = 0.51 log_{10} pond area (ha)+3.47 (Keely and Slaney 1996 as cited in Slaney and Zaldokas 1997) for overwintering ponds.

Proposed Work

There are several other sites including wood complexing and rearing pond development within the Kwatna River watershed for which prescriptions have already been drawn. These are scheduled to be completed during the instream window of 1999. As well, seeding and riparian planting along the created channel will be completed in 1999.

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Figure 5-29. Off-channel rearing pond excavated along Kwatna River mainstem prior to LWD complexing and planting of broadcast overburden materials.

Little Bridge Creek Restoration

Objectives
To reduce the impacts of agricultural management practices on the fish habitat of Little Bridge Creek as they pertain to water quality.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Michael Parker

Proponent
Ainsworth Lumber

Watershed
Little Bridge Creek

Location
Little Bridge Creek is a tributary to Bridge Creek, and flows through the community of 100 Mile House in the 100 Mile Forest District.

Introduction
A MELP survey of Exeter Lake, within the Little Bridge system revealed the presence of a large number of lake whitefish (*Coregonus clupeaformis*), a provincially red-listed species. Rainbow trout were the target species for the efforts on this system. Ainsworth Lumber negotiated with Bridge Creek Estates and FRBC to undertake improvements on private ranch lands that run through the community of 100 Mile House for the benefit of fish habitat in Little Bridge Creek and public education / awareness of correct herd management practices. In 1996 Ducks Unlimited provided fencing around Exeter Lake and the reach of Little Bridge Creek below the lake. Upstream reaches were unprotected from cattle impacts.

Assessments and Prescriptions
An Overview FHAP Assessment of Bridge Creek watershed was completed in 1997 by Bioterra Consulting Ltd. Level 2 prescriptions were completed in Little Bridge Creek sub-basin during 1998, and subsequent instream works began during the fall of this year.

Rehabilitation Work
This project is a private land project dealing with agricultural impacts on Little Bridge Creek. Approximately 1.4 km of Little Bridge Creek was fenced to exclude cattle access to the riparian area. Four fords and cattle watering/crossing locations were replaced with log crib bridges made with materials donated by the landowner. An abandoned low head weir was removed to improve fish access, and pool habitat excavated and complexed at the site. Three small trodden springs were developed for cattle watering away from the mainstem by installing concrete cisterns as catchments.

Cost Summary

Materials	$ 11,000
Labour	$ 12,500
Machinery	$ 4,500
Total	$ 28,000*

*all prices are estimates.

Restoration Results
As the primary spawning habitat for rainbow trout in Exeter Lake, the reach above the lake underwent several improvements to limit the impact of cattle on the fish habitat of Little Bridge Creek. Reduced sedimentation from fencing and providing crossings along approximately 1.4 km of stream, and developing alternate watering sources should help the local population.

Proposed Work
No further works are proposed for Little Bridge Creek. Level 2 prescriptions are expected for other locations on Bridge Creek during 1999, with possible instream activities getting underway before the end of the year.

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Rebman Creek Rock Riffle Construction

Objectives
The objective of this project is to re-establish pool-riffle morphology within the system. Minimal existing pool habitat was determined to be a detriment to low flow refuge and to rearing capabilities of the system. Re-establishment of a higher percentage of pool area is the primary objective.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Michael Parker

Proponent
Weldwood of Canada Ltd.,
Quesnel Division.

Watershed
Rebman Creek

Location
Rebman Creek is a tributary to the Willow River. Located in the Quesnel Forest District, it lies approximately 100 km northeast of the city of Quesnel.

Introduction
Rebman Creek is approximately 3 m bankfull in width with a gradient ranging 3-6%. It is a rearing area and high water refuge for fish from the mainstem Willow River. An extremely high (>53%) proportion of the watershed has been logged, with much of it leaving little to no riparian area. Pool habitat was approximately 3% over the first 4 reaches. LWD was extremely limited. Extreme low flows in August often cause the first reach to go dry, and lack of pools in the upper reaches cause a variety of problems from thermal warming, predation, crowding, etc. during low flow periods.

Assessments and Prescriptions
As part of the Willow River watershed, Rebman has been subject to Overview and Level 1 Fish Habitat and Riparian Assessments completed in early 1998 by LGL Ltd. Level 2 assessments were conducted during the fall of 1998. Many upslope assessments have also been completed and road deactivation and slope stabilization projects were underway during the fall of 1998.

Rehabilitation Work
Given the late start of instream works in Rebman, six consecutive sites in Reach 4 were prescribed for works during the fall of 1998. The remaining 40+ will be completed in 1999. This years' work consisted of the construction of rock riffles using local materials and a hand crew from Randall and Associates (Fig.5-30). This crew pioneered a technique of using compressed air to loosen impacted substrates, freeing the rocks necessary to construct the riffle and pool sequence. This technique appeared to be successful in execution, and will therefore likely be used in the coming year to eliminate riparian damage that would be caused by using a machine. This was deemed important as regeneration of riparian was providing the primary cover along the mainstem. Fish salvage was conducted prior to construction of individual structures.

Cost Summary

Materials	nil
Labour	$15,800
Machinery	nil
Total	$15,800

Restoration Results
Six structures were completed over a test section of approximately 200 m of stream. Re-evaluation of these hand constructed structures that utilized on site materials will be done in the spring, and a determination made if it is necessary to use machinery and/or imported materials to complete the remaining structures.

Proposed Work
Approximately 40 remaining riffle structures and bank stabilization efforts are to be completed during the 1999 season.

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Figure 5-30. Hand constructed rock riffle completed on Rebman Creek mainstem.

Spanish Creek Tributary Culvert Replacement 7000 Road

Objectives
To replace a series of culverts that are acting as a barrier to fish movement and to reduce the risk of sediment delivery to Spanish Creek.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Ken MacKenzie

Proponent
Weldwood of Canada Ltd.,
100 Mile House Operations.

Watershed
Spanish Creek

Location
The site is located at 31 km on the 7000 Road just south of Spanish Lake and west of Wells Gray Park on an unnamed tributary to Spanish Creek.

Introduction
This stream is one of the main tributaries to upper Spanish Creek and has relatively high densities of rainbow trout downstream of the culverts.

Assessments and Prescriptions
This site was listed as the highest priority crossing for restoration in the Deception/ Spanish watershed in the Boss-Deception fish passage-culvert inspection report. Four culverts existed at the crossing all of which were barriers to fish passage due to high flow velocities and outfall drops (Fig. 5-31). The site was a potential sediment source as well due to high flows and insufficient culvert capacity.

The 10 m width of the stream required that a clear span structure be used to provide fish passage and accommodate spring flow volumes.

Rehabilitation Work
Silt fences were placed downstream of the works to maintain water quality during construction. Water was diverted into a single culvert while the remainder were removed and a new channel was constructed. An environmental monitor was on site during all phases of construction.

Structure Details
- Eighteen meter concrete deck composite design (Fig. 5-32).
- Pre-cast concrete footings with 12 inch steel towers.
- Three percent slope to deck.
- Reconstructed stream channel approximately 10 m wide.

Cost Summary

Bridge design, supply and install	$ 65,917
Rip-rap, site plan and supervision	$ 16,820
Total	$ 82,737

Environmental Benefits
Reduced risk of serious sediment introduction into Spanish Creek from a road washout due to blocked culverts. Fish access to 6.3 km of additional habitat.

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Figure 5-31. Culverts prior to replacement.

Figure 5-32. Final installation.

Talchako River Groundwater Channel

Objectives
To restore access to existing off-channel habitat and restore groundwater off-channel habitat in the Talchako River for overwinter and high flow refuge for coho and cutthroat.

FRBC Region/ MELP Region/ MOF Region
Pacific / Cariboo / Vancouver

Author
Michael Parker

Proponent
International Forest Products,
Mid-Coast Division, Hagensborg, B.C.

Watershed
Talchako River

Location
The Talchako River, partially defines Tweedsmuir Provincial Parks' southwest boundary. It is located approximately 380 km west of the city of Williams Lake and 60 km east of the community of Bella Coola. Along with the Atnarko River it forms the Bella Coola River.

Introduction
All significant tributaries to the Talchako are glacial fed and limited to fish access by gradient within less than 1 km. The Talchako itself is highly glacial with very little off-channel habitat. Several off-channel ponds and groundwater channels exist between 72-84 km. As most of these run parallel to the mainstem on the valley floor, they were areas that were logged. Beaver activity has also prevented access to several of these high value clear water areas.

Assessments and Prescriptions
In 1996, Overview and Level 1 Assessments was completed for the Bella Coola River including the Talchako and some of its major tributaries. In 1998, further Level 1 assessments were completed on several of the small groundwater channels and off-channel habitat in the upper regions of the watershed. Ministry of Environment completed prescriptions for SOD removal through old cutblocks, access structures around beaver dams and groundwater channel excavation to re-open and enhance areas within cutblocks.

Rehabilitation Work
On the ground activities can be divided into three:

- SOD removal was carried out in three cutblock locations along small groundwater channels to improve flow and scour. These clearwater channels were full of past logging slash. Over 550 linear meters of channel was hand cleared at three different sites. Any material under 15 cm diameter and/or 2 m in length was removed from the channels. All large material was left in place.
- Groundwater channel excavation was carried out at one location during 1998. Roughly 200 m of channel was excavated to redefine stream banks and establish deep pond areas in an area that had seen past impacts from skidding and other logging activities (Fig. 5-33). This channel was typically excavated 2 m wide and 1 m deep, with meanders, pools and pond areas. LWD was re-established to the channel and ponds and keyed into the banks. As flows are stable through this groundwater area, no cable anchoring was employed.
- A hand dug channel was established around a deserted beaver dam to gain access to nearly 1 km of groundwater channel and rearing pond area (Fig. 5-34). The 20 m long channel consisted of a series of step pools that dropped in total 0.8 m (Fig. 5-35). Each step was no more than 15 cm to ensure access of juvenile target species to the habitat upstream. The channel was lined with filter fabric and covered with an assortment of angular substrate. Rock/log structures created the plunge pools and were keyed to the banks for stability. Minimal riparian impact was created through the use of hand construction and a variety of local sedges, conifers and other vegetation transplanted to the edge of the channel. As the beaver dam itself created high value pond habitat heavily complexed by mature LWD, it was a feature that should be maintained for a long period. Therefore, plastic was placed along the dam on the

upstream side to ensure all water goes through the created side channel and would not percolate through the dam at lower flows. The plastic was then covered with soil and rock to hold it in place, and the whole dam covered with soils to promote vegetative growth, and establish the dam as a permanent feature. A small rip-rapped overflow channel was created to handle any excessively high flows.

Cost Summary

Machine	$ 22,200
Materials	$ 2,600
Labour	$110,000
Total	$134,800

Restoration Results

Within two hours of completing the beaver dam bypass channel one juvenile coho and one cutthroat were into the second step pool. By the next day fish were found throughout the steps. Minnow traps will be set in the pond and channel above in 1999 to examine distribution and species.

Removal of SOD created a visible increase in localized stream velocities and scour of fines in some areas was revealing buried cobble and gravel substrate.

Groundwater channel excavation was not completed at the time of writing this report.

Proposed Work

Further groundwater channel excavation and complexing is anticipated at three locations for 1999. Access problems at two long abandoned beaver dams will also be evaluated and prescriptions written.

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Figure 5-33. Portion of excavated groundwater channel at 77 km, Talchako River prior to LWD complexing.

Figure 5-34. Initial hand excavation of beaver dam bypass channel, Talchako River, 77 km.

Figure 5-35. Same section of bypass channel with flow and vegetated banks, Talchako River, 77 km.

Woodjam Creek Culvert Access

Objectives
To restore fish passage at this mainstem culvert crossing for all life stages of the target species.

FRBC Region/ MELP Region/ MOF Region
Cariboo-Chilcotin / Cariboo / Cariboo

Author
Michael Parker

Proponent
Weldwood of Canada Ltd.,
Williams Lake Division.

Watershed
Woodjam Creek

Location
Woodjam Creek is a tributary to the Horsefly River. A wide range of fish including anadromous species utilize the majority of this watershed that is located approximately 25 km east of the community of Horsefly, in the Horsefly Forest District.

Introduction
This project was undertaken to address concerns within the proponent's operating area as identified through an assessment conducted by another licensee. As WRP is meant to be conducted on a watershed scale it often does address issues for more than one operator, and as such operators in this case chose to address identified projects individually.

Assessments and Prescriptions
Minimal assessments have been conducted in this watershed on fish or riparian habitat. However, a Fish Passage Culvert Inspection was completed in 1998 by Bioterra Consulting for Riverside Forest Products, Soda Creek Division. As part of this watershed is in the operating area of Weldwood of Canada Ltd., this firm proceeded with the replacement of the one high priority identified barrier within their area of the watershed. This replacement provides access to 3.6 km of high value fish habitat, not including tributaries above this mainstem crossing.

The existing culvert was determined to be undersized for the crossing according to Forest Practices Code requirements as the 1400 mm culvert was not adequate for high flows on the 2.3 m bankfull channel. It is expected that velocities impact adult migration during spawning periods, as well as juvenile passage.

Rehabilitation Work
The old 1400 mm culvert was replaced with a full spanning bridge structure. Fill was pulled back and the channel around the bridge abutments armoured. Gradient through this area was approximately 1.5%.

Cost Summary

Materials	$ 44,000
Labour	$ 3,000
Machinery	$ 6,000
Total	$ 53,000*

*budget is estimated based on similar project activities at other locations.

Restoration Results
Over 3.6 km of mainstem habitat is now accessible to all life stages of fish. As well, tributaries above the crossing will be accessible from the mainstem for rearing. The mainstem itself is approximately 2.3 m bankfull at the crossing, and provides rearing and spawning habitat upstream of the crossing.

Proposed Work
Level 1 FHAP assessment and instream works are scheduled to begin in Woodjam Creek during 1999.

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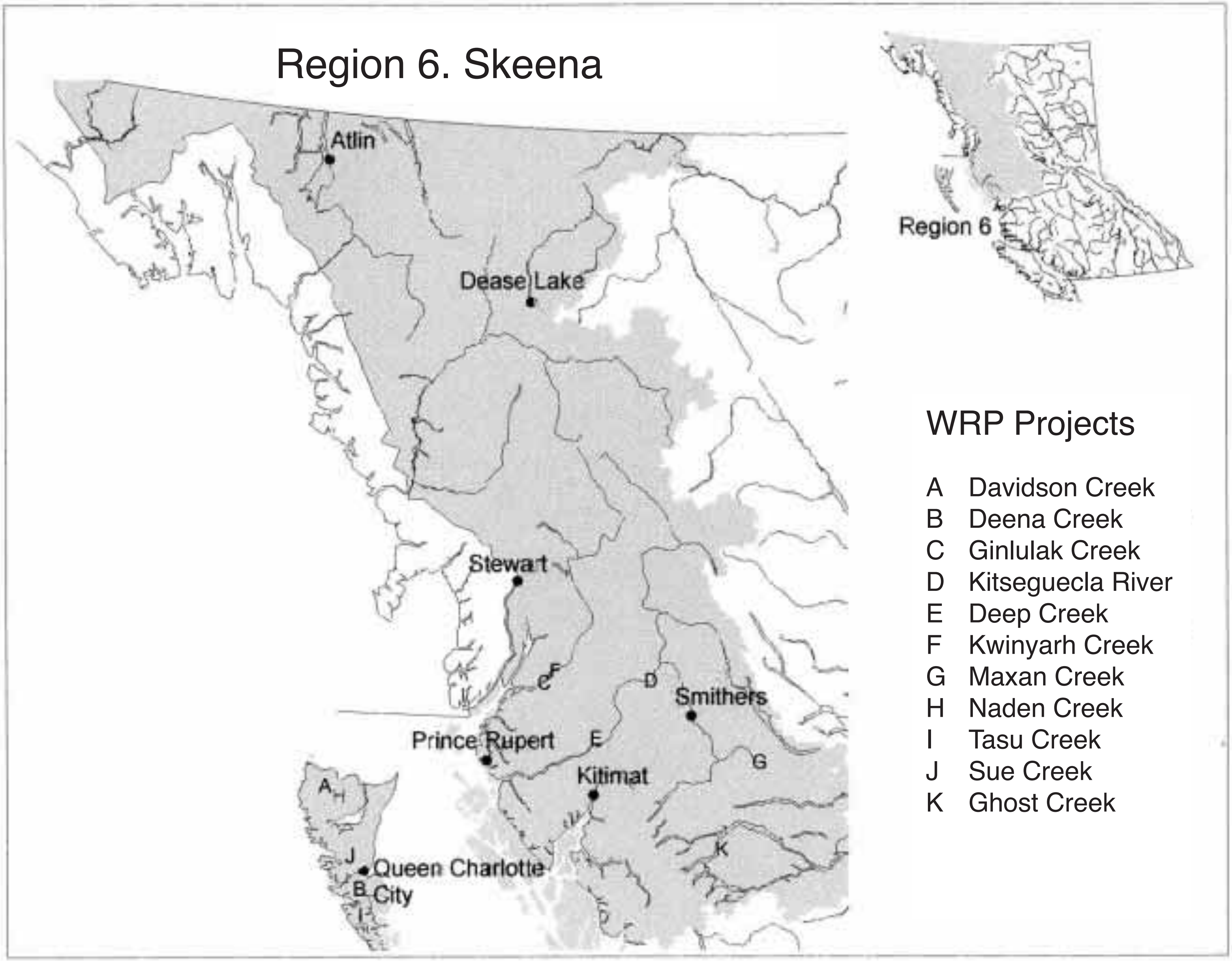
Skeena Region


Region 6. Skeena
Atlin
Dease Lake
Stewart
Smithers
Prince Rupert
Kitimat
Queen Charlotte City
A
B
C
D
E
F
G
H
I
J
K
Region 6
WRP Projects
A Davidson Creek
B Deena Creek
C Ginlulak Creek
D Kitseguecla River
E Deep Creek
F Kwinyarh Creek
G Maxan Creek
H Naden Creek
I Tasu Creek
J Sue Creek
K Ghost Creek

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 6, Skeena.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
A	**Skeena**	Davidson Creek	Davidson Creek	8	5980625	651944	940-661700	00000GRAI
B		Deena River	Deena River	8	5892963	693075	950-974300	00000MORI
C		Ginlulak Creek	Ginlulak Creek	9	6099370	468612	500-090500	00000LNAR
D		Kitseguecla River	Kitseguecla River	9	6105637	574758	450-000000	00000KISP
E		Kitsumkalum River	Deep Creek	9	6046293	521719	430-067600	00000KLUM
F		Kwinyarh Creek	Kwinyarh Creek	9	6111382	478456	500-136800	00000LNAR
G		Maxan Creek	Maxan Creek	9	6029731	686621	460-924300	00000BULK
H		Naden River	Naden River (Reach 3-1)	8	5978588	652175	940-665100	00000GRAI
I		Naden River	Naden River (Reach 4-2)	8	5978588	652175	940-665100	00000GRAI
J		Tasu Creek	Tasu Creek	8	5860601	696313	950-734400	00000MORI
K		Yakoun River	Sue Creek	8	5915220	685593	940-896100-80800-28300	00000GRAI
L		Yakoun River	Ghost Creek	8	5923715	680753	940-896100-63600	00000GRAI

Davidson Watershed, 15 K Creek Slide Stabilization Project

Objectives
The objective of the 15K Creek Slide project was to revegetate four slides that deliver excessive amounts of sediment into 15K Creek.

FRBC Region/MELP Region/MOF Region
Pacific / Skeena / Vancouver

Author
Ian Dodd

Proponent
Husby Forest Products Ltd.

