

