Watershed
Davidson Creek

Location
Davidson Creek is located in the northwest corner of Graham Island, the northernmost island of the Queen Charlotte group. 15K Creek is a tributary creek that flows east into Davidson Creek. The slope failures can be accessed from the Eden Lake logging camp by traveling to the 12.5 km mark on the Davidson mainline then exiting onto Branch 50 and traveling to the 14 km marker. From the 14 km marker, follow the short spur road west to 15K Creek. The slides are within 800 m of one another on the east bank of the creek.

Introduction
The Davidson Creek watershed, is a wet hypermaritime Coastal Western Hemlock (CWHwh1 and CWHwh2) ecosystem that has been extensively logged for approximately the last 20 years. 15K Creek is a low gradient, large S2 tributary creek to the Davidson. Historical logging activities have impacted the fish habitat in the creek in a number of locations. One of the first steps to rehabilitation of this tributary is to address the sediment source problems in the drainage. An assessment identified that the seven slides were harvesting-induced and are the main contributors of sediment into the system. After the assessment was completed a stabilization works project (on four of the sites) was initiated in the summer of 1998.

Assessments and Prescriptions
Reach 1, Section 2, of 15K Creek was being impacted by a number of slope failures. These slides are located on side slopes to the creek where the top section of these slopes had been harvested within the past 15 years. In a number of cases logging debris was left on landings located on the break in the slope. Assessment of the slides has identified that they were initiated by these landings and debris. Stream channel assessments have determined that the slides have contributed to creating new log jams and extensive sediment wedges in the creek. The slide paths had not revegetated and therefore fine sediment continued to be deposited into the creek impacting salmonid spawning, incubation and rearing.

Assessment of the 15K Creek slides recommended a bioengineering prescription (treatment) on 4 of the 7 slides in 1998.

Rehabilitation Work
Works were initiated in August of 1998, and the following steps were taken:

- The spur road above the slides was deactivated prior to the commencement of the bioengineering work. During the deactivation, logging debris was pulled back from the break in the slope below the road.
- A helicopter long-lined a palette of rebar, boards, Sitka alder (*Alnus crispa spp. sinuata*) plugs, red and yellow cedar seedlings, cedar cages, cage stakes, and fertilizer to the four sites. Willow was not used because it is a relatively scarce plant species in this area.
- For 15K- 4 slide, Modified Brush Layers (MBL) were rebarred into place on the steeper sections of the slide. The brush layer consisted of Sitka alder plugs and 1 m tall cedar seedlings that were planted 30 cm apart. Sitka alder plugs were planted on the slope between the MBLs. Cedar seedlings were planted in the organic soil on the lower gradient sections of the slide. Live gully breaks were not used. The MBLs were extended into the gullied section of the slide to prevent further gully development. The MBL in the gullied section contained only cobbles to allow water passage.

- 15K-3b slide was bioengineered in a similar manner as the 15K-4 slide, but only Sitka alder was used in the MBL.
- 15K-3 and 15K-2 slides still contain a large amount of logging debris that still overhangs the escarpment. These slides will be addressed in 1999. Regardless, cedar seedlings were planted in the organic soil at the base of 15K-2 slide.
- 15K-3a slide was planted with Sitka alder plugs on the main slide area and cedar seedlings in the organic soil at the base.
- 15K-5 slide, which is a lower gradient slide that still contains organic soil, was planted with cedar seedlings.

Cost Summary

Construction including supervision, design, labour	$ 25,000
Materials	$ 9,000
Total	$ 34,000

Production Estimates

Reach 1, Sections 1 and 2, of 15K Creek provide high quality rearing and spawning habitat for coho, pink, cutthroat and Dolly Varden. The slides have terminated in the creek creating large jams and sediment wedges. The jams do not prohibit fish passage but downstream of the slides the channel is moderately to severely aggraded with channel dewatering occurring during low flows. The bioengineering will reduce the amount of sediment delivery to the creek which is the first step towards rehabilitating this reach and increasing the long-term productivity of the stream.

Slides 15K-2 and 3 will be addressed in 1999 once the logging debris on the escarpment has been stabilized.

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Deena River Instream Rehabilitation

Objectives
To improve spawning, rearing and overwintering habitat and access for salmonids (primarily coho as well as pink, chum and steelhead) in smaller tributaries of the Deena Creek watershed.

FRBC Region/ MELP Region/ MOF Region
Pacific / Skeena / Vancouver

Author
Leandre Vigneault

Proponent
Gwaalagaa Naay Corporation

Watershed
Deena River

Location
The Deena River is located on Haida Gwaii in the southwest corner of Skidegate Inlet on Moresby Island. The work sites can be reached by traveling the Timberwest logging roads to West Deena Mainline. The work sites are located on three tributaries, two which cross the West Deena Mainline at 7.5 mile and 8.75 mile and one which crosses Security Mainline 500 m from the junction with West Deena Mainline.

Introduction
The Deena River has been extensively logged over the past 40 years with only the west and upper Deena sub-basins having less that 20% of their watershed area affected by timber harvesting. Due to a combination of high annual rainfall, unstable terrain and extensive timber harvesting the watershed has experienced numerous landslides and significant channel instability in both tributaries and the mainstem. Changes in the main channel and numerous small tributaries have resulted in the loss of rearing and overwintering fish habitat. Coho salmon are the primary target species for rehabilitation due to lower returns in recent years and the importance of coho to the commercial and recreational fisheries. Restoration works were initiated on three tributaries (Reaches 2B2, 2C3 and 5D) of the Deena in July and August 1997. The 1998 work involved completion and fine-tuning of the 1997 works following a cycle of winter high flows.

Assessments and Prescriptions
All prescriptions for the 1997 work were generated from WRP Level 1 assessments followed by an agency review and engineered plans. All the proposed rehabilitation work for 1998 was subject to an agency field review prior to the commencement of prescription development. The prescriptions were developed using information collected during the Level 1 assessment and the 1997 prescription development.

Rehabilitation Work
The 1997 works can broken up into three projects.
1. Reach 2B2 is a tributary to the Deena River with a bankfull width between 2 and 5 m, a wetted width between 1 and 3 m and approximately 500 m of useable habitat. The 1998 work consisted of 3 separate hand labour projects:

- Creation of two steps to allow fish passage over a 1m falls. The falls developed due to head cutting upstream from the confluence with the Deena to a log sill installed in 1997. Two sills were installed approximately 3 m apart downstream of the original sill to create three 0.3 m high steps (Fig. 6-1).
- Hand excavation of the outlet from an off-channel pond to increase useable rearing space and allow entry and exit at lower flows.
- Excavation of a natural depression to create a 4 m x 1.5 m alcove pond. The pond was excavated by hand and then covered over with limbs and other small woody debris to provide cover.

2. Reach 2C3 is a tributary to the Deena River with a bankfull width between 2 and 15 m and a wetted width between 1 and 3 m and approximately 1200 m of useable salmonid habitat. The 1998 work involved the installation of 10 wooden structures to increase the sinuosity of the channel as well as promote scouring of pools and provide cover for rearing and overwintering fish. The structures were built using large wood collected by hand from a near by clear cut and small "standing dead" saplings

cut out of the riparian zone. A great deal of help and advice was provided by Brian Bair of the USDA Forest Service in demonstrating the use of small wood debris catchers to provide bank and bar protection as well fish habitat. These techniques have been used successfully on both a small and large scale in Washington and Oregon to treat long sections of rivers and streams at low cost using available materials. All work in this reach was accomplished using hand tools and manual labour. The structures consisted of three types:

- Debris catchers installed on the leading edge of gravel bars. These structures were built by driving sharpened upright stakes into the ground, then pre-loading with debris by weaving small wood between the uprights to form a semi-permeable wall. These structures were constructed in pairs and the area between the two walls was loaded with more small woody debris to prevent scour during high flow events (Fig. 6-2).
- Bank protectors were constructed by laying saplings parallel to the bank. Wherever possible these structures were woven into existing wood and roots. Other saplings were then interwoven into this structure to create a mat. Stakes were also driven through the mat into the bank to increase the stability of the structure. These mats of small wood break up the flow of water running against the bank and provide good cover for rearing fish.
- V-deflectors were installed to constrict the flow and cause scour under a recently rebuilt bridge. During the bridge reconstruction the left bank sill was removed while right bank sill was left in place. The original bridge had sills placed approximately 0.8 m apart. When the left sill was removed the channel was left in the constricted state with nothing to protect the highly erodable left bank. V-deflectors were installed to simulate the constriction and scour caused by the original bridge, while providing protection to the newly exposed left bank. The deflectors were constructed using short sections of LWD and small rootwads keyed into the left bank to form the V-shape and back filled with large rock (Fig. 6-3). The left bank between the structures was lined with large rock to prevent erosion. The logs and rootwads used to make the V-structures were pined together using rebar.

3. Reach 5D is a tributary to Porter Creek (a Deena River tributary) with a bankfull width between 2 and 10 m and a wetted width between 2 and 4 m and approximately 1200 m of accessible fish habitat. This was the only project which was not completed with hand labour as a excavator was needed to place some of the larger rocks and construct and install two wooden walls for bank protection. The 1998 work consisted of four separate small projects:

- Construction of two rock riffles following the techniques described by Newbury et al. in Chapter 12 of Technical Circular No. 9 to stop further down cutting and provide vertical complexity to the channel. Prior to the start of the instream work the area was blocked off with stop nets and all fish present were removed using an electrofisher. Once the fish exclusion was complete, oil soak-up booms were installed at the downstream end of the work area and the excavator was allowed to work in the channel. The two riffles were constructed using 40 m^3 of blasted granite 20 to 70 cm in diameter. Most of the rock used was left over from work conducted at the same site in 1997 and as a result only 10 m^3 were purchased this year. Both riffles were constructed with a 5:1 slope on the upstream face and 15:1 slope on the downstream face with a separation of 5 bankfull widths. The crests were constructed with a V-shaped cross-section to concentrate low water flows and allow fish passage. The downstream riffle had a crest of 0.5 m and was constructed using a small excavator. The riffle crest was keyed to an embankment constructed in 1997 on the left bank and keyed into a large stump on the right bank (Fig. 6-4). The upstream riffle was constructed by hand, following the excavator placement of bank protectors, made from bundled large woody debris cabled and anchored with rock deadmen, along both banks. The second riffle had a crest of 0.3 m and was keyed to the two wooden walls. Care was taken to ensure that downstream slope of both riffles was roughened by embedding larger rocks into it.
- Placing large woody debris in the pools created by the rock riffles to provide cover. Three rootwads were placed with the

excavator to form a V-shaped structure in the pool created between the two riffles. The rootwads were pinned to each other and the low embankment (built in 1997) using rebar.
- Placing large woody debris to protect an eroding bank. One large log (0.8 m dia. by 8.0 m long) was moved from the road to an eroding bank located approximately 50 m downstream using a small skyline and a chainsaw winch. Once the log was set in place it was secured with two rock deadmen buried by hand and attached to the log using steel cable and epoxy. The log was placed parallel to the bank and the space between the log and the bank was filled with small woody debris to further break up water flow and prevent erosion.
- Loading the surface of a highly erodable bar on the right bank with small and large woody debris to prevent erosion during high flows. The wood was obtained by thinning a stand of alder located along the access road and was placed and interwoven by hand.

Cost Summary

<u>Reach 2B2</u>	
Design	$ 4,000
Labour	$ 3,900
Equipment	$ 2,400
<u>Reach 2C3</u>	
Design	$ 4,000
Labour	$ 3,900
Equipment	$ 2,400
<u>Reach 5D</u>	
Design	$ 4,000
Labour	$ 5,200
Materials	$ 1,500
Equipment	$ 5,300
Total	$ 36,600

Outputs and Production Estimates

The in-channel work completed on the three reaches has resulted in improved access as well as direct habitat improvements to approximately 300 m of stream channel. A further 8 m^2 of off-channel habitat was created in Reach 2B2.

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Figure 6-1. Reach 2B2 view from downstream looking up at the three steps created by the installation of two sills.

Figure 6-2. Reach 2C3 debris catcher placed on the leading edge of a gravel bar. The structure was pre-loaded with small woody debris.

Figure 6-3. Reach 2C3 V-shaped deflector installed under a bridge to protect an eroding bank and promote channel scouring

Figure 6-4. Reach 5D view from upstream looking downstream at the downstream rock riffle.

Mainstem Habitat Complexing and Construction of Off-channel Habitat in Ginlulak Creek

Objectives
The primary purpose of this project is to improve spawning and rearing habitat for coho salmon by: 1) complexing mainstem habitats to promote scour, increase cover and stabilize the stream bed; and 2) enhance existing off-channel habitats for spawning and rearing.

FRBC Region / MELP Region / MOF Region
Skeena-Bulkley / Skeena / Prince Rupert

Author
Robert Bocking

Proponent
Nisga'a Tribal Council

Watershed
Ginlulak Creek

Location
Ginlulak Creek is approximately 9.2 km long and drains a 43 km^2 watershed. Restoration works were restricted to the Ginlulak East sub-basin which is 15 km^2. Ginlulak East Creek drains into the west side of a *Carex* marsh from where it flows into the mainstem of Ginlulak Creek and then into the Nass River.

Introduction
Historically, the Ginlulak system supported annual runs of pink salmon, chum salmon, and coho. Dolly Varden char and cutthroat trout also inhabited the system. Pink and chum are rarely observed in the system, while coho salmon are still prevalent. Juvenile rearing habitat is prevalent throughout the system, but particularily in the extensive *Carex* marsh. However, young of the year also make extensive use of the off-channel habitats along East Ginlulak Creek. The most critical spawning habitat for the watershed is on the alluvial fan area of East Ginlulak Creek. Coho spawners utilize both the mainstem and off-channel areas.

The majority of logging took place in the Ginlulak watershed between 1954 and 1973. Logging in the Ginlulak East sub-basin accounts for 74% of all historic logging in Ginlulak Creek watershed. To date, 37% of Ginlulak East sub-basin has been logged. The alluvial fan of East Ginlulak Creek has been heavily impacted by logging.

Reaches 6 and 7 of East Ginlulak Creek were identified as candidates for restoration. Reach 6 is the mainstem of East Ginlulak Creek and is primarily used by coho for spawning. Logging of the fan has resulted in destabilization of the stream banks and frequent avulsions. Reach 7 is a series of off-channel areas that are fed by subsurface flows that surface as "springs". These spring-fed channels provide stable flows year-round but show evidence of degradation. Alder leaf litter, small woody debris, and silt are choking the channel in parts. Despite this, these off-channel areas are heavily utilized by both spawning and rearing coho.

Assessments and Prescriptions
The fish habitat assessment of East Ginlulak Creek concluded that spawning habitat could be improved by rehabilitating both the lower 400 m of the mainstem (just before it enters the *carex* marsh) as well as approximately 300 m of off-channel. Pool habitat was deficient in the mainstem because of a lack of flow control structures (LWD) and off-channel habitat appeared degraded. A high priority for restoration was given to Reaches 6 and 7.

The mainstem Reach 6 and portions of Reach 7 were first treated in 1997 when a significant amount of LWD was added to Reach 6 and some small structures were added to Reach 7. As well, a major avulsion near the apex of the alluvial fan was pinched off to protect the off-channel areas on the fan.

1998 Rehabilitation Work
Works conducted in August and September of 1998 consisted of:

- Modification of existing LWD structures which were originally constructed in Reach 6 in 1997. This work was intended to: better define the thalweg; promote further scour; and improve cover (Fig. 6-5).
- Construction of a head-water pond on Reach 7 along with placement of LWD to provide

cover (Fig. 6-6).

- Cleaning of silt and small woody debris from Reach 7 to enhance rearing and spawning habitat condition (Fig. 6-7).

Cost Summary

The following costs are for approximately 300 m of off-channel restoration and 200 m of mainstem LWD work. These costs are for 1998 only.

Construction and materials	$ 18,000
Supervision, design and labour	$ 39,000
Total	$ 57,000

Production Estimates

The restoration works in East Ginlulak Reach 6 and 7 were intended to improve spawning and rearing habitat for coho by stabilizing the stream bed, cleaning off-channel areas, and increasing habitat complexity with LWD. In total, approximately 400 m of mainstem habitat and 300 m of off-channel habitat has been intensively treated over 2 years. Mainstem treatments in 1998 were limited to approximately 200 m.

Preliminary data indicated that over 400 adult coho returned to Reaches 6 and 7 of East Ginlulak Creek in 1998. Monitoring and assessment of the structures for juvenile use will take place during low flow conditions in 1999. It is expected that the LWD structures will provide important rearing habitat for coho juveniles.

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Figure 6-5. LWD added to Reach 6 in Ginlulak Creek to promote scour, improve channel definition and provide cover for coho salmon.

Figure 6-6. Headwater pond constructed at top end of Reach 7 in Ginlulak Creek.

Figure 6-7. One section of Reach 7 after stream cleaning and placement of LWD for cover.

Kitseguecla River WRP 1998 Site Works

Objectives
Site 3 on the Kitseguecla River South tributary is one of a series projects on that tributary initiated with the objective to rehabilitate timber harvesting-related impacts to fish spawning, rearing, and refuge habitats. This objective was facilitated using a variety of stream channel complexing and stabilization techniques that will be discussed below. The fish species' habitats targeted for rehabilitation include rainbow trout (steelhead), chinook, and Dolly Varden.

FRBC Region/MELP Region/MOF Region
Skeena-Bulkley / Skeena / Prince Rupert

Author
Bill Fell

Proponent
Gitsegukla Band Council

Watershed
Kitseguecla River

Location
Tributary 1 of the Kitseguecla is located 15 km upstream from the confluence of the Kitseguecla River with the Skeena River. It is accessed at 17 km on the Kitseguecla FSR 200.

Introduction
The Kitseguecla River is rated very high in the Kispiox Forest District for both timber and bio-diversity values. The watershed also contains some rare ICH ecosystem variants and high fisheries values. Presently depressed stocks of fish are a result of both fishery interception issues and logging-related impacts. Tributary 1 was extensively logged just prior to a 100-year rainfall event, which significantly altered natural recovery of fish stocks. The stream channel has a narrow wetted width relative to the channel width, and an average gradient of less than 5%. It also has poor pool frequency and large woody debris (LWD) ratios. The substrate is cobble-dominated with fair gravel quantities.

Assessments and Prescriptions
An Overview Assessment initiated in 1995 identified the Kitseguecla River South sub-basin as the highest priority area for a Level I detailed Fish Habitat Assessment (FHAP). Impacts identified by this assessment included collapsed bridges (Fig. 6-8), perched culverts, extensive sediment agradation upstream of the old structures, lost stream complexity and reduced cover. A logged riparian area also reduced any opportunity for future LWD recruitment into the channel. The site works in this report focuses on one of the bridge sites where the habitat complexity was restored after removal of the failed structure by the WRP upslope program one year earlier (Fig. 6-9). Both longitudinal and cross-section surveys of the channel were completed for the site design. Regulatory approvals were issued and works were initiated in September 1998. Structures were designed for streambank armouring. In addition both partial and full spanning logs were to be installed to address the initial component of the rehabilitative works required for the reach. The project was also an opportunity to demonstrate and learn restorative techniques for the Gitxsan Nation/ Gitsegukla watershed restoration crew.

Rehabilitation Work
Pre-work visits produced recommendations to be incorporated into the site design. Specifically, debris catchers were constructed by inserting 1.5 m logs at a <30% angle into the streambank at 3 to 5 m intervals where streambank stability was poor due to the previous removal of the failed bridge structure. Stems were tied to stumps and trees with hemp rope and anchored with rock that was embedded in the stream channel. Logs with rootwads attached were supplied by a Ministry of Highways field crew clearing a gravel pit and were transported by a self-loading logging truck. Pre-trimming the roots and tops for highway safety was easier before the logs were loaded but unfortunately reduced the overall complexity and longevity of the LWD structures. Although cedar logs appeared to be a good choice for longevity of works (in the area with low LWD recruitment for the next 100 years), few of the branches survived the loading and skidding process while staging the materials. The tree tops from the stems were trimmed and

used for debris catchers as stems over 15 m in length required a pilot vehicle.

Access to the work site was relatively simple as the road to the deactivated bridge was still open. In addition the low complexity on the gravel bars of the stream channel provided easy dry access to the entire length of the wetted stream channel for placement of LWD. Structures were generally placed to provide channel complexity, and to increase both bank and bar stability (Fig. 6-10). The logs were generally oriented downstream and were comprised of full length trees, 0.4 m diameter at breast height (DBH) or larger. The final restorative works for this reach will be initiated in 1999 which will include monitoring and possible adjustment to the current structures. An as-built survey using bench marks and a total station will be replicated on a periodical basis (after high water events) for the purpose of monitoring the project's success relative to its' objectives and to refine the restorative techniques applied at the site. The 1998 prescription team for these restoration works included a forester, geomorphologist, biologist and a hydrologist.

Equipment

A 1997 EX200 Hitachi excavator with biodegradable hydraulic fluid was towed to the site with a tandem axle (4WD) dump truck. Cable and winches were used to tension geotextile sediment traps in stream. Clean-up tools, seeding tools, and positioning winches were also utilized.

Cost Summary

Prescription and drawings	$ 4,200
Equipment and materials	
(20pcs w/ roots)	$ 8,300
Project management/reports	$ 1,650
Total	$ 14,150

Production Estimates

An 80 m site was rehabilitated which increased fish habitat values for rainbow trout, chinook, and Dolly Varden char. Fish production estimates from LWD placement are increased 9.3-fold for chinook, 2.3-fold for steelhead, and 1.3-fold for Dolly Varden char.

Proposed Work

Additional channel complexing and stabilization for another 800 m of channel in this sub-basin is proposed. In addition monitoring of current and future structures will be completed to determine if the project's objectives were met.

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Figure 6-8. Downstream view of Site 3 on a tributary of the Kitseguecla River. Photo was taken prior to pull back of a failed bridge and channel rehabilitation.

Figure 6-9. Upstream view of Site 3 showing the site immediately after the bridge pull back. The banks were seeded and LWD was placed in the channel to later be dispersed in prescribed locations downstream.

Figure 6-10. Aerial view of Site 3. Note high quality second growth for future long-term recruitment of LWD. To address short-term LWD deficiencies logs were placed parallel to the stream flow to encourage bank and mid-channel bar stabilization.

Deep Creek Side Channel and Bank Stabilization

Objectives
The Deep Creek side channel and bank stabilization project is intended as a demonstration project to create off-channel rearing and overwintering habitats for salmonids (cutthroat, coho, steelhead /rainbow) as well as additional spawning habitat for coho, pink salmon and cutthroat trout in the Kitsumkalum watershed.

FRBC Region / MELP Region / MOF Region
Skeena-Bulkley / Skeena / Prince Rupert

Authors
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Proponent
Kitsumkalum Band Council

Watershed
Kitsumkalum River

Location
Deep Creek is a tributary to the Kitsumkalum River approximately 6 km north of Terrace, B.C. along the Nisga'a Highway.

Introduction
Logging took place adjacent to the creek likely sometime during the 1960's. Since that time, channel scouring has become more prevalent, turbidity is more common and log jams appear to be more numerous. This change in the fish habitat has caused the habitat to be less productive and inclined to have a negative impact upon eggs incubating in the gravel as a result of siltation and scouring.

Assessments and Prescriptions
The decline in fish habitat productivity in Deep Creek moved the Terrace Salmonid Enhancement Society to submit a plan and apply for funding through the Watershed Restoration Program to stabilize the eroding banks of Deep Creek adjacent to the Deep Creek Fish Hatchery and downstream for about 200 m. As well, the plan includes a scheme to alter the configuration of a log jam at the end of the lower eroded bank to reduce or eliminate future erosion caused by the jam and create a controlled flow surface water side channel just downstream from the hatchery.

Rehabilitation Work
The side channel construction began in August 1997 with the excavation of a dry area 383 m^2 by a 490E John Deere excavator (Figs. 6-11, 6-12). A log cribbing berm was built adjacent to Deep Creek and some of the excavated material and large rocks were used as ballast (Fig. 6-13). A deep pool was dug immediately behind the cribbing to create a head pond behind a control structure. Three spawning pads were created in the channel with the existing gravel that was graded by hand using a mesh grader with aluminum pipe grates spaced 3.5 cm apart to regulate the water flow through the channel. A flow control structure was constructed using treated lumber 15 m downstream from the cribbing (Fig. 6-14). The structure is a stop-log design with an opening 120 cm wide by 80 cm deep with slotted sides that 2"x6" planks fit into to control the flow of water. Upon completion of the channel construction, 3 Big 'O' pipes with a diameter of 15 cm and a length of 3 m were placed in the berm to provide, along with the opening through the rocks, an intake for the creek water to flow into the side channel. Following completion of the intake, woody debris and large rocks were installed at key locations in the channel.

Drought conditions during July 1998 caused very low water conditions in Deep Creek resulting in the channel inflow to be dramatically reduced. This threatened the ability of the channel to maintain suitable water conditions for fish to rear in. To alleviate the low flows into the channel during drought periods, a 20'x 12" culvert was placed under the berm at the top of Deep Creek side channel in August 1998 (Fig. 6-15). To accomplish this, a trench was excavated with a mini excavator and covered over by the restoration crew who also completed the bank cleanup and rock placement. The end result of this additional intake was the establishment of suitable flows that will support spawning, incubation and rearing of salmonids during low flows (Fig. 6-16).

Cost Summary

Fees	$ 23,164
Equipment rental	$ 3,616
Disbursements	$ 3,364
Total	$ 30,144

Production Estimates

This project has created overwintering and rearing habitat. Using the biostandards from Marshall and Britton (1990), the coho smolt carrying capacity for the side channel based on its area is 306 per year. This calculation does not factor nutrient level, stream gradient, temperature or flow. A carrying capacity estimate has not been made for other species.

On May 20, 1998, a pair of cutthroat were observed spawning in the lower section of the side channel. On August 31, 1998, one pair of pink salmon was seen spawning in the top gravel pad, 40 m downstream from the control flow structure. Another pair spawned just upstream of the pad. On four occasions, between August 31, 1998 and September 14, 1998, chum salmon were seen swimming through the channel. Two days later, another pair of chum spawned in the channel outlet. In mid-October a lone coho was observed in the channel and on November 25, 1998, a pair of coho were seen spawning at the same location where the chum spawned. In addition, coho, rainbow and cutthroat fry, parr and smolts have been observed throughout the length of channel.

A steady water flow was maintained in the side channel for most of the winter of 1997/98. The bank stabilization under the walking bridge is holding to date.

The culvert installed in August 1998 is working very well, providing a flow of water to the channel that should be sufficient during the lowest Deep Creek water conditions.

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Figure 6-11. Abandoned side channel on Deep Creek prior to off-channel habitat rehabilitation.

Figure 6-12. Abandoned side channel after excavation without water intake open.

Figure 6-13. Construction of a berm to protect off-channel development.

Figure 6-14. Box culvert construction; controls flow into side channel.

Figure 6-15. Additional culvert intake installed to increase low flow levels in the side channel.

Figure 6-16. Deep Creek side channel water levels during low flows.

Construction of Off-channel Habitat in Kwinyarh Creek

Objectives
The purpose of this project is to create off-channel spawning and rearing habitat for coho salmon.

FRBC Region / MELP Region / MOF Region
Skeena-Bulkley / Skeena / Prince Rupert

Author
Robert Bocking

Proponent
Nisga'a Tribal Council

Watershed
Kwinyarh Creek

Location
Kwinyarh Creek drains 15.6 km^2 as it flows for 7 km in a north-westerly direction from the Kitimat mountain range to its confluence with the Nass River. There are two sub-basins in the watershed: North Kwinyarh and Lower Kwinyarh (mainstem). The creek flows under the Nisga'a Highway before entering the Nass River.

Introduction
The Kwinyarh is a small-sized, cold-water system supporting some species of salmonids including coho, pink, chum salmon, Dolly Varden, and cutthroat trout. The presence of steelhead/rainbow trout in Kwinyarh Creek was unknown until discovered during the Level 1 assessment.

Juvenile rearing habitat is prevalent throughout the system, but particularily in the extensive *Carex* marsh located in the lower reaches. All species utilize spawning habitat throughout the accessible portions of the watershed and there is no single area concentration.

The Kwinyarh watershed was logged from 1964 to 1983 in the lower and north sub-basins. Logging in the Lower Kwinyarh sub-basin accounted for 72% of all historic logging in the study area. In total, 20% of the Kwinyarh watershed has been logged with most of the logging occurring in the lower elevations of the watershed.

Assessments and Prescriptions
A Level 1 Assessment identified impacts to fish habitat including, channel de-stabilization due to logging of riparian areas, lack of LWD, and lack of pools. However, opportunities to improve habitat on the mainstem Kwinyarh are limited due to high flows and poor access.

However, the Level 1 Assessment of Kwinyarh Creek identified an opportunity to create off-channel spawning and rearing habitat at the base of an alluvial fan on the mainstem Kwinyarh, just upstream of the Nisga'a Highway. The proposed channel is on the Kwinyarh alluvial fan and feeds directly into a *Carex* marsh with an abundance of rearing habitat. A groundwater assessment conducted in 1997 determined that groundwater quality and quantity was sufficient to proceed with the proposed channel construction.

Detailed plans were prepared for a 100 m x 2 m channel that would mimic natural coho spawning habitat. Since coho prefer to spawn at the tailouts of pools with good cover, it was important to build riffle structures that would promote pool formation downstream and hold gravels upstream. LWD additions to the pools was essential for cover. Also a protective berm would be required to prevent overflows from the Kwinyarh mainstem into the channel.

The Level 1 assessments also identified an avulsion point along the mainstem Kwinyarh that was resulting in stranding of juvenile coho during periods of rapid changes in flows. The study team recommended that this avulsion be closed off using a semi-permeable debris jam.

1998 Rehabilitation Work
Works conducted in August and September of 1998 consisted of:

- Construction of a groundwater-fed channel along the valley wall on the right side of the alluvial fan (Fig. 6-17).
- Construction of a berm along the right bank of the Kwinyarh mainstem, commencing at the apex of the alluvial fan to protect the newly constructed channel (Fig. 6-18).
- Complexing of the new groundwater channel with riffle structures and LWD to create coho spawning habitat and provide cover.

- Addition of spawning gravel to the channel.
- Construction of a LWD jam on the left bank of the Kwinyarh mainstem to close off an avulsion channel (Fig. 6-19).

Cost Summary

The following costs are for approximately 100 m of off-channel construction, the protective berm, and the LWD jam.

Construction and materials	$ 24,000
Supervision, design and labour	$ 36,000
Total	$ 60,000

Production Estimates

The restoration works in Kwinyarh Creek created 200 m^2 of off-channel spawning and rearing habitat for coho salmon.

Preliminary data indicated that 10 adult coho were spawning in the new channel in 1998. Monitoring and assessment of the structures for juvenile use will take place during low flow conditions in 1999.

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Figure 6-17. Groundwater channel constructed along valley wall of Kwinyarh Creek alluvial fan.

Figure 6-18. Construction of protective berm along right bank of Kwinyarh mainstem to protect newly constructed channel.

Figure 6-19. LWD jam constructed along left bank of Kwinyarh mainstem to close off an avulsion channel.

Maxan Creek Stream Channel, Bank Stabilization and Aquatic Habitat Rehabilitation Project

Objectives

The primary objective of the 1998 works was to rehabilitate forest harvesting and agricultural impacted salmonid spawning and rearing habitat. This is expected to be achieved by reducing the delivery of sediments to the stream channel from excessively eroding streambanks, increasing stream diversity by installing and trapping LWD to encourage pool scour and provide cover.

The secondary objective of this project is to reduce maximum stream temperatures by narrowing the stream channel, and re-establishing riparian vegetation.

FRBC Region/MELP Region/MOF Region

Skeena-Bulkley / Skeena / Prince Rupert

Authors

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Proponent

Ministry of Environment, Lands and Parks, Lakes District.

Watershed

Maxan Creek

Location

The Maxan watershed is approximately 83,000 ha in area. It includes the upper most portion of the Bulkley River and it's tributaries flow out of the Lakes Forest District. The works described in this report are located on Reach 1 of Maxan Creek which flows into Bulkley Lake approximately 40 km east of Houston.

Introduction

Reach 1 of Maxan Creek meanders through flat bottom land into Bulkley Lake. The reach is 7.3 km in length. About half of the reach is located on private lands. On these lands, large clearings have removed most of the riparian vegetation to the streambank and actively eroding, vertical streambanks are common. Other disturbance indicators in the reach included, LWD parallel to banks, low LWD frequency, extensive sediment wedges and fines, low pool frequency and high water temperatures. These limiting or poor habitat conditions are believed to be primarily caused by the loss of the riparian vegetation and instream LWD causing extensive erosion, and sedimentation.

After two years of field assessments and prescriptions, rehabilitative work was initiated on Reach 1 of Maxan Creek. Rainbow trout, "early run timing" chinook and bull trout were the target species.

Assessments and Prescriptions

In April 1995 an Overview Assessment on the Maxan watershed was completed. The purpose of the assessment was to identify areas in the watershed with potential impacts from forest harvesting which required further assessment or remedial action. The results of this Overview identified Maxan Creek, the Bulkley River and Foxy Creek as the top three priority sub-basins in the watershed for further detailed assessment.

In 1996 a Level 1 detailed Fish and Fish Habitat Assessment Procedure (FHAP) was initiated to determine the quality of the aquatic habitats and prescribe remedial actions for reaches of Maxan Creek. This assessment identified the following habitat features:

- Average bankfull width for Reach 1 is 20 m with a mean wetted width of 8 m.
- Pools, riffles and glides comprised 13%, 18% and 20% of the reach, respectively. Average gradient for the reach is <2%.
- Stream temperatures measured mid-summer reached 22 ^{o}C.
- Approximately 30% of the forest east of the reach had been harvested.
- Stream channel habitat consisted of large riffle/pool/glide sequences but the substrate was frequently embedded with fines. These fines also dominated channel margins, back eddies, pools and downstream ends of channel bars.
- Distribution of LWD was clumped and low in frequency (less than 1 piece per Wb) for the entire reach.

In 1997 detailed rehabilitative designs were completed for Reach 1 on lower Maxan Creek and in 1998 the remedial works for those prescriptions were completed.

Rehabilitation Work

The "works" were initiated and completed between August 1 to August 15 and largely consisted of bank and bar stabilization techniques. All works were completed by local contractors under the supervision of MELP.

The basic method used to stabilize banks was to use large woody debris revetments for moderate energy sites (Slaney and Zaldokas 1997). The revetments began and ended at locations where there was opportunity to key the structures into a naturally protected section of streambank. Willow cuttings were staked inside the header and footer logs, and grass seed was planted over all disturbed areas of the bank. It is anticipated that the structures will limit streambank erosion by reducing water velocities adjacent to the eroding banks. It is also anticipated that the structures will catch and accumulate floating debris thereby further armoring the banks and creating diverse habitats.

The bar stabilization structures were designed to encourage fines to settle out behind the structures in the low water velocity areas. Vegetation will colonize these areas and stabilize the bars, increase cover and decrease stream temperatures. An attempt was made to mimic the natural patterns of LWD deposition and bar stabilization observed in the project area. Structures were anchored in place using driveable duck bill anchors and rock. The net effect of the prescriptions will be to promote the formation of a narrower and deeper stream channel and improve substrate quality for salmonid spawning and rearing. The increased stream cover will contribute to reducing summer low flow stream temperatures.

Equipment

Equipment used for the project included a Hitachi EX 200LC-3 excavator, a D-6 Caterpillar, skidders, self-loading logging trucks, and gravel dump trucks. Trees were knocked over (for LWD) using the D6 cat or excavator and were hauled to the sites using either self-loading logging trucks and/or skidders. Rock was loaded into dump trucks using an excavator and was imported to the rehabilitation sites. Fortunately, access was relatively good and materials could be hauled and stockpiled adjacent to most sites relatively easy.

Trees, rocks and willow cuttings were obtained free of charge except for hauling costs. Rock was obtained from local MOF rock pits. About half of the trees (LWD) used for the project were obtained from Crown Land and half were from the local land owner. The willow cuttings were surplus to another project's needs that were slated for disposal.

Labour was provided by Waterside Ventures (Burns Lake) and consisted of a crew ranging from two to four people, as required.

Cost Summary

Manpower	$ 17,825
Equipment	$ 20,901
Materials	$ 4,173
Total	$ 42,899

Production Estimates

Rehabilitative works at eight sites on Reach 1 of Maxan Creek will contribute substantially to rehabilitation of fish habitat and improve water quality for approximately 7 km of stream. The early run timing chinook, the target species in this watershed are extremely depressed. Rainbow trout are an important species for recreational uses in the watershed, and bull trout are a provincially blue listed species. It is believed that the rehabilitative measure taken will contribute to improved survival of these stocks.

Proposed Work

A comprehensive report was completed in the winter of 1998 (Olsen 1999) which will provide the basis for future project effectiveness monitoring. Monitoring of structure stability, riparian vegetation condition, habitat condition (via FHAP) and fish use is proposed to be conducted on an annual basis. Simple structural monitoring will occur following each spring freshet and repairs may be conducted as required. Additional willow planting will be conducted in the spring of 1999 as required.

Future work at these sites will also include measures to reduce livestock impacts to the stream and riparian areas, and additional planting of spruce and cottonwood in riparian areas. In addition, a tentative agreement has been reached with the landowner and the Department of Fisheries and Oceans (DFO); to fence and manage the area as a riparian pasture/ hay field. Fencing materials will be provided by DFO, manpower and equipment to construct the fences will be provided by the landowner. Additional technical supervision and materials would be provided by MELP as required through funding from FRBC. In return for the fencing materials and manpower funding, the landowner will agree to utilize the pasture areas for hay production, leaving a riparian buffer area, and only allow livestock into the area for a short period in the fall.

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Lower Naden River, Reach 3-1 Instream Structures

Objectives
The purpose of the Lower Naden Reach 3-1 project was to add functional large woody debris (LWD) to increase habitat complexity.

FRBC Region/MELP Region/MOF Region
Pacific / Skeena / Vancouver

Author
Ian Dodd

Proponent
Naden Harbour Timber Ltd.

Watershed
Naden River

Location
Naden River is located in the northwest corner of Graham Island, the northernmost island of the Queen Charlotte group. Lower Naden Reach 3-1 flows east into the Naden River. The creek can be accessed from the Eden Lake Logging Camp by traveling north 6 km on the Naden Mainline to the 9 km road sign where the road crosses the creek. The instream structures are located immediately upstream of the stream crossing.

Introduction
The Naden River watershed (wet hypermaritime Coastal Western Hemlock (CWHwh1 and CWHwh2 ecosystem) has sustained logging for approximately the last 30 years. The watershed has been extensively logged during this time period. Lower Naden Reach 3-1 is a low gradient, low velocity, S3 creek with fine sediment and organic substrate.

Assessments and Prescriptions
Lower Naden Reach 3-1 Creek was harvested to the banks between 1974 and 1979. The creek now consists of sections of long glides and lacks long-term LWD and LWD recruitment.

The project consisted of adding 10 log deflectors to a 400 m section of creek. The logs were positioned to enhance existing shallow pools.

Rehabilitation Work
Works were initiated in July of 1998, and the following steps were taken:

- Sites along the creek that lacked long-term functional LWD were flagged.
- Western red cedar logs located in close proximity to the creek sites were hand-winched into place.
- The logs were not harnessed down but were positioned to withstand increased flows.

Cost Summary

Construction including supervision, design, labour	$ 6,000
Equipment rental and camp costs	$ 2,000
Total	$ 8,000

Production Estimates
This project increased fish habitat complexity and habitat cover.

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Lower Naden River, Reach 4-2 Instream Structures

Objectives
The purpose of the Lower Naden Reach 4-2 project was to increase habitat complexity for coho by adding functional large woody debris (LWD).

FRBC Region/MELP Region/MOF Region
Pacific / Skeena / Vancouver

Author
Ian Dodd

Proponent
Naden Harbour Timber Ltd.

Watershed
Naden River

Location
Naden River is located in the northwest corner of Graham Island, the northernmost island of the Queen Charlotte group. Lower Naden Reach 4-2 flows east into the Naden River. The creek can be accessed from the Eden Lake Logging Camp by traveling north 0.5 km on the Naden Mainline to the first bridge crossing. The instream structures are located immediately upstream of the stream crossing.

Introduction
The Naden River watershed (wet hypermaritime Coastal Western Hemlock (CWHwh1 and CWHwh2 ecosystem) has sustained logging for approximately the last 30 years. The watershed has been extensively logged during this time period. Lower Naden Reach 4-2 is a low gradient, small S2 creek with gravel substrate. Logging has impacted fish habitat in a number of locations.

Assessments and Prescriptions
Lower Naden Reach 4-2 creek was harvested to the banks between 1974 and 1979. The creek now consists of sections of long riffles and lacks LWD and LWD recruitment. Fish utilization was low based on pre-project assessment using minnow traps.

The project consisted of adding 12 triangle log jams to a 400 m section of creek. The log jams were positioned to enhance existing shallow pools. A helicopter was used to place the logs and boulders in the creek.

Rehabilitation Work
Works were initiated in July of 1998, and the following steps were taken:

- The riparian zone was dominated by pole - sapling red alder which provided 100% crown closure of the creek. Alder was removed from each site to provide a hole in the canopy for the logs and rocks to be lowered to the creek.
- Western red cedar logs with attached rootwads were salvaged from roadsides and transported to a landing located close to the creek. Boulders from a quarry were transported to the landing site using a gravel truck. The logs weighed between 1000 and 3000 lbs and each boulder weighed between 300 and 450 lbs.
- A generator, electric wood auger, and electric rock drill were used at the landing to prepare the rock and logs for transport into the creek. Holes were drilled through both ends of the logs. Two 8-inch holes were drilled into the boulders. The two ends of a 3/8" galvanized metal cable were fastened into the holes of two separate boulders using epoxy.
- The logs and rocks were then transported by helicopter to the creek sites. The helicopter pilot was directed to each site by the radio-person in the creek. The pilot could not see the creek and the radio-person in the creek could not see the helicopter. Good communication between the pilot and the radio-person was important. Costs were reduced by first using a Hughes 400 helicopter to transport the logs weighing less than 1300 lbs. A Bell 212 helicopter then transported the logs greater than 1300 lbs into the sites.
- For the next three days the logs were re-positioned in the creek by using hand winches. The Hughes 500 helicopter then transported the boulders in pairs to each of the sites. The logs and boulders were then cabled together in the creek.

Cost Summary

Construction including supervision, design and labour	$ 26,000
Equipment rental including helicopter, gravel truck, generator, drills, skidder, Hyab loader, and camp costs	$ 10,000
Materials	$ 1,000
Total	$ 37,000

Production Estimates

This project has created approximately 500 m^2 of high quality pool habitat.

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Tasu Creek Restoration Project

Objectives

The Tasu Creek project is one of a series of restoration projects Western Forest Products Limited has undertaken on Morseby Island in the Queen Charlotte Islands. These projects are part of its program to preserve undisturbed habitat, control in-channel sediment sources, maintain channel stability, and restore or rehabilitate fish habitat for rearing and overwintering salmonids.

FRBC Region/MELP Region/MOF Region

Pacific / Skeena / Vancouver

Authors

Bruce Walsh and Ken Hall

Proponent

Western Forest Products Limited

Watershed

Tasu Creek

Location

Tasu Creek flows into the northern end of Newcombe Inlet on Moresby Island.

Introduction

Tasu Creek supports coho, pink and chum salmon, steelhead, sea-run Dolly Varden and resident trout and char. Escapement records suggest a decline in the numbers of pink, and possibly, coho salmon returning to the creek, for reasons including logging-related changes to the habitat.

Assessments and Prescriptions

A logging-related landslide and the removal of riparian vegetation has increased the supply of coarse sediment to the lower reaches of Tasu Creek. The increased sediment supply has resulted in the growth of bars, channel widening, bank erosion and sedimentation, which in turn affected fish habitat including the loss of deep pools and reduced effectiveness of the large woody debris.

The Tasu Creek project involved creating a series of off-channel ponds near the estuary and hand-cleaning and complexing a small tributary and side channel to develop off-channel rearing and overwintering habitat.

Rehabilitation Work

Work was started on August 6, 1998 and was completed at the close of the construction window on August 15. The following works were competed:

<u>Off-channel Ponds</u>

- Excavated six off-channel ponds on the right floodplain; approximately 850 m^3 of material was excavated. Each pond is a minimum 1.2 m deep, during low flow conditions, and on average 12.5 m long by 7.5 m wide.
- Placed rootwads and large logs in ponds for overhead cover.

<u>Small Tributary</u>

- Cleaned fine sediments and organic detritus from small tributary creek to promote flow along the channel.
- Installed or modified six log steps and four deflector logs.
- Excavated a small off-channel pond.
- Increased pool depth by excavating excess fine sediment.
- Installed small bank protection structures.
- Placed larger woody debris in channel to provide overhead cover.

<u>Side-Channel</u>

- Cleaned fine sediments and organic detritus from side channel to create deep pools.
- Excavated a small pool upstream of side channel log jam.
- Partially opened log jam midway along the side channel to promote flow along the side channel during summer low flow conditions.
- Excavated gravel wedge in lower end of side channel.

Equipment and Labour

A Hitachi 300 excavator was used to excavate the six off-channel ponds.

A six-person crew was hired through New Forest Opportunities and Haida Fisheries to hand clean and complex the small tributary and side channel.

Cost Summary

Construction (hoe)	$ 5,000
Supervision, design, labour and materials	$ 30,000
Total	$ 35,000

Production Estimates

The project has created 640 m^2 of high quality rearing and overwintering habitat and has rehabilitated over 180 m of productive off-channel habitat.

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LWD Placement in Sue Creek using Rigging with Chainsaw Winches and Hand Tools

Objectives
This large woody debris placement project, completed in August 1998, is the first phase of a two-phase project to re-introduce instream LWD to Sue Creek, a low-gradient, lake-headed tributary to Brent Creek, a major coho producing tributary of the Yakoun River. The LWD placements are designed to increase fish habitat diversity by scouring deeper pools for holding of salmonid spawners and by creating more low-velocity water pockets during higher flows for winter rearing by juvenile salmonids.

In addition to improving fish habitat, the second objective of this project was to place the LWD structures with minimum impact, without the use of large machines in the stream. A rigging course using chainsaw winches and manually operated turfer-jacks was held in conjunction with this works project on August 8 and 9, to train local stream crews in utilizing these techniques.

FRBC Region/MELP Region/MOF Region
Pacific / Skeena / Vancouver

Author
Lynn Lee

Proponent
MacMillan Bloedel Limited in partnership with the Old Massett Village Council.

Watershed
Yakoun River

Location
Sue Creek is a tributary flowing south into Brent Creek approximately 2.8 km upstream from the Brent Creek confluence with the Yakoun River, Graham Island, Queen Charlotte Islands/Haida Gwaii. Sue Creek is crossed twice by Lake Road (MacMillan Bloedel logging road) and the two LWD placement sites are located immediately upstream of the lower road crossing and immediately downstream of the upper road crossing.

Introduction
The majority of the Sue Creek mainstem was logged to one or both banks between 1970 and 1986. Logging practices have contributed to the loss of instream large woody debris and the 1.8 km of stream between the upper and lower road crossing lacks large woody debris and its associated fish habitat. Sue Creek is a particularly good stream for LWD placement work because the mainstem is low gradient throughout its entire length and the creek is lake-headed, moderating the effects of rainfall on the stream flow. Increasing fish habitat, particularly for overwintering salmonids, will help to maintain a healthy population of juvenile salmonids throughout the length of the stream channel. Although the focus of the restoration work is on maintaining and improving existing rearing habitat for coho salmon juveniles, other salmonid species such as cutthroat trout and Dolly Varden char will also benefit from the work.

Along both treated sites, the creek was logged to both banks and although the riparian area is re-establishing with conifers, the trees will not be large enough to contribute significant pieces of LWD to the stream channel for several decades. The LWD placements are meant as an interim measure to maintain and improve existing fish habitat until trees in the riparian area are of a sufficient diameter to maintain stream channel diversity.

Assessments and Prescriptions
A WRP Level 1 Fish Habitat Assessment was conducted in the lower reach of Sue Creek (Reach 6a) in October of 1996. This reach was found to have moderate to low amounts of functional LWD in the stream channel. Because Sue Creek is a low-energy stream, the stream channel has remained relatively stable with a diversity of habitat units, despite the deficit of channel control elements such as LWD. From a fish habitat perspective however, winter rearing conditions for salmonids, particularly juvenile coho and trout, are poor because the fish are associated with woody debris during this time. Electrofishing studies conducted throughout the Brent Creek watershed by MacMillan Bloedel Ltd. in the late 1970's showed that where there

was LWD, salmonids would be found in abundance and, where there was little to no LWD, few salmonids and particularly no juvenile coho, would be present. Comparisons between photos of the 1978 sampling sites in Reach 6a of Sue Creek and the sampling site in 1996 showed that less LWD is now present in the stream channel. In addition, logging to the banks has rendered the riparian area ineffective as a source for instream LWD in the immediate future.

The upper LWD placement site located in Reach 6b and similar to the lower site, was found to have a low abundance of instream LWD and low potential for LWD recruitment from the riparian area due to logging to both banks.

Since portions of both the upper and lower sites were adjacent to logging roads, access to some of the LWD placement sites was good. These site locations were ideal as a training ground for a rigging course using chainsaw winches and hand tools to move the LWD and boulders from the road to the placement sites. The intent was both to provide training in different stream rehabilitation techniques and to minimize the potential negative impacts of running a machine in or near the stream.

The prescription for LWD placement extended from the lower Lake Road crossing upstream for approximately 200 m and from the upper Lake Road crossing downstream for approximately 700 m. The schedule for work divided the prescription into two phases:

- Phase 1 was completed in the summer of 1998 and included 4 structures extending approximately 70 m upstream from the lower Lake Road crossing and 4 structures extending approximately 80 m downstream from the upper Lake Road crossing. As indicated above, these structures were placed without the use of machines in the creek.
- Phase 2 is scheduled for completion in the summer of 1999 and includes approximately 32 remaining LWD placement structures. The prescription calls for general placement of these structures at specific sites along the creek using a logging helicopter. The helicopter will fly the LWD and boulders from designated locations and gently place them into the stream channel. Placement sites will be relatively easy to mark due to an open canopy throughout most of the treatment area. Following general placement of the structural elements, work crews will create the prescribed LWD structures using chainsaw winches, blocks and tackle, and hand tools.

Rehabilitation Work

Rehabilitative works were initiated in late July of 1998. Earlier in July, site prescriptions were marked in the field, including site location, length and diameter of LWD required, size and number of rootwads required, and size and number of boulders required for anchoring. Schematic diagrams of all Phase 1 structures were prepared for field crews prior to commencement of works. Following is a summary of events:

- Appropriately-sized pieces of LWD were salvaged from Lake Road in the vicinity of Sue Lake using an excavator, and moved to both road crossings using a dump truck. Boulders were obtained from a gravel pit adjacent to the upper Lake Road crossing and moved close to both road crossings.
- Boulders were drilled using a Hilti rock drill with a 5/8” drill bit. Holes were approximately 8” deep. Dry galvanized 9/16” cable approx. 2 m long was glued into the holes using Hilti epoxy resin, for lifting boulders and cabling them to anchor the LWD.
- The first day of rigging work was conducted in conjunction with the rigging workshop and took place at the upper Lake Road crossing site. For moving pieces of LWD and boulders from the road to the stream channel, a skyline cable with a chain hoist was established from upstream of the road crossing to approx. 20 m downstream of the bridge. The LWD and boulders were moved along the skyline and dropped at the approximate location of the placement sites (Fig. 6-20). One end of larger logs, for example 0.5 m in diameter and 7 m long, were partially dragged on the stream bed as they were moved along the stream; however, disturbance was minimal.
- Once at the placement site, the LWD and boulders were moved into final position using blocks and a chainsaw winch and/or a manually operated turfer jack. Although simple to describe, the process of moving material into the creek using skylines was

very time consuming and sometimes required an abundance of manpower to bully the pieces into place.
- On the second day of the rigging course, another skyline, spanning approximately 50 m of stream channel, was established to move material further along the stream. Logs and boulders were moved to the third site located approximately 57 m downstream of the road crossing and placed using blocks with the chainsaw winch and turfer jack.
- A fisheries biologist from the US Forest Service, Brian Bair, participated in the workshop. He demonstrated the weaving of small diameter trees (<10 cm dbh) into the streambank, both to provide cover for fish and natural armouring from erosive forces.
- Rigging work continued for 8 days after the workshop with a crew of 3 to 4 people. In total, 7 of the 8 LWD structures were in place and another day was spent cabling the structures (Fig. 6-21).

Cost Summary

Excavator for LWD and boulder salvage	$ 965
Project design	$ 2,200
Supervision and labour	$ 9,000
Materials and rentals	$ 6,000
Total	$18,165

Production Estimates

This project treated approximately 150 m of the mainstem of Sue Creek through the placement of large woody debris structures to maintain hydraulic processes which contribute to fish habitat diversity. These structures were placed in locations where pools have been maintained or in places where hydraulic forces are expected to scour deeper pools and/or optimize and create low velocity water pockets during higher flows.

Salmonids, particularly juvenile coho and trout, are known to be associated with woody debris during winter rearing in the stream and placement of the LWD structures will improve the winter rearing capacity for juvenile coho in the Sue Creek mainstem. In the fall of 1998, after several high flow events, the LWD structures are in place and physically functioning as expected. Fish use of the structures will be monitored this winter.

In addition to improving fish habitat diversity in the stream channel, this project also provided a platform for training local stream rehabilitation crews in different techniques for stream rehabilitation using hand and power tools. Many thanks to the Watershed Restoration Program office at the University of British Columbia for funding the development of this rigging workshop, and to Tom Kennedy from Courtenay and Kevin Mearns from Skidegate for instructing the workshop.

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Figure 6-20. A large Western red cedar log being moved from the road to the creek using a skyline and chainsaw winch.

Figure 6-21. Completed wood structure at the lower wood placement site.

Re-establishing Coho Spawner Access Upstream of an Impassable Culvert and LWD Placement in a Small Tributary to Ghost Creek

Objectives
The objectives of this project were two-fold: one was to re-establish access for coho spawners upstream of an impassable culvert on the Branch 46 road crossing and the other was to improve fish habitat diversity upstream of the culvert.

FRBC Region/MELP Region/MOF Region
Pacific / Skeena / Vancouver

Author
Lynn Lee

Proponent
MacMillan Bloedel Limited in partnership with the Old Massett Village Council.

Watershed
Yakoun River

Location
This section of Reach 1a-4, a small, southeast-flowing tributary to Ghost Creek, is located near Branch 46, approximately 0.4 km up from the junction of Branch 46 and the Queen Charlotte Mainline logging road. The rehabilitated area extends from the downstream end of Branch 46 for approximately 130 m upstream.

Introduction
At the Branch 46 crossing of Reach 1a-4, twin culverts approximately 0.6 m in diameter existed, with a third culvert approximately 10 m to the northeast. Access for anadromous salmonids upstream of the Branch 46 culvert had been blocked in recent years by gravel infilling of the upstream ends and by a 0.5 m drop between the end of the culvert and the stream bed at the downstream end. At the time of the survey in July of 1997, the water flow was low and water was ponded upstream of the twin culverts. The surface flow was directed along the ditchline towards the third culvert which was also perched and impassable. A small amount of sub-surface flow through the gravel wedge upstream of the twin culverts resulted in some water flow through the twin culverts at low flows. During the survey, one juvenile coho 75 mm in length was caught upstream of the culvert indicating that coho salmon had access upstream within the past few years.

At the time of the survey, the channel upstream of the culvert consisted primarily of riffles and glides with few pools. The streambanks were low and regularly overtopped during higher flows.

There were very few pieces of LWD in the stream channel. All pools noted were associated with pieces of LWD, including many cut pieces which were left from logging activities.

This section of the tributary had been logged to both banks in 1965 with a mixed riparian forest re-establishing but with little potential for contributing significant instream LWD for several decades. Large woody debris placement upstream of the culvert should improve existing spawning and rearing habitat for salmonids and particularly coho salmon. The LWD placements are meant as an interim measure to maintain and improve existing fish habitat until trees in the riparian area are of a sufficient diameter to maintain stream channel diversity.

Assessments and Prescriptions
The WRP Level 1 Fish Habitat Assessment conducted on Reach 1a-4 of Ghost Creek identified the Branch 46 culverts as a barrier to anadromous salmonid migration upstream. Due to the infilled upstream end of the culvert and the perched downstream end of the culvert, removal of the culvert and excavation of a channel would likely have caused severe downcutting upstream of the excavation. Large woody debris structures were designed to step the gradient gradually enough to prevent severe downcutting:

- Four cross-spanning logs structures placed approximately 8m apart along the excavated channel were prescribed (Fig. 6-22).
- Large cobble-sized and larger material was required to armour the bed for the logs to prevent undermining of the log structures.

Re-establishing access upstream would open up approximately 0.9 km of spawning area which was not available prior to rehabilitative works.

The survey upstream of the culvert indicated that this section of the reach had low amounts of functional LWD in the stream channel and also showed that good spawning gravels existed upstream of the culverts. Additional pieces of LWD were prescribed upstream of the culvert to introduce more control elements to the stream channel to improve the fish habitat diversity.

Prescriptions for all LWD placements were developed following field reviews with a geomorphologist and the contract monitor from the Ministry of Environment, Lands and Parks.

Rehabilitation Work

Removal of the culverts and placement of the LWD structures to stabilize the excavated channel took place on July 31, 1998. The culvert removal project was completed in conjunction with road deactivation activities and the machine time was paid through the WRP road deactivation budget. Placement of the LWD pieces upstream was completed over 2 days in mid-August 1998. Following is a summary of events:

- The day prior to commencement of the works, the area immediately upstream and downstream of Branch 46 was blocked off with stop nets and the fish in this work area were relocated. The one juvenile coho was caught upstream and relocated downstream.
- The LWD pieces were delivered to the work site prior to commencement of works. On the day of work, the large crush rock for armouring LWD structures was delivered and excavation of the channel proceeded in a downstream direction. A water pump was prescribed to pump surface water flow from a temporary dam upstream of the work site, to an area downstream of the culvert such that there would be minimal surface flow during the excavation. Unfortunately, a pump could not be obtained on the day of the work. This precautionary measure would have been useful to keep logs from floating during placement in the channel and to minimize siltation during the excavation.
- An existing log located approximately 28 m upstream from the downstream end of Branch 46 marked the start of excavation. The log was retained as one of the control elements to prevent downcutting of the channel upstream. The first log structure was placed 4.5 m downstream of the natural control log. Further excavation revealed a second log, sound and stable in the channel, which was part of the former stream channel at 10.6 m downstream. This uncovered log was retained as a control structure. The third log structure was placed at 19 m downstream (Fig. 6-23) and the last log was placed at 28 m, marking the downstream end of the excavation. Placed log structures were keyed into the banks by at least 0.5 m on either side.
- In mid-August, a crew of 5 people moved the LWD from the road site upstream to the placement sites. All single-log structures were placed by hand and the end on the bank was keyed in with a piece of rebar hammered through the LWD. The ends of the LWD pieces were placed slightly lower than the bank height to minimize bank erosion due to presence of the woody debris.
- In late October, several returning adult coho salmon were observed moving upstream through the work area.

Cost Summary

Excavator and truck for LWD and armour rock	
(Paid by WRP road deactivation)	$ 0
Project design	$ 2,500
Supervision and labour	$ 2,000
Materials and rentals	$ 500
Total	$ 5,000

Production Estimates

This project treated approximately 130 m of Reach 1a-4 from the Branch 46 road crossing upstream by removing an impassable culvert and by placing instream large woody debris structures to maintain channel stability following removal of the culvert. Re-establishing access upstream of Branch 46 has opened up approximately 0.9 km of good coho spawning habitat.

Large woody debris structures upstream of the Branch 46 crossing will also contribute to fish habitat diversity, improving the quality of both spawning and rearing areas. Over the course of the high flow season, the large woody debris placements are expected to scour pools and create low-velocity backwaters for rearing of juvenile salmonids. Success of the project will be evaluated next summer when fish sampling will show whether coho salmon juveniles are present upstream of Branch 46.

Once the creek stabilizes following this high flow season, the remainder of the LWD sitting by the road will be moved into the stream to augment desirable fish habitat characteristics.

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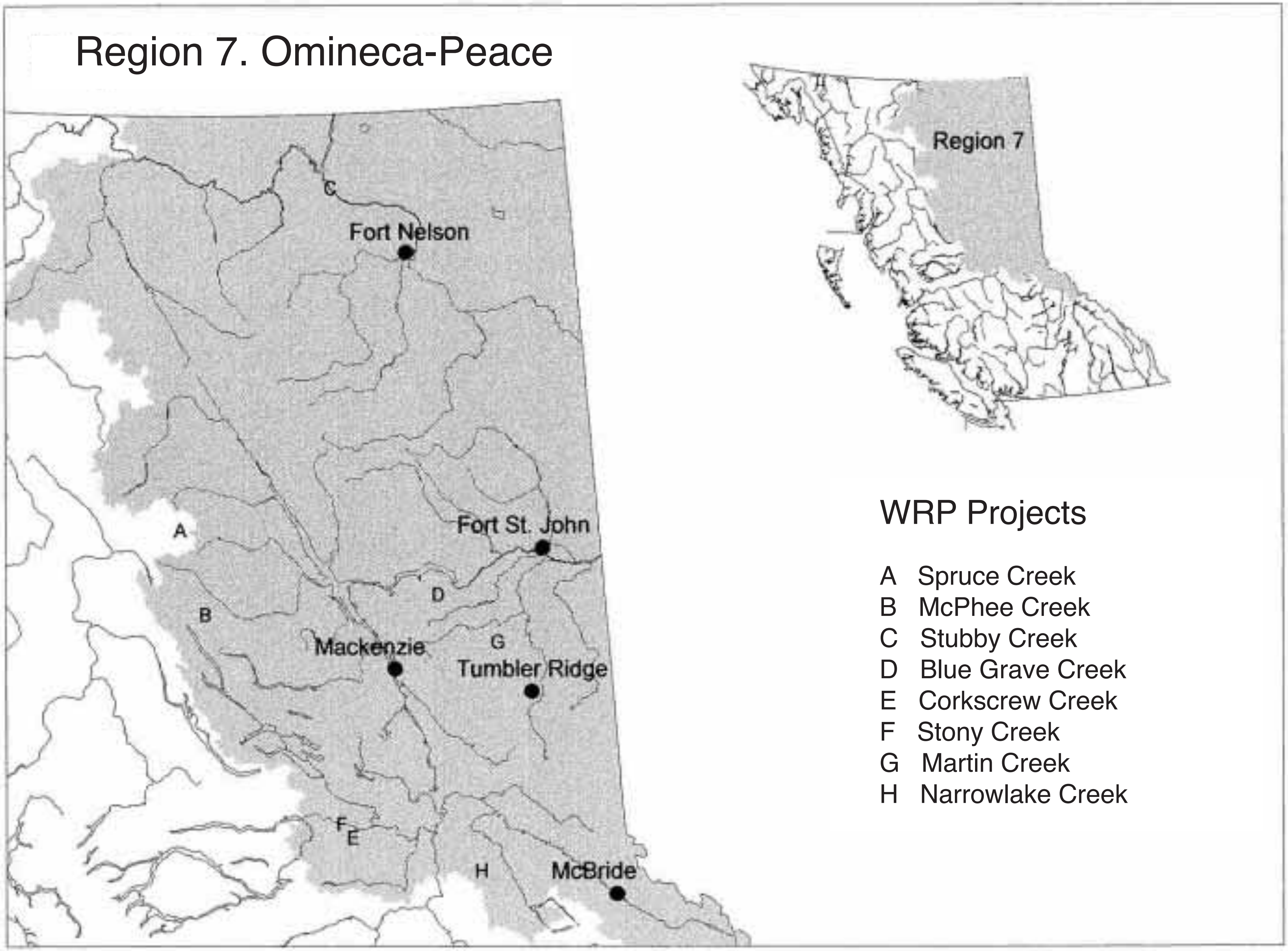
Figure 6-22. Excavation of channel in preparation for the installation of the second upstream log.

Figure 6-23. View from downstream looking upstream at the completed project.

Omineca - Peace Region


Region 7. Omineca-Peace
Region 7
Fort Nelson
Fort St. John
Mackenzie
Tumbler Ridge
McBride
A
B
C
D
E
F
G
H
WRP Projects
A Spruce Creek
B McPhee Creek
C Stubby Creek
D Blue Grave Creek
E Corkscrew Creek
F Stony Creek
G Martin Creek
H Narrowlake Creek

UTM (NAD 83) zones, northings and eastings; watershed codes and waterbody identifiers for aquatic rehabilitation projects for Region 7, Omineca-Peace.

No.	Region	Watershed	WRP Projects	(NAD 83) UTM Zone	(NAD 83) UTM Northing	(NAD 83) UTM Easting	Watershed Code	Waterbody Identifier
A	**Omineca-Peace**	Bowron River	Spruce Creek	10	5953643	582113	100-657000-44700	00000BOWR
B		Chilako River	McPhee Creek	10	5979287	503653	180-039000-00000	00000LCHL
C		Fort Nelson River	Stubby Creek	10	6582036	448357	212-083400	00000LFRT
D		Halfway River	Blue Grave Creek	10	6272533	535089	235-371300	00000UHAF
E		Nulki-Tachick Lakes	Corkscrew Creek	10	5973076	442082	180-271000-56200	00000NECR
F		Nulki-Tachick Lakes	Stoney Creek	10	5985923	432056	180-271000	00000NECR
G		Sukunka River	Martin Creek	10	6150032	585514	234-443900-14100	00000PINE
H		Willow River	Narrowlake Creek	10	5937121	561213	100-596500-43500	00000WILL

Spruce Creek Stream Restoration Project: Horses and Helicopters

Objectives

The Spruce Creek watershed restoration project was initiated in 1998 to restore a small, sensitive stream before further degradation to productive fish habitat occurs. The small stream size combined with the total removal of future LWD within the riparian area, along with flat ground, small channel width, and easy access provided an excellent project area to evaluate the use and cost effectiveness of horses and helicopters for small stream restoration projects. Specifically, Phase 1 of the project used manual labour and draft horses to position instream structures. Phase 2 of the project utilized a combination of labour, horses and helicopters to access upstream locations. The costs and benefits of using labour, horses and helicopters were evaluated.

FRBC Region/ MELP Region/ MOF Region

Omineca-Peace/ Omineca-Peace/ Prince George

Author

Cathy Harris

Proponents

Northwood Inc., and Ministry of Environment, Lands and Parks.

Watershed

Spruce Creek (Bowron River Watershed Group)

Location

Spruce Creek is located approximately 85 km northeast of Prince George, and is accessed from the Bowron Forest Service Road at km 54.

Introduction

Spruce Creek is a third-order stream draining an area of 67.3 km^2. The elevation at the Bowron River confluence is 790 m. Spruce Creek is located in the Sub-boreal Spruce, wet cool biogeoclimatic zone (SBSwk 1) (Meidinger et al. 1991) with a annual total precipitation of approximately 1028 mm (49% is snowfall and 51% is rainfall, with the majority of the rainfall occurring in the summer months). Summer low flow discharges were measured at 1.5 $m^3 \cdot s^{-1}$. Return rates Q50, Q100 are 8.92 $m^3 \cdot s^{-1}$ and 9.8 $m^3 \cdot s^{-1}$, respectively. Instream temperatures range from 4 to 15 degrees Celsius. The average bankfull channel width in this system is 7 m.

Fish species found within Spruce Creek are bull trout, rainbow trout, with chinook salmon in the lower reaches.

Forest harvesting activity in the lower reaches of Spruce Creek started in the early 1970's, with the Bowron Forest Service Road bridge crossing about 100 m upstream from the Bowron. Harvesting plans maintained a 100–250 m reserve on both sides of the stream until 1988. At that time, an escaped slash burn damaged the reserve from the Bowron FSR to 2 km upstream from the confluence, the current mature forest. Clearcut salvage harvesting took place on the south side of Spruce Creek in winter 1988, and on the north side of the creek in 1989. Safety regulation required the felling of all trees (small residual balsam included) along both banks of the stream. Both areas were planted with lodgepole pine (*Pinus contorta*) and spruce in 1990. The southern areas were declared Free Growing in 1998. As a result, the lower two reaches of this stream have experienced a total loss of long-term LWD input to the stream channel.

Assessments and Prescriptions

In 1997, Overview and Level 1 Fish Habitat Assessments for several Bowron River tributaries were conducted with Spruce Creek being identified as having the highest potential to benefit from instream restoration activities. During the spring of 1998, Reaches 1 and 2 were selected for mainstem habitat complexing and channel restoration prescriptions.

Prescriptions focused on the mainstem habitat complexing, maintenance and creation of new instream LWD, as well as enhancing pre-disturbance LWD jams that were beginning to deteriorate and become nonfunctional. A total of 15 different types of instream structures were constructed throughout the stream in 85 separate locations. These structures were designed to reflect the natural features and processes found upstream in unharvested templates.

The post project monitoring methods used included:

- Establishment of pre- and post-structure construction with photo control points established along the streambanks.
- Stream channel cross-sectional surveys at each structure site.
- Water quality and temperature.
- Fish population monitoring.
- Sediment source monitoring.
- Pre- and post-restorative habitat monitoring.
- Low level aerial photo mosaics (pre- and post-treatment).

Rehabilitation Work

Instream rehabilitation work was initiated in July 1998. Wood for the project was purchased from Northwood Inc. sawmills' cedar log decks; rootwads were obtained from nearby logging road development operations. Boulders were obtained from scaling debris from a rock cut on a logging road.

In 1998, instream restoration efforts included 85 fish habitat and channel restoration structures comprised of 115 pieces of LWD and 240 boulders and 10 rootwads.

The structures are broken down as follows:

- 81 LWD / boulder structures (including 14 jam enhancers, 14 bank deflectors / pool complexes, 33 bank stabilizers, 19 angled logs, 8 rootwad complexes and 3 upstream V-notches).
- 1 boulder complex, 1 Hewitt Ramp, 2 overwintering ponds, and 1 barrier removal.

Equipment Used

Large woody debris and rootwads were transported to the project site via self-loading logging trucks. In Phase 1, all wood was placed instream using two Belgian draft horses "George and Red" (Fig. 7-1). In Phase 2, all materials were located in a central landing site and transported to each structure site via Bell 205 logging helicopter and exact positioning of materials was done by manual labour and the two draft horses. Wood at the cutblocks was moved to loading sites with a grapple skidder.

Figures 7-2 and 7-3 portray the pre- and post-effects at site 7. Here, restorative actions were done to create a boulder garden and bank deflector as well as a pool complex. Figures 7-4 and 7-5 show the pre- and post-treatment effects of opposing wing deflectors at site 9, as well as jam enhancing upstream at site 10. Figure 7-6 is an example of a Hewitt ramp at site 13.

Cost Summary

Both Phase 1 and Phase 2 used horses and manual labour to position structures accurately. Phase 1 treated 600 m of stream, whereas Phase 2 treated 1300 m with the helicopter being used to transport the materials to the structure sites. In order to assess the costs associated with the two separate methods of materials transport, each phase was reviewed separately.

A. Phase Cost Summary

	Phase 1	Phase 2
Materials	$ 6,846	$ 4,745
Labour	$21,000	$31,425
Equipment	$ 1,254	$ 1,276
Helicopter		$19,072
Administration	$ 6,030	$ 6,000
Phase totals	$35,130	$62,518
Total		$97,648

B. Total Project Costs

Materials	$11,592 (12%)
Labour	$52,425 (54%)
Equipment	$21,601 (22%)
Administration	$12,030 (12%)
Total	$97,648

The above cost summary indicates that Phase 1 was less expensive (nearly half the cost of the helicopter/horse phase), but it treated less than half of the stream distance than in Phase 2. As a result, the two systems are very similar when evaluating the total costs/km of stream. It is important to note that the total project cost/stream km was $51,395. This figure is at the low end of the scale for machinery figures conducting the same works at $50,000 to $60,000 per km as noted by Slaney and Martin (1997). As a result, based on costs alone, horses or a combination of horses/helicopters are comparable for a project of similar nature. When given the additional benefits of the low impacts to the sensitive site along with labour, training, and employment benefits, this project was highly successful in achieving many of the WRP program objectives, cost included.

The overall productivity indicators chosen to assess costs of this study were the total cost to move each piece as well as the distance of stream restored. Specifically, review of the costs indicate that Phase 1 had 144 pieces (rocks/logs/rootwads) within 17 structures over 600 m, whereas Phase 2 had 221 pieces within 68 structures over 1300 m of stream. The overall costs of placing each piece were $188/piece in Phase 1 and $251/piece in Phase 2. This indicates that although more pieces were placed in Phase 2, the cost per piece was higher. This higher cost/piece can be partly attributed to the longer transportation distance of materials in Phase 2. Another important point to consider was that Phase 1 had more complicated habitat structures, but the overall cost per structure was lower. Assuming an average of 8 pieces per structure, Phase 1 structures cost $1320 each whereas Phase 2 structures cost $2000 each. In summary, using the above productivity indicators, Phase 1 was more cost effective.

The most important point to note is that the overall costs associated with both phases were close from a production objective. The fact that horses and manual labour were used in both instances, but could not have been used alone in Phase 2 due to safety concerns, supports either method being cost effective on a site specific basis. Future works should consider either method with similar expectation of costs, with the use of horses and manual labour only being more cost effective given favorable site conditions. Additionally, factors other than cost (i.e., employment, training, time, distance of stream to be treated etc.) will directly effect the method chosen for any given project.

Production Estimates

Spruce Creek at present supports a small rainbow, bull trout and chinook salmon population. Theoretical fry densities were determined from fish population estimates using randomized triple pass depletion methods (Platts et al. 1983). Estimates for rainbow fry were 300 fry per 100 m^2 of habitat whereas triple pass population surveys indicate that less than 10 rainbow fry per 100 m^2 currently exist in the reaches treated in this project. (Triton 1998).

The proposed results of the habitat complexing in this project target the findings similar to those of Koning and Keeley (1997). They indicate that a 2.5-fold increase in rainbow trout production resulting from increased woody debris complexity in mainstem pools, is likely to occur. The 1998 instream works stabilized existing instream structures while increasing overall habitat complexity by 20 to 30%. This suggests that the probability of an increase in production will likely result due to the restoration efforts.

Proposed Work

Future considerations proposed for Spruce Creek include ongoing monitoring of the results of the habitat complexing.

Attention will be focused towards recording changes in the overall fish production as a result of the mainstem habitat complexing as well as the future durability and stability of various instream structure types.

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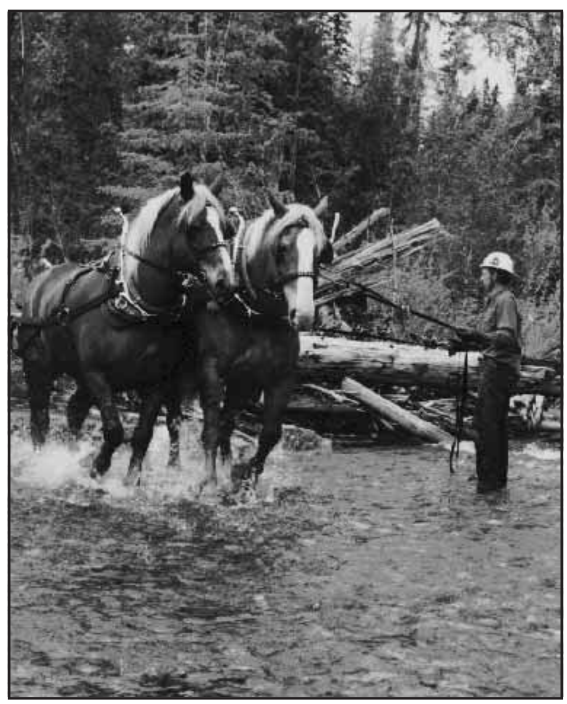

Figure 7-1. Both phases of the project involved manual labour and "George and Red", a team of draft Belgian horses, to position the structures in prescribed locations.

Figure 7-2. Site 7. Pre-restoration. Exposed banks, extended riffles, and lack of pool cover were predominant throughout the lower reaches.

Figure 7-3. Site 7. Post-restoration showing the addition of bank deflectors, LWD in pools, and a boulder garden.

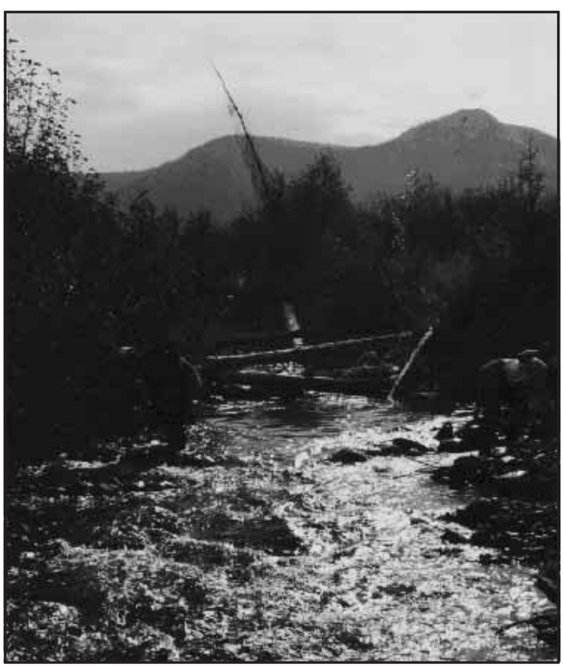

Figure 7-4. Site 9/10. Pre-restoration indicating channelized sections and current LWD breaking down in a small jam upstream.

Figure 7-5. Site 9/10. Post-restoration photo of stabilized opposing V-wing deflectors, creating pool habitat, focusing scour, and reducing flow velocities throughout the habitat units.

Figure 7-6. Site 13. A Hewitt ramp structure was constructed in a long riffle section. Cedar logs were manually sawn to create 8 foot cedar planks on the ramp. The restored site now provides deep backwater pools and an overall increase in wetted habitat and cover under the structure.

McPhee Creek Fish Habitat Restoration

Objectives
The McPhee Creek watershed restoration project was initiated in 1998 to address concerns over the future depletion of woody debris and associated fish habitat within the stream channel and to stabilize road-related streambank sediment sources.

FRBC Region/ MELP Region/ MOF Region
Omineca-Peace/ Omineca-Peace/ Prince George

Authors
Ray Pillipow, Fisheries and Watershed Restoration Technician (BC Conservation Foundation), and Andrew Wilson, WRP Specialist (MELP/Omineca sub-Region 7a).

Proponent
Ministry of Environment, Lands and Parks.

Watershed
McPhee Creek (Lower Chilako River Watershed Group).

Location
McPhee Creek is located approximately 10.5 km northwest of Prince George. North Nechako Road, or McPhee Creek Road via Chief Lake Road will allow access to the restoration sites.

Introduction
McPhee Creek is a fourth-order stream draining an area of 37 km^2, over 14.1 km. Emerging from numerous groundwater sources in the upper watershed, the stream flows through agricultural, forested, and wetland areas. The elevation at the Nechako River confluence is approximately 580 m, and 780 m at its source.

McPhee Creek is located in the Sub-boreal Spruce, dry warm biogeoclimatic zone (SBSdw) (Meidinger et al. 1991) with a mean annual precipitation of 628.3 mm (Prince George airport).

Summer low flow discharges were measured at 0.28 $m^3 \cdot s^{-1}$ (ARC Environmental Ltd. 1998). Return rates (e.g., Q50 or Q100) do not accurately reflect McPhee Creek's peak discharges due to its groundwater dominated source.

Fish species found within McPhee Creek are rainbow trout, and within the lower reaches chinook salmon fry (ARC Environmental Ltd. 1998). Anecdotal information indicates that bull trout were once present throughout the second reach, however none were caught during sampling.

Forest harvesting activity in the McPhee Creek watershed has been limited to pre-1970's logging in Reach 2, and late 1970's logging in Reach 3. Reach 2 was harvested to the streambank over a distance of approximately 1.5 km. The riparian areas have become re-established following harvesting, but large woody debris and associated fish habitat is still lacking in the area. Reach 3 of McPhee Creek was harvested to the streambanks during the late 1970's. The area logged has not been replanted, though there are localized patches of natural regeneration. As a result, Reach 3 has experienced a total loss of long-term wood supply to the stream channel, and beaver activity has increased as a result of abundant deciduous second growth. Numerous beaver dams have created potential fish passage and channel stability problems and are inhibiting riparian succession to the conifer stage due to creation of unfavorable growing conditions.

Although McPhee Creek has only 2 reaches affected by past forest harvesting, it runs the risk of significant geomorphologic change as a result of lost or compromised inputs of large woody debris to the stream channel.

Assessments and Prescriptions
In 1996, ARC Environmental was contracted to conduct Overview and Level 1 Fish Habitat Assessments for several Nechako River tributaries (ARC Environmental Ltd. 1998). McPhee Creek was found to have the highest potential for conducting instream restoration works of the tributaries examined.

During the spring of 1998, Reaches 2 and 3 were selected for channel restoration prescriptions. Restoration sites were selected and fish population estimates were determined using randomized triple pass depletion methods (Platts et al. 1983).

Prescriptions in Reach 2 which is characterized by a significant increase in gradient and substrate size compared to Reach 3, focused on enhancing pre-disturbance LWD jams that were beginning to deteriorate and become nonfunctional. Additional treatments included placement of LWD debris catchers in existing pools (Figs. 7-7, 7-8) as per Slaney et al. (1997), armoring eroding banks with rootwads and LWD (Figs. 7-9, 7-10) and the addition of boulder complexes along glides to increase habitat complexity for juvenile salmonids (Fig. 7-11). Prescriptions in Reach 3, characterized by a complete loss of LWD on both banks, were similar to those described in Reach 2.

The post-project monitoring methods used included:

- Setting up photo point benchmarks at each structure.
- Stream channel cross-sectional surveys at each structure site.
- Cataloging of wood pieces in each structure with metal discs.
- Water quality and temperature.
- Fish population monitoring.

Rehabilitation Work

Instream rehabilitation work was initiated in July 1998. Wood for the project was provided by project partners from local blow-down sites between blocks, rootwads were obtained from local landscaping projects, and rock material was obtained from a local government quarry.

In 1998, instream restoration efforts included 22 fish habitat and channel restoration structures comprised of 131 pieces of LWD and 60 boulders. The structures are broken down as follows:

- 11 boulder complexes.
- 9 lateral (triangular log jams).
- 2 LWD revetments.

Additionally, a collapsed bridge at the top end of Reach 2 was pulled from the stream. The road leading to the collapsed bridge was recontoured and deactivated by removing the fill used to create the road, and scattering the collapsed bridge material over the exposed soils in a pattern that would minimize runoff to the stream, providing fine sediment entrapment for natural regeneration of vegetation.

Equipment Used

Wood at the cutblocks was moved to loading sites with a grapple skidder. Transportation of materials from the cutblock landings to the restoration sites was completed with a self-loading logging truck. Fish habitat structures were constructed along Reach 3 using a Schaeff Spyder^{TM} HSM41 mobile walking excavator.

The collapsed bridge removal and access deactivation was completed with an EX 220 John Deere excavator. Along treatment Reach 2, LWD was moved by the use of labourers from the Lheidli T'Enneh First Nation. This was accomplished with block and tackle pulley systems, and an 8000 lb truck winch (Fig. 7-12).

Cost Summary

Engineering	$ 8,000
Labour	$ 30,642
Equipment	$ 10,442
Materials	$ 8,420
Total	$ 57,504

Production Estimates

McPhee Creek instream habitat in its present state supports a very healthy rainbow trout population suggesting that an increase in production as a result of restoration efforts would be minimal. Therefore, as described in Koning and Keeley (1997), a 2.5-fold increase in rainbow trout production resulting from increased woody debris complexity in mainstem pools, is not likely to occur.

The intention of adding wood and boulder complexes to McPhee Creek is to preserve the stream channel and rainbow trout population as it exists until the riparian succession has been restored to its previous state.

Proposed Work

Future considerations proposed for McPhee Creek will include restoring the cutblock section of the riparian to its pre-harvest state, which will allow for natural recruitment of wood to the stream, and control of beaver induced disturbances.

Attention will also be focused upon the stabilization of a section of eroding bank that is linked to improper road location. Prescriptions for this area will include recontouring and restoring a slumping bank and removing a bridge. This will serve to reduce non-point source of sediments to the stream.

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Figure 7-7. Pre-restoration photograph of McPhee Creek, Reach 2 site 5. Note absence of woody debris cover in pool.

Figure 7-8. Post-restoration photograph of McPhee Creek, Reach 2 site 5. Lateral triangular large woody debris structure constructed in pool to provide overhead cover and induce additional scour.

Figure 7-9. Pre-restoration photograph of McPhee Creek, Reach 3 site 6. Note localized area of bank erosion on outside of bend.

Figure 7-10. Post-restoration photograph of McPhee Creek, Reach 3 site 6. Large woody debris and boulders armoring area of bank erosion and providing overhead cover.

Figure 7-11. Post-restoration photograph of McPhee Creek Reach 2 site 4. Note boulder clusters in groups of four placed in mid-stream channel to provide juvenile rainbow trout rearing habitat.

Figure 7-12. Manual labourers from Lheidli T'Enneh First Nation maneuvering large woody debris into McPhee Creek with winches and block and tackle.

Stubby Creek - Restoring Fish Passage

Objectives
To restore bull trout, Arctic Grayling (*Thymallus arcticus*) and possibly northern pike (*Esox lucius*) access to approximately 12 km of stream habitat.

FRBC Region/ MELP Region/ MOF Region
Omineca-Peace/ Omineca-Peace/ Prince George

Author
Paul MacMahon

Proponents
Slocan Forest Products Ltd. - Fort Nelson Woodlands and Ministry of Environment, Lands and Parks.

Watershed
Stubby Creek is a third-order tributary to the Fort Nelson River with a mainstem length of 13 km.

Location
The creek is located on the Etcho Plateaux, about 250 km northwest of Fort Nelson in northeast corner of B.C.

Introduction
The Liard Mainline Road, an inactive winter forestry road crosses Stubby Creek about 600 m upstream of its confluence with the Fort Nelson River. An assessment of several road systems in the Fort Nelson Forest District was conducted in the summer of 1998 to identify barriers to fish passage. The Stubby Creek crossing was identified as one of several barriers.

Assessments and Prescriptions
The assessment indicated a 3 m^2 by 28 m long log box culvert was blocking fish passage (Fig. 7-13). At a moderate discharge the water entering the culvert traversed half the culvert length before disappearing through the log floor. The outlet was also perched 20 cm above the creek surface (Fig. 7-14). Restoring fish passage would allow access to 12 km of high quality stream habitat. The restoration prescription was to remove the crossing and re-establish a natural stream bottom and stable banks (because the road was inactive and the logs deteriorating).

Restoration Work
Due to the poor bearing capacity of the lowland (muskeg) soils in the area, the restoration work was completed in the winter. The snow was cleared on the road for a distance of 15 km to the site. A bulldozer and excavator removed the 3-6 m high road prism, removed the culvert, recontoured the banks and stream bottom and buried the wood waste off site. The exposed soils were then seeded.

Equipment
- Two D6 Cats cleared road access to the restoration site.
- A Cat 225 tracked excavator was used to remove the culvert and recontour the streambed and banks.
- A D8 Cat with a ripper removed the road prism, the culvert and recontoured the banks.
- A lowbed and pilot vehicle was used for mobilization and demobilization.

Cost Summary

Project co-ordination/ on-site supervision	$ 9,000
Excavator	$14,500
D8 Cat	$27,500
D6 Cats	$ 4,500
Labour	$10,000
Mobilization and demobilization	$ 2,500
Total	$68,000

Proposed Work
Check the site in the spring to ensure the seed germinated and assess the need for any further bank stabilization (e.g., stake the banks with willow and poplar).

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Figure 7-13. Aerial view of the box culvert crossing on Stubby Creek.

Figure 7-14. A view of the outlet of the box culvert crossing on Stubby Creek.

Blue Grave Creek - Restoration of Fish Passage and Bank Stabilization

Objectives
To restore bull trout passage at four road crossings and stabilize the streambanks in a stream reach that was logged to both banks.

FRBC Region/ MELP Region/ MOF Region
Omineca-Peace/ Omineca-Peace/ Prince George

Author
Paul MacMahon

Proponents
Canadian Forest Products Limited - Fort St. John Division (Canfor) and Fisheries Section, Peace Sub-Region, Ministry of Environment, Lands and Parks.

Watershed
Blue Grave Creek is a fourth-order tributary to the Halfway River with a watershed size of 16,120 ha and an elevation of 730 - 1340 m. Total precipitation averages approximately 500 - 600 mm annually.

Location
The watershed is located on the east slope of the Rocky Mountain Foothills in northeastern B.C. approximately 120 km WNW of Fort St. John. The restoration sites are located on the mainstem and one tributary in the upper third of the watershed. They can be accessed by vehicle at km 88, 91.5, 92.4 and 92.7 of the Halfway - Graham Forest Service Road (FSR) and 4 km of the Horseshoe Creek Road.

Introduction
Blue Grave Creek is an important bull trout stream. The upper reaches of the watershed serve as a cold water refuge where juvenile bull trout grow and escape competition from rainbow trout that utilize the warmer middle and lower reaches. However, logging roads built in the early 1990's resulted in several mainstem culvert crossings located in the upper watershed. Additionally, Blue Grave Creek passes through a number of cutblocks that were logged to both banks 7 years ago.

Assessments and Prescriptions
Level 1 Fish Habitat and Riparian Assessments were conducted in 1997. The assessments indicated fish habitat quality in the upper reaches of the watershed was very high. The primary watershed concerns were fish passage and streambank stabilization in one cutblock. Three mainstem road crossings and one tributary crossing were blocking juvenile bull trout from utilizing 4.5 km of habitat. The banks along a 1 km stream segment had held up fairly well to a variety of high water events. However, the remnant stumps that were holding the bank together were in a moderate state of decay and the outbends of several curves were beginning to erode at an advanced rate.

Detailed prescriptions for restoring fish passage were developed by D.R. Estey Engineering Ltd. and MELP. The three mainstem culvert crossings were close together and similar in size (1200-1400 mm diameter), number (two per crossing) and set angle (2.4-2.9 %). They were barriers to juvenile fish by virtue of high water velocities (1.0-1.9 $m{\cdot}s^{-1}$) and one was also perched 32 cm. We chose to apply three different restoration techniques, a low, medium and high cost alternative, so we could evaluate their relative success in future years. The fourth crossing was perched 1.3 m and set at a very steep angle (11%) resulting in a total drop in bed elevation of 3.5 m over the 13 m culvert length (27% average gradient).

The prescription for stabilizing the banks was developed by Brinkman and Associates and BCCF. The strategy was to stabilize the banks of four eroding outbends for the next 10 years or so while the conifer seedlings planted by the forestry company continue to grow and their root masses begin to consolidate the soils. Bioengineering techniques were used.

Restoration Work
A detailed description of the fish passage restoration and bank stabilization techniques follow:

- Crossing 1 was selected as the low cost restoration site. Four "poseidon" baffles (Armtec Construction Products Co.) were welded into the bottom of the 1200 mm diameter by 16 m long culvert on river-left as it exhibited the highest average water velocity (1.9 vs 1.3 m·s-1). Each baffle was spaced 4 m apart with the first one set 3.5 m from the inlet. Each baffle was 200 mm high with a 100 mm vertical V-notch removed. The notches were offset 245 mm from the culvert centreline and the baffles installed so that the notches alternated from left to right (Fig. 7-15). Once the baffles were installed, the existing riffle and adjacent banks downstream of the culvert were built-up 350 mm so the elevation of the riffle crest caused the stream to backwater the culvert to the top of the first baffle. The riffle was constructed using the techniques of Newbury et al. (1997). The substrate size used to construct the key components of the riffle exceeded the tractive force of water at bankfull stage.

- Crossing 2 was selected as the high cost restoration site. Because the culverts were perched 32 and 34 mm (Fig. 7-16), they were removed and a bottomless arch culvert 5180 mm wide, 2180 mm high and 18.3 m long was installed. This provided a natural stream bottom consisting of gravels, cobbles and a few boulders in the culvert (Fig. 7-17).
- Crossing 3 was selected as the medium cost restoration site. Both culverts were carefully removed from the stream, the streambed excavated down and the culverts reset so that they were embedded 200 mm into the stream bottom at a lower gradient (1.5%). Streambed material was then placed in the bottom of the culverts and a low profile riffle (150 mm high crest) built 15 m downstream of the crossing to prevent bed scour at the outlets during high flows and provide a staging area for fish moving upstream through the culverts.
- Crossing 4 required some fairly aggressive restoration measures (Fig. 7-18). To reduce the existing bed gradient of 27 % a bottomless arched culvert was installed at a 6.5% gradient (Fig. 7-19). To overcome the remainder of the elevation change (2.2 m) the streambed and banks upstream of the culvert were excavated down to a maximum depth of 0.3 m at the inlet over a 30 m distance and the streambed downstream of the culvert was built up to a maximum height of 1.9 m at the outlet over a 22 m distance (8.6 % gradient). To prevent the stream from going subsurface alternating layers of fine and coarse fill were compacted and filter cloth was placed at about 2/3 depth. The filter cloth was designed to trap the fine sediment producing an impervious "cement" layer. Large cobbles and boulders were used for the surface layer. This technique was in maintaining surface flows in near record low flow conditions 2 months later. The eroding cutbanks were planted with willow stakes (Fig. 7-20). The vertical faces were planted with horizontal stakes spaced every 0.3 m and the bank tops planted with vertical stakes spaced 1.5 m apart back a distance of 5 m from the stream edge.

Equipment

- John Deere 792 tracked excavator was used to remove and install culverts, construct riffles, install temporary bridges, excavate and build up stream beds, etc.
- Two end dump trucks hauled fill material, rip -rap and riffle materials.
- A Caterpillar dozer was used to rip up the road surface atop the culverts.
- A roller compactor packed the fill materials.
- Several large trash pumps diverted the water at crossing 4.

Materials

- One 5180 mm wide by 2180 mm high by 18.3 m long and one 3960 mm wide by 1680 mm high by 20 m long multi-plate arched culvert.
- 75 m^3 of rock for riffles.
- 150 m^3 of rip-rap.
- 250 m^3 of fill.
- 4 "poseidon" baffles to fit a 1200 mm diameter corrugated culvert.
- 600 m of willow whips (1250 stakes).

Cost Summary

Crossing	#1	#2	#3
Design	$2,400	$ 6,500	$ 2,400
Supervision	$ 600	$ 4,000	$ 600
Construction	$5,660	$49,230	$15,930
Materials	$ 600	$12,120	$ 1,200
Misc.	$ 80	$ 4,500	$ 60
Total	$9,340	$76,350	$20,190

Crossing	#4	Bioengineering
Design	$ 7,000	$ 1,200
Supervision	$ 4,000	$ 2,300
Construction	$34,920	$ 4,230
Materials	$18,580	$ 1,550
Misc.	$ 210	$ 60
Total	$64,710	$ 9,340

Production Estimates

This project will restore fish access to 4.5 km of high quality juvenile bull trout rearing habitat. Based on production estimates of 0.16 bull trout per m^2 of restored mainstem (Koning and Keeley 1997), the stream is expected to support approximately 3168 more bull trout per year.

Proposed Work

Spring/Summer 1999 - Exposed soils on all construction sites will be seeded with a mix of legumes and grasses in the spring. Willow and poplar staking will occur on the excavated banks at crossings 3 and 4. A sequence of riffles: pools will be constructed in a channelized stream section downstream of crossing 1. Two large road-related gullies are a chronic source of sediment to the stream. They will be stabilized in 1999.

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Figure 7-15. Upstream view of crossing #1 with the baffles installed in the culvert but prior to construction of the downstream riffle.

Figure 7-16. Upstream view of crossing # 2 before restoration.

Figure 7-17. Downstream view of crossing #2 following replacement with a bottomless arched culvert.

Figure 7-18. Upstream view of crossing #4 before restoration. Note the 1.5 m drop at the outfall.

Figure 7-19. Downstream view of crossing #4 following replacement with a bottomless arched culvert and recontouring of the streambed.

Figure 7-20. Horizontal willow staking of an eroding cutbank on Blue Grave Creek.

Nulki-Tachick Watershed Restoration Project

Objectives
The Nulki-Tachick watershed restoration project (NTWRP) began in the fall of 1995 as a multi-year project under Forest Renewal BC and initially sought to answer the broad questions "What is the present state of health of this watershed?" and "Why are the wild rainbow trout stocks of this once flourishing fishery, in such decline?". This natural resource provides an important sport fishery to residents of the Vanderhoof and Prince George region and contributes to a sustenance fishery for the people of the Saik'uz First Nation. An IWAP (1996), a Level 2 Fish Population and Riverine Habitat Assessment (1996), a Water Quality Study (1996/97) and a Fisheries Investigation (1995-1997) contributed data that directed the development of the 1998 NTWRP objectives. This year the three main objectives were to:

- conduct a rainbow trout mark and recapture program on Stoney Creek between Nulki Lake and Tachick Lake to clarify fisheries issues;
- replant a mixture of hybrid spruce (White/Engleman), low level willow and black cottonwood in logged riparian zones throughout the watershed; and
- restore altered riparian and stream habitat at selected areas in order to aid the natural recovery of the local rainbow trout fishery.

FRBC Region / MELP Region / MOF Region
Omineca-Peace/Omineca-Peace/Prince George

Authors
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Proponent
Saik'uz First Nation

Watershed
Nulki-Tachick Lakes

Location
The Nulki-Tachick lakes watershed is located in British Columbia's central interior, 100 km west of the city of Prince George, and 20 km southwest of the District of Vanderhoof. Corkscrew Creek (124 10'47"W 53 54'06"N) is a fourth-order stream located in the central interior on the south side of Nulki Lake, approximately 8 km southwest of Vanderhoof. Stoney Creek (124 05'45"W 53 58'15"N) is the principle outlet stream of Nulki Lake and is also the principal inlet stream to Tachick Lake, flowing north for 6.4 km to connect the two lakes.

Elevation in the watershed ranges from approximately 730 m (above sea level) at the surface of Nulki and Tachick Lakes to approximately 1340 m at Corkscrew Creek's headwaters in the Nulki Hills (southern portion of the watershed). The H_{60} elevation for the Corkscrew Creek watershed was determined to be 1030 m. Although the southern-most edge of the watershed has steep gradients (hilly to mountainous), most of the watershed is flat or gently sloped.

Introduction
The Nulki-Tachick watershed lies within the Sub-boreal Spruce biogeoclimatic zone, a montaine region that dominates the central interior of British Columbia. White spruce (*Picea glauca*) and subalpine fir (*Abies lasiocarpa*) are the dominant upland climax tree species. Lodgepole pine and trembling aspen (*Populus tremuloides*) are common seral species, with paper birch (*Betula papyrifera*) occasionally pioneering disturbed sites. Douglas-fir are common at dry, nutrient-rich sites. Black spruce (*Picea mariana*) are common in the wet, swampy areas. Extensive wetlands (sedge marshes, shrub fens, treed fens, and moss bogs) occur in poorly drained post-glacial depressions. Black cottonwood are common along streams shores. Soils in the Nulki-Tachick watershed, being derived from glaciofluvial processes, are dominated by sandy to gravely textures (moderate to well drained).

Luvisolic, Podzolic and Brunisolic soils are common on morainal deposits. Poorly drained organic soils are associated with damp depressional areas.

Total precipitation in this 47,000 ha watershed averages 26.5 cm annually, with 75% of all rainfall occurring between May and October inclusively.

The Nulki-Tachick watershed hosts a diverse list of fish species including mountain whitefish, burbot, northern pike, northern squawfish (*Ptychocheilus oregonensis*), peamouth chub (*Mylocheilus caurinus*), lake chub (*Couesius plumbeus*), redside shiner, longnose sucker (*Catostomus catostomus*), largescale sucker and prickly sculpin, many of which are utilized in the Native sustenance fishery of the Saik'uz First Nations people. However, the focus over the four year duration of this project, has specifically been on rainbow trout. This system sports a unique feature in that the principle stream used by rainbow trout for spawning and rearing purposes, Corkscrew Creek, boasts a 60 km monoculture network of stream created by a 2 m waterfall located 2 km from it's confluence into Nulki Lake. Only rainbow trout are able to negotiate these falls and access the extensive habitat above.

Approximately 35-50% of the watershed has been cleared by agricultural and forest industries since the 1950's with major developments in the headwaters prior to implementation of the Forest Practices Code. A network of logging roads, culverts, bridge crossings and timber staging areas exist within the watershed. Much of the Corkscrew Creek mainstem and tributary riparian zone forest (approx. 35 km) has been harvested; therefore, recruitment sources for large woody debris (LWD) have been removed in this drainage area. Subsequent loss of instream LWD and pool habitat has been detrimental to juvenile rearing habitat.

Assessments and Prescriptions

The Nulki-Tachick watershed restoration project, 1995-1997 fisheries investigations and population assessments in Corkscrew Creek offer an accumulation of aging data that indicate rainbow parr overwinter in this system for one to three years before taking up residence in the lakes downstream. Large woody debris and complex habitats serve to increase stream productivity. These habitats are rare in Corkscrew Creek. Furthermore, unstable banks void of riparian vegetation are eroding and embedding spawning gravel in the lower reaches of Corkscrew Creek. Stoney Creek also lacks habitat that can provide predation refuges for young fish. These factors are likely contributing to poor juvenile survival and low rainbow trout recruitment to Nulki Lake and Tachick Lake. In 1998, the NTWRP focused on restoring those high priority habitats which have the greatest probability of increasing juvenile survival and, thus, increase recruitment to rainbow trout populations.

Rehabilitation Work

An integrated watershed scale approach to restoration of critical areas included:

- revegetation of riparian habitat and placement of instream debris structures along Stoney Creek;
- bank stabilization, riparian revegetation, and instream LWD structures in the Johnson's Meadow area of Corkscrew Creek; and
- bank stabilization, riparian revegetation, and instream LWD structures near the Fish Creek -Corkscrew Creek confluence area of Corkscrew Creek.

In 1998, 13 fish habitat structures were placed in a 300 m portion of Reach 5 of Corkscrew Creek, 6 structures were placed in a 200 m portion of Reach 4 of Corkscrew Creek and 5 structures were placed in a 300 m portion of Reach 2 of Stoney Creek. LWD structures were designed after Cederholm et al. (1997) and natural templates. These required 107 LWD pieces, 31 rootwads, and 154 boulders (Figs. 7-21a to 7-24b). The Hilti-epoxy method (Fontaine and Merritt 1988) was used to anchor boulders to LWD in the structures.

In these same reaches of Corkscrew Creek, 200 linear m of streambank were stabilized, covering an area of 0.42 ha. Bioengineered slope stabilization strategies were designed after Babakaiff et al. (1997) to re-establish willow and cottonwood on riparian banks and to stop further erosion. Willow wattles, brush layers, live stakes and willow mattresses were assembled and put in place by a crew of six Saik'uz First Nation technicians through August and part of September (Figs. 7-21b and 7-25). Additionally, a riparian planting program, carried out by nine Saik'uz First Nation students, planted 20,000 spruce and 88 alder seedlings, as well as 16,185 willow and 15,519 cottonwood whips. These were planted throughout the watershed specifically, in areas where past logging practices deforested riparian areas. In the long term these shrubs/trees will help stabilize streambanks and contribute to instream LWD recruitment.

Flow and temperature data was collected from the mainstem of Corkscrew Creek by a permanent hydrometric station (WSC Station 08JC017) while water temperatures in Stoney Creek and the main spawning tributary of Corkscrew Creek were monitored using Starlog™ data loggers.

Employment for 1998 NTWRP restoration

Heavy equipment operators	16	days
Draft horse operators	22	days
Project manager	260	days
Project biologist	125	days
Habitat technicians	559	days
Tree planters	267	days
First Nations workers	826	days
Displaced forest workers	277	days

(days of labour are based on 8-hr working days)

Equipment

Equipment required for project completion included an excavator (Hitachi EX200), a backhoe (426Ford/NewHolland), a dump truck, a team of draft horses and a logging cart. Some light equipment was also required (rock and wood drills, a power saw and cable cutters). Also expended were 9 drill bits, 200 m of 9/16" wire rope cable, 35 tubes of epoxy glue and 36 duckbilled™ earth anchors.

Cost Summary

Salaries	$ 55,034
Heavy equipment	$ 8,633
Draft horses and operator	$ 6,050
Materials	$ 7,910
Surveying	$ 9,688
Rentals	$ 6,298
Total	$ 93,613

Restoration Results

Restoring fish habitat by strategically introducing structures of LWD and boulders is expected to increase rainbow trout productivity in Corkscrew Creek by providing more refuges and overwintering habitat for rainbow parr. In Stoney Creek, the addition of LWD structures will provide refuges and velocity breaks for migrating adult and juvenile rainbow trout thereby reducing predation pressure.

The growth and stability of bank stabilization projects which used bioengineering techniques will be assessed in 1999. In addition, the 1998 LWD placements will be monitored to determine rainbow trout use and pool depth in relation to pre-restoration conditions.

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Figure 7-21a. Before restoration of an eroding bank.

Figure 7-21b. After restoration of an eroding bank.

Figure 7-22. Draft horses placing LWD.

Figure 7-23. Lateral debris jam.

Figure 7-24a. Anchoring LWD structures.

Figure 7-24b. Anchoring LWD structures.

Figure 7-25. Willow wattle and brush layer placement.

Martin Creek Fish Habitat Rehabilitation

Objectives
To rehabilitate and restore historically productive spawning and rearing habitat for Arctic grayling, bull trout, rainbow trout, and mountain whitefish to the Martin Creek watershed.

FRBC Region/ MELP Region/ MOF Region
Omineca-Peace/ Omineca-Peace/ Prince George

Authors
Lynn Westcott and Paul MacMahon.

Proponent
Fisheries Section, Peace Sub-Region, Ministry of Environment, Lands, and Parks.

Watershed
Martin Creek is a fourth-order tributary to the Sukunka River with a watershed size of 12,000 ha. Total annual precipitation reaches approx. 500 mm.

Location
The watershed is located on the east slope of the Rocky Mountain Foothills in northeastern B.C. approximately 26 km south of Chetwynd. The project area is adjacent to the bridge at km 1 of the Sukunka Forest Service Road (FSR). The restoration sites are located in the lower reaches of the stream and begin approximately 200 m downstream of the bridge and continue 800 m upstream of the bridge.

Introduction
The upper reaches of the Martin Creek watershed experienced streambank logging during the 1960's and 1970's. However, the most damaging forestry practice was the straightening and channelization of a 400 m section of the stream that approaches and flows under the FSR bridge. This was done following the washout of the bridge approaches in an effort to prevent it from re-occurring. These activities caused the stream to downcut and become isolated from its historic floodplain, which resulted in the loss of pool habitat, channel complexity, and an increase in gradient due to channel straightening. The lower reaches also suffered from a lack of large woody debris (LWD). Martin Creek has been identified as high priority for restoration based on historic data that suggests it is one of the most important sportfish spawning and rearing streams in the lower Sukunka River drainage, especially for Arctic grayling.

Assessments and Prescriptions
Level 1 fish habitat and riparian assessments and a sediment source survey were conducted in 1997. The assessments indicated the primary watershed concerns were channel instability in the lower reaches and loss of fish habitat, particularly the loss of pools for adults and large juvenile holding and feeding areas and the loss of slow water and side channel juvenile rearing areas. The lower reaches consisted almost entirely of riffles with a large width:depth ratio.

Detailed prescriptions were developed in the spring and summer of 1998 by BCCF (Mark Potyrala), LGL Limited (Marc Gaboury), and MELP, Fort St. John. To stabilize and narrow the channel and create pool habitat in the straightest portion of the channel immediately upstream of the FSR bridge a sequence of pools and riffles were designed with rootwads to be added to the pools for cover. Restoration designs also included a variety of LWD structures in locations that would promote bed scour and pool formation, two deflectors to narrow the channel immediately below the bridge, and reconstruction of a historical side channel to provide juvenile rearing habitat for Arctic grayling.

Rehabilitation Work
Instream work began 22 July 1998 and was completed by the end of August 1998. A more detailed description of the restoration techniques follows:

- Construction of 8 riffle-pool sequences in a 500 m section of the main channel using the Newbury/Gaboury technique of tying the crest elevation of the most downstream riffle into the toe elevation of the upstream riffle (Figs. 7-26 and 7-27). Pools were excavated to a depth equal to riffle crest heights and rootwads or other cover structures were placed in most pools (Fig. 7-28). The substrate size used to construct the key components of the riffles exceeds the tractive force of water at bankfull stage thereby preventing further downcutting of the streambed.

- Construction of 14 low profile LWD structures in the mainstem (Fig. 7-29). They were generally multiple log structures arranged in a triangular geometry and ballasted with rock.
- Construction of 2 deflectors downstream of the bridge on the FSR serves to narrow the overwidened channel. The deflectors were constructed from logs and rocks/ boulders and built with a low profile to allow high flows to overtop the structures thereby reducing erosion of the opposite bank.
- Excavation of an existing but elevated side channel down to groundwater level to ensure the channel will no longer de-water to a level that will strand and kill juvenile fish. The side channel is connected to the mainstem at the outlet end. The channel was reconstructed as a series of 7 shallow pools separated by short (5 m) riffle sections (Fig. 7-30). The newly excavated clay bed was lined with round rock (10 - 20 cm diameter) to provide more suitable substrate for fish and aquatic insect production.
- Construction of a berm between the mainstem and the side channel to protect the side channel during peak flows (Fig. 7-30).

Equipment

- A Hitachi EX 200 tracked excavator completed riffle-pool construction, side channel excavation, temporary bridge placement, and berm construction.
- LWD placement was accomplished using a Schaeff Spyder™ HSM 41.
- Rock used to construct riffles and side channel was hauled to the work site using 2 box trucks.
- Wood used to construct LWD structures was hauled to the work site and unloaded using a self-loading log truck.
- Hilti TE-75 hammer drill, Milwaukee 'Hole Hawg' reduction drill, and portable generator were used to drill anchor holes in ballast rock and LWD pieces.

Material

- 1/2 inch cable, 800 m.
- 30 tubes Hilti HY 150 epoxy.
- 14 Hilti carbide tip heavy shank hammer drill bits (9/16 inch diameter).
- 2 ship auger bits (3/4 inch diameter).
- 800 m^3 native rock (30-120 cm diameter).
- 35 white spruce trees with roots.

Cost Summary

Restoration design	$ 5,300
Project coordination/ on-site supervision	$ 16,000
Hitachi EX 200 excavator	$ 22,000
Schaeff Spyder™	$ 13,000
Felling and delivery of LWD	$ 4,500
Rock delivery to work site	$ 17,500
Portable bridge	$ 2,400
Labour	$ 5,500
Equipment rental	$ 1,700
Materials (rock, LWD, cable, epoxy)	$ 9,400
Total	$ 97,300

Production Estimates

The 1998 project rehabilitated approximately 12,000 m^2 of spawning and rearing habitat for Arctic grayling, bull trout, rainbow trout, and mountain whitefish. Little literature exists for production estimates of these species, however, estimates of 0.16 fish $\cdot m^{-2}$ (catchable size, > 15 cm) for rainbow trout and Dolly Varden char were reported by Koning and Keeley (1997). Using these values, we expect the rehabilitated section of Martin Creek to support a mixed stock of perhaps 1900 rainbow trout and bull trout (based on similar life-history for Dolly Varden and bull trout and in the absence of grayling and whitefish). However, the absence of similar data for grayling and whitefish coupled with a lack of understanding of the effect of interspecific interactions among the four species on production, leaves us unable to confidently estimate numerical fish production benefits for each species.

Proposed Work

Spring 1999 - The berm and side channel bank tops will be planted with nursery-grown shrubs collected from a nearby site. Willow and poplar cuttings will be used for gravel bar staking and planting on the banks of the side channel and mainstem in the construction zone. The planting will assist in soil and bank stabilization as well as provide cover, shade, and nutrient input, particularly for the side channel. LWD will be placed in the side channel to increase instream cover. The construction zone will subsequently be seeded using a mix of grasses and legumes specially formulated for the site.

Summer 1999 - The channel within the 1200 m reach just upstream of the 1998 restoration reach has been migrating within the floodplain for several years in an effort to establish a stable bedform. We hope to establish several "hard points" that will encourage the stream to approximate its historical gradient and planform. The "hard points" will consist of large log jams and a few riffles. Locally available sources of rock and about 260 full-length conifers (with roots attached) will be used.

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Figure 7-26. Upstream view of channel (from FSR bridge) before riffle-pool construction and LWD placement.

Figure 7-27. Upstream view of channel (from FSR bridge) after riffle-pool construction and LWD placement.

Figure 7-28. LWD structure constructed over a pool excavated below riffle #8.

Figure 7-29. Low profile LWD structure designed to maintain pool habitat through bed scour.

Figure 7-30. Side channel following its excavation to groundwater level and the berm protecting it from high mainstem flows.

Narrowlake Creek Restoration (Year 2)

Objectives
The primary objectives during year two of the Narrowlake Creek restoration project were to control rates of lateral erosion on a large eroding bank while continuing with channel stabilization works and mainstem fish habitat complexing initiated in 1997.

Along with construction of instream structures, pre- and post-restoration monitoring of fish populations, riparian assessments, and structure cataloging and surveying were implemented to track the effectiveness of the project over time. Information collected will allow for further refinement of restoration techniques.

FRBC Region/ MELP Region/ MOF Region
Omineca-Peace/Omineca-Peace/ Prince George

Authors
Ray Pillipow, Fisheries and Watershed Restoration Technician (BC Conservation Foundation), and Andrew Wilson, WRP Fisheries Specialist (MELP/ Omineca sub-Region 7a).

Proponent
Ministry of Environment, Lands and Parks.

Watershed
Narrowlake Creek (Willow River Watershed Group).

Location
Narrowlake Creek is located approximately 80 km southeast of Prince George, and is accessed from the Willow 100 Forest Service Road at km 169.5.

Introduction
Narrowlake Creek is a fifth-order stream located in a Sub-boreal Spruce wet cool biogeoclimatic zone which drains an area of 187 km^2 into the Willow and subsequently Fraser River. Annual precipitation in the watershed averages 615 mm. Daily 50 year and 100 year return flood discharges for the Narrowlake Creek drainage have been estimated to be 63.4 $m^3 \cdot s^{-1}$ and 71.2 $m^3 \cdot s^{-1}$, respectively. The elevation at the confluence with the Willow River is 914 m. The bankfull channel width ranges from 16.8 m in stable sections to 57.3 m in unstable sections.

The fish species found within the Narrowlake Creek watershed include: bull trout, rainbow trout, lake trout, kokanee, rocky mountain whitefish, slimy sculpin, burbot, longnose sucker, and when flow conditions are favorable, chinook salmon.

Trout densities have been found to be the highest where pools with woody debris cover exist. Burbot and sculpin were also found to be associated with abundant woody debris cover, as well as larger substrates with high porosity.

The watershed was extensively harvested from 1966 to 1974. A total of 35% of the basin has been logged (the majority of which has occurred in the low elevation valley bottom) with 80% of the mainstem creek being harvested to the streambank. The soils in the watershed are comprised of non-cohesive cobble and gravel alluvium.

Assessments and Prescriptions
A Riparian Assessment and Prescriptions Procedure was completed on the lower 4 km of Narrowlake Creek during the field season of 1998. Prescriptions generated from the procedure are set for implementation in the spring, 1999.

Fish population assessments were completed for three treatment reaches of Narrowlake Creek using triple pass depletion (Platts et al. 1983), with sites either identified through stratified random selection or at completed restoration sites.

Completed structures were surveyed using the two-pin survey method (Miller et al. 1998), and stamped metal discs were attached to structure components to identify individual pieces of wood to allow for future monitoring of structure movement.

<u>1998-99 Prescriptions</u>
Following from 1997 prescriptions, additional LWD lateral debris jams and deflectors were constructed in mainstem Narrowlake Creek as per Slaney et al. (1997) to induce scour, provide overhead cover, and protect eroding banks by shifting the thalweg and dispersing hydraulic energy.

Gravel bar stabilization treatments were continued in 1998 with the addition of LWD to selected areas of the floodplain and gravel bars. This will function to trap fine sediment and will serve to promote the establishment of vegetation and ultimately, restore stream channel stability to pre-harvest regimes (Soto et al. 1997).

An engineered prescription was completed for a lateral eroding bank along the mainstem of Narrowlake Creek. The eroding bank material is characterized as non-cohesive gravel alluvium along the upper third and alluvium with clay seams near the downstream end of the bank. As a result the angle of the bank is unstable and annually erodes during high discharge events. To demonstrate different prescription types for controlling lateral erosion, and to protect the forest resources along the bank, the final design included three distinct treatment areas along the length of the eroding bank generally following from Babakaiff et al. (1997):

- rock groynes/deflectors (Figs. 7-31 to 7-33);
- LWD revetments (Figs. 7-31 to 7-33), and
- an LWD/rip-rap combination to be constructed in winter 1999.

The application of rock groynes at the top of the eroding bank will serve to shift the thalweg away from the bank and dissipate the energy downstream. The LWD revetments and young trees used from local spacing contracts were placed along the banks to amour the bank, deflect currents, and allow eroded materials from the bank to settle behind the LWD. Over time it is expected that erosion from flows will be minimized and erosion from weathering will lessen the bank angles and provide greater stability.

Rehabilitation Work

Year one of the restoration work can be reviewed in Zaldokas [ed.] 1998.

Year two rehabilitation work was initiated on Narrowlake Creek in July 1998. As with 1997, boulders and blow-down spruce were provided by project partners and transported to the restoration sites by locally contracted dump trucks, skidder and self-loading logging trucks. Boulders and bucked rootwads were obtained from areas of recent road construction and spruce trees with roots attached were skidded from roadside blow-down areas within the Narrowlake Creek drainage.

In 1998, 22 fish habitat and channel restoration structures comprised of 124 pieces of LWD and 140 boulders were constructed. Since 1997, a total of 67 restoration structures have been installed over 3.5 km of Narrowlake Creek utilizing 252 pieces of LWD (including rootwads), and 321 boulders. Structures are broken out as follows:

- 2 rock groynes (Figs. 7-31 to 7-33);
- 2 LWD revetments (Figs. 7-31 to 7-33);
- 19 single logs;
- 21 lateral (triangle) log jams (Fig. 7-34);
- 6 LWD flow deflectors (Fig. 7-35), and
- 16 gravel bar stabilization structures (Fig. 7-36).

Equipment Used

Transportation of materials from the staging site to restoration sites was completed with a Sikorsky 61 helicopter. Fish habitat structures were assembled using a Schaeff Spyder™ HSM 41 mobile walking excavator. Lheidli T'Enneh Native Council provided labour to move rock to the groynes after machine work was completed and to move trees from local spacing contracts to fill spaces behind the tree revetments.

Cost Summary

Engineering	$ 8,800
Labour	$ 18,790
Equipment	$ 65,390
Materials	$ 12,340
Total	$ 105,320

The 1998 cost is $19,000 less than what was expended on restoration works in 1997. This cost saving was due to LWD and boulders being more readily accessible in 1998.

Production Estimates

The LWD structures placed in the wetted channel were colonized by rainbow trout, bull trout, and whitefish almost immediately following installation. These structures, when constructed in existing pools or placed in pool-forming areas provide an immediate benefit to fish habitat as the percentage of woody debris cover in pools increases by approximately 20% following restoration (Fig. 7-34). From production estimates described in Koning and Keeley (1997), it is anticipated that over time the increased woody debris complexing in mainstem pools will lead to a 2.5-fold increase in total rainbow trout numbers in treatment reaches of Narrowlake Creek.

Restoration structures placed on gravel bars or along eroding banks will not immediately lead to increases in fish production. The objective of these structures is to return the stream channel to a pre-disturbance level of stability which will occur over a longer time period than the pool forming structures mentioned above.

Proposed Work
Years 1 and 2 of the Narrowlake Creek restoration project focused on instream fish habitat and channel restoration. Additional attention was applied to riparian assessments, fish population assessments, and the development of post-project monitoring. Continuing phases of work will be concentrated on riparian restoration as a result of the riparian prescriptions generated from the 1998 assessment, post-project monitoring, and where required additional instream LWD placement.

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Figure 7-31. Pre-restoration downstream view of large eroding bank along Narrowlake Creek mainstem.

Figure 7-32. Mid-restoration upstream view of large eroding bank along Narrowlake Creek mainstem. Note LWD revetment and rock groynes under construction.

Figure 7-33. Post-restoration downstream view of large eroding bank along Narrowlake Creek mainstem. Rock groynes were colonized by juvenile rainbow trout within days of structure completion.

Figure 7-34. Post-restoration view of lateral LWD jam. Note depth of pool scoured out after October rainstorms. Large woody debris cover in pools is increased on average 20% following restoration.

Figure 7-35 Post-restoration view of LWD / boulder deflector.

Figure 7-36. Post-restoration view of multiple lateral gravel bar stabilization structures in the lower reaches of Narrowlake Creek.

Late Submissions

Birk Creek Channel Restoration: Phase 1

Objectives
The objectives of this project are to:
- re-establish a stable equilibrium channel; and
- accelerate the recovery of fish habitat by construction of instream structures.

FRBC Region/MELP Region/MOF Region
Thompson-Okanagan / Southern Interior/ Kamloops

Authors
L. Uunila[1], B. Guy[1], J. Fraser[2], M. Ross[3], W.O. Rublee[4], and G. Smith[5].

Proponent
Tolko Industries, Louis Creek Division.

Watershed
Barriere River watershed, Birk Creek.

Location
In June, 1998 channel restoration was initiated on the lowest 1 km of Birk Creek, a tributary of the Barriere River approximately 22 km northeast of Barriere, B.C.

Introduction
The collective impacts of forest harvesting and roads, and in particular a major washout of a public road in 1997 had caused aggradation behind debris jams, overbank flows, channel avulsions, accelerated bank erosion and riparian tree mortality. These processes created fish migration barriers and reduced both spawning and rearing habitat for coho and chinook salmon and rainbow and bull trout.

Assessments and Prescriptions
In order to restore and maintain fish habitat over the medium-term, a two-phase approach was adopted. The goal of Phase 1 (1998) was to accelerate the re-establishment of a stable equilibrium channel both in profile and planform, that was free of barriers to fish migration. Since the project reach is located on an alluvial fan "stability" is at best a transient state, attainable for no more than 20 years. Pre-construction activities included an assessment of the channel to identify fish barriers and areas requiring stabilization and restoration. Risks to the project reach from upstream were determined to be low.

Phase 2 (to be conducted in 1999) will involve the construction of habitat features. This sequenced approach will allow a period of time (including one freshet) for natural stream processes to re-establish an equilibrium channel after the selective removal of LWD and sediment in Phase 1, prior to the construction of habitat features in Phase 2. Such a phased approach should increase the likelihood of long-term success of the habitat features.

Rehabilitation Work
Conceptual prescriptions for 12 sites (including 7 debris jams) were prepared. A total station survey using 41 representative bench-marked cross-sections was conducted to determine the pre-construction bed topography. Semi-permanent photo locations were established along the project reach for pre- and post-construction assessments and long-term monitoring.

An excavator that was provided by the North Thompson Indian Band (NTIB) was used to remove portions of debris jams and excavate sediment wedges and excess bed material. In selected locations, the natural meander pattern was enhanced and the proportion of pools to riffles was increased. Secondary channels were re-established or blocked off to promote channel stability. To improve future habitat conditions, hydraulic connections at low flow were re-established between the outlets of selected secondary channels and the main channel. Where necessary, banks were stabilized using a combination of boulders and LWD (cabled to either the bank or rock ballast). Finally, bed structures such as stone lines and turning weirs were installed to dissipate flows and promote channel stability.

Post-construction activities included a re-survey of the channel and follow-up photographs at all semi-permanent photo locations. A post-construction report was produced along with a summary map. The summary map indicates the locations of the restoration sites and permanent photo locations and includes the pre- and post-construction cross-sections, longitudinal profiles and bed topography of the project reach. For long-term monitoring purposes, a comprehensive pre- and post-construction photo collection and pre- and post-construction sketches were also compiled.

It is anticipated that natural stream processes between fall 1998 and late summer 1999 will result in additional channel adjustment, such that a significantly stable channel will exist for the implementation of specific habitat restoration features in 1999.

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Note: this project summary was taken from the Abstract of the Birk Creek Channel Restoration: Phase 1 report prepared for the 1999 Interior Forest Site Rehabilitation Workshop, April 7-8, 1999, Kamloops, B.C.

UTM (NAD 83) Coordinates
Zone: 11
Northing: 5688760
Easting: 298103

Watershed Code
129-190100-49300

Waterbody Identifier
00000LNTH

Haggard Creek Culvert Removal

Objectives

The objectives of this project were to:

- remove a pair of perched culverts from Reach 1;
- conduct a cross-sectional survey of the site prior to culvert removal; and
- establish baseline fish sampling (conducted by ARC Environmental Ltd.) in Reach 1 and Reach 3 to better understand and compare fish species assemblages and habitat use both before and after the removal of culverts.

FRBC Region/MELP Region/MOF Region

Thompson-Okanagan / Southern Interior / Kamloops

Author

G.D. Smith, AScT

Proponent

ARC Environmental Ltd.

Watershed

Barriere River watershed, Haggard Creek.

Location

Haggard Creek is a small tributary of the East Barriere River located in the Shuswap Highlands near Barriere, B.C. The Haggard Creek site is located in the Barriere River system about 18 km from the North Thompson River confluence.

Introduction

Local records from DFO indicate coho and chinook salmon have been present throughout this system in past years. The pair of perched culverts had been installed to provide access for Tolko's timber harvest and were limiting upstream fish movement.

Assessments and Prescriptions

Haggard Creek was included in the WRP's IWAP, SSS, FHAP, AMM and CCPA for the Barriere River watershed. Baseline fish sampling and channel cross sections were completed prior to and following the removal of the lower Haggard Creek culverts. The baseline sampling shows anadromous fish present throughout the system. This sampling is scheduled to be carried out again following the spring freshet in 1999.

Rehabilitation Work

The instream restoration work in Haggard Creek has been limited to culvert removal and baseline monitoring thereby improving conditions in the upstream channel. The removal increased movement through an additional 3 km of Haggard Creek. Another upstream culvert barrier remains limiting full movement of all age classes through the system.

Cost Summary

The costs for baseline monitoring of the Haggard Creek Project was included with baseline monitoring on Birk Creek at a cost of $3,839 in fees and $1,220 in expenses for a total of $5,059. An overflight of the Barriere River watershed was also conducted at the same time as the baseline monitoring of Haggard and Birk Creeks at an additional cost of $4,887 bringing the total cost of the two projects to $9,946.

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UTM (NAD 83) Coordinates

Zone: 11
Northing: 5681011
Easting: 295521

Watershed Code

129-190100-31800-00800

Waterbody Identifier

00000LNTH

Clear Creek Side Channel Habitat Development Project

Objectives
Skeena River coho have been identified as a provincially and regionally high priority target species for habitat rehabilitation. To address these priorities, the primary objective of the Clear Creek project was to expand the amount of stable coho spawning and rearing habitat in this tributary of the Kitsumkalum and Skeena watersheds. The secondary objective of this project was to provide employment and training opportunities for local stakeholders in the discipline of fish habitat restorative work.

FRBC Region/MELP Region/MOF Region
Skeena-Bulkley / Skeena / Prince Rupert

Watershed
Kitsumkalum (Skeena)

Proponent
Kitsumkalum Band Council (KBC),Terrace, B.C.

Rehabilitation Work
This rehabilitative project was planned primarily by the staff of Biolith Scientific Consultants Inc. who were under contract to the KBC. Technical input was received from the Ministry of Environment Lands and Parks (MELP) and technical field support was provided by staff of the KBC.

After a year of monitoring subsurface (ground) water levels in strategically placed test pits, a survey and project plan was submitted for technical and regulatory approval. Phase One of project construction was initiated in the summer of 1998 which involved developing 1.4 km of a relic side channel utilizing subsurface water as a water supply. The entire excavation and protective berm was constructed in isolation of Clear Creek mainstem. Phase Two of this project is slated to begin in the summer of 1999 which will involve complexing the channel with wood to improve the quality and quantity of the fish habitats. The final Phase of this project will be to connect the new channel to Clear Creek to provide access for both juvenile and adult fish. This aspect of the project is also slated for completion during the summer of 1999.

Cost Summary
Phase One of this project cost $43,100 for labour, equipment and materials combined.

For Further Information, Contact:
Lyle Bolton (KBC, Terrace- 250-635-6177)
Glenn Grieve (Grieve@Biolith.bc.ca)
Jeff Lough (MELP, Smithers- 250-847-7337)

UTM (NAD 83) Coordinates
Zone: 9
Northing: 6075418
Easting: 513248

Watershed Code
430-465300

Waterbody Identifier
00000KLUM

Glacier Creek Large Woody Debris Bar Stabilization Project

Objectives
Skeena River summer run steelhead and coho have both been identified as provincially and regionally high priority target species for habitat rehabilitation. To address these priorities, Glacier Creek, an important steelhead and coho tributary to the Kitsumkalum River, was identified as a priority impacted watershed. Glacier Creek also has technically feasible opportunities to stabilize it's currently mobile gravel bars and accelerate vegetative growth closer to the stream channel. Collectively this treatment will contribute to a more diverse and stable habitat for both coho and steelhead.

The secondary objective of this project was to provide employment and training opportunities for local stakeholders in the discipline of fish habitat restorative work.

FRBC Region/MELP Region/MOF Region
Skeena-Bulkley / Skeena / Prince Rupert

Watershed
Kitsumkalum (Skeena)

Proponent
Kitsumkalum Band Council (KBC)

Rehabilitation Work
Phase One of the Glacier Creek project was initiated by modifying a conceptual idea provided by the KBC and Biolith. The modified plan was laid out in the field by staff from the MELP and the United States Forest Service (USFS). This plan was formalized in a drawing and submitted for regulatory approval during the summer of 1998. The prescription identified approximately 50 wood structures to be placed along 0.5 km of stream in the lower reach of the creek. Due to the high energy of Glacier Creek at the project site (2.5% gradient) the structures were designed to be non-channel spanning. Most are to be located on gravel bars to slow the velocity of high water flows across the bars. The slower flows in these areas will allow fines to settle behind the structures and encourage vegetative growth in these currently denuded areas.

Full length logs (with rootwads attached) were salvaged from large floating "rafts" in Kitsumkalum Lake under regulatory approval. The logs were sorted, transported by truck and stock piled on a landing close to Glacier Creek for placement during Phase Two. Technical field support was provided by staff of the KBC.

Phase Two of this project is proposed to be implemented during the summer of 1999. The LWD pieces will be quickly transported to the creek using a large capacity helicopter. Once placed in their approximate location, KBC technicians will fine tune and anchor the structures. In some cases willows will be planted behind the LWD structures to accelerate the initiation of vegetative growth on the bars.

Monitoring of this project is planned to be completed by installing permanent photo points at strategic sites along the creek. In addition an "as-built" survey will be completed after the structures are all built. Subsequent surveys and photos of the sites after high water events will give the proponent and the regulatory agencies an excellent opportunity to evaluate if the project's structural objectives are being met.

Cost Summary
Cost summary of this project was not available at the time of printing.

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UTM (NAD 83) Coordinates
Zone: 9
Northing: 6057514
Easting: 517570

Watershed Code
430-256600

Waterbody Identifier
00000KLUM

Mann Creek Fish Habitat Restoration

Objectives
The objective of this project was to accelerate the recovery of fish habitat within Mann Creek.

FRBC Region/MELP Region/MOF Region
Thompson-Okanagan / Southern Interior / Kamloops

Author
ARC Environmental Ltd.

Proponent
Slocan Forest Products Ltd., Vavenby Division.

Partner
North Thompson Indian Band (NTIB)

Watershed
Mann Creek

Location
The instream works project study area is located in Reach 7 of Mann Creek, approximately 23 km upstream of the Mann Creek and North Thompson River confluence.

Introduction
The Mann Creek watershed encompasses 291 km^2. Reach 7 of Mann Creek has been impacted by past forestry activities including logging of mature coniferous vegetation from both sides of the stream.

Assessments and Prescriptions
Restoration activity was conducted in a 1040 m section of the reach. This section was identified by the Overview and Level 1 FHAP. Within this stream section, the relative abundance of both rainbow trout and eastern brook trout was proven to be lower than the relative abundance occurring within unimpacted sections within the same reach. Diagnostics performed on various fish habitat variables within the impacted section indicated that the quality and quantity of fish habitat available was also reduced. On-site prescriptions were conducted on August 18, 1998. At this time, 1040 m of impacted stream within Reach 7 of Mann Creek was surveyed and approximately 31 sites containing 81 individual structures were identified as requiring instream habitat improvement structures.

Rehabilitation Work
The Level 2 instream works portion of the project was conducted from September 10 to 14, 1998. A total of 135 fish habitat structures were constructed at 20 different sites along the 1040 m of stream within the study area. The structures consisted of 23 stone lines, 43 pieces of LWD, 11 boulder V-weirs, and 58 boulder clusters.

Cost Summary
The total cost to construct the instream structures within a kilometer of Mann Creek, including labour, excavator and machinery rental and materials was approximately $19,843 or $144 per structure.

For Further Information, Contact:
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Kamloops, BC V2C 6N6
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Ministry of Environment, Lands and Parks
1259 Dalhousie Dr.
Kamloops, BC V2C 5Z5
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Note: this project summary was taken from the Executive Summary of the Mann Creek Watershed: Level 1 & 2 Instream Works report prepared by ARC Environmental Ltd. for Slocan Forest Products in partnership with NTIB (December 1998).

UTM (NAD 83) Coordinates
Zone: 10
Northing: 5716656
Easting: 698451

Watershed Code
129-335800

Waterbody Identifier
00000LNTH

Mobbs Creek Fan Re-profiling

Objectives
The objective of this project is to re-profile the level of the fan at the confluence of Mobbs Creek and the Lardeau River to reduce backwatering of Trout Lake and the Gerrard rainbow spawning area at the outlet of the lake.

FRBC Region/MELP Region/MOF Region
Kootenay-Boundary / Kootenay / Nelson

Author
Rob Baldwin

Proponents
MELP, and Slocan Forest Products Ltd.

Watershed
Lardeau River / Mobbs Creek

Location
Mobbs Creek flows into the Lardeau River approximately 750 m below the outlet of Trout Lake.

Introduction
The outlet of Trout Lake is a spawning area for the famous Gerrard rainbow trout from Kootenay Lake. The Mobbs Creek fan over the past 10-12 years has built up in height causing a slight backwatering of Trout Lake and the spawning area. The fear was that this backwatering may impair the spawning success of the Gerrard rainbow trout.

Assessments and Prescriptions
Over the past ten years there have been surveys conducted to monitor the Mobbs Creek fan. A survey was conducted prior to works being implemented to determine the present elevations and compare them to historical elevations.

Rehabilitation Work
The rehabilitation work involved the excavation and re-profiling of the fan to resemble the historical elevations of the fan. The rehabilitation of the fan was completed in one day. Elevations were shot during the re-profiling to guide the excavations and re-profiling.

Cost Summary

Equipment and labour	$ 2,500
Total	$ 2,500

Outputs
The re-profiling of the fan protected approximately 400 m of significant spawning habitat.

Future Work
The Mobbs Creek fan may require periodic excavation over time if the fan builds in height. Profiles of the fan will be surveyed periodically to monitor the fan.

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UTM (NAD 83) Coordinates
Zone: 11
Northing: 5595192
Easting: 480894

Watershed Code
340-218400-07200-64200

Waterbody Identifier
00000DUNC

Winlaw Creek Fan Restoration

Objectives
The objectives of this project were focused on improving fish passage, improving fish habitat and improving sediment passage through the lower watershed to improve water quality.

FRBC Region/MELP Region/MOF Region
Kootenay-Boundary / Kootenay / Nelson

Author
Terry Anderson

Proponents
MELP, and Winlaw Watershed Association.

Watershed
Slocan River / Winlaw Creek

Location
Winlaw Creek flows into the Slocan River through the Village of Winlaw in the Slocan Valley.

Introduction
Winlaw Creek is a small tributary of the Slocan River. The creek contains resident rainbow trout and supports some spawning and juvenile habitat for Slocan River rainbow trout. The watershed is also a community drinking water supply.

Assessments and Prescriptions
The watershed has had several assessments conducted including: Fish Habitat Assessments, Channel Assessments and some Restoration Prescriptions.

Rehabilitation Work
The rehabilitation work was conducted in the late summer and involved hand labour only. Several potential and existing barriers comprised of LWD were altered to improve passage and sediment transport. Sections of LWD were removed or re-positioned to improve the passage while maintaining quality fish habitat. Several water intake structures were also altered or changed to allow for better sediment transport.

Cost Summary

Equipment and labour	$ 30,000
Total	$ 30,000

Outputs
The restoration works restored 300 m of habitat and regained up 1000 m of habitat through barrier restoration. It is difficult to assign an output to improved sediment transport but it is hoped that water quality will be improved.

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UTM (NAD 83) Coordinates
Zone: 11
Northing: 5495439
Easting: 458901

Watershed Code
340-047200-34900

Waterbody Identifier
00000SLOC

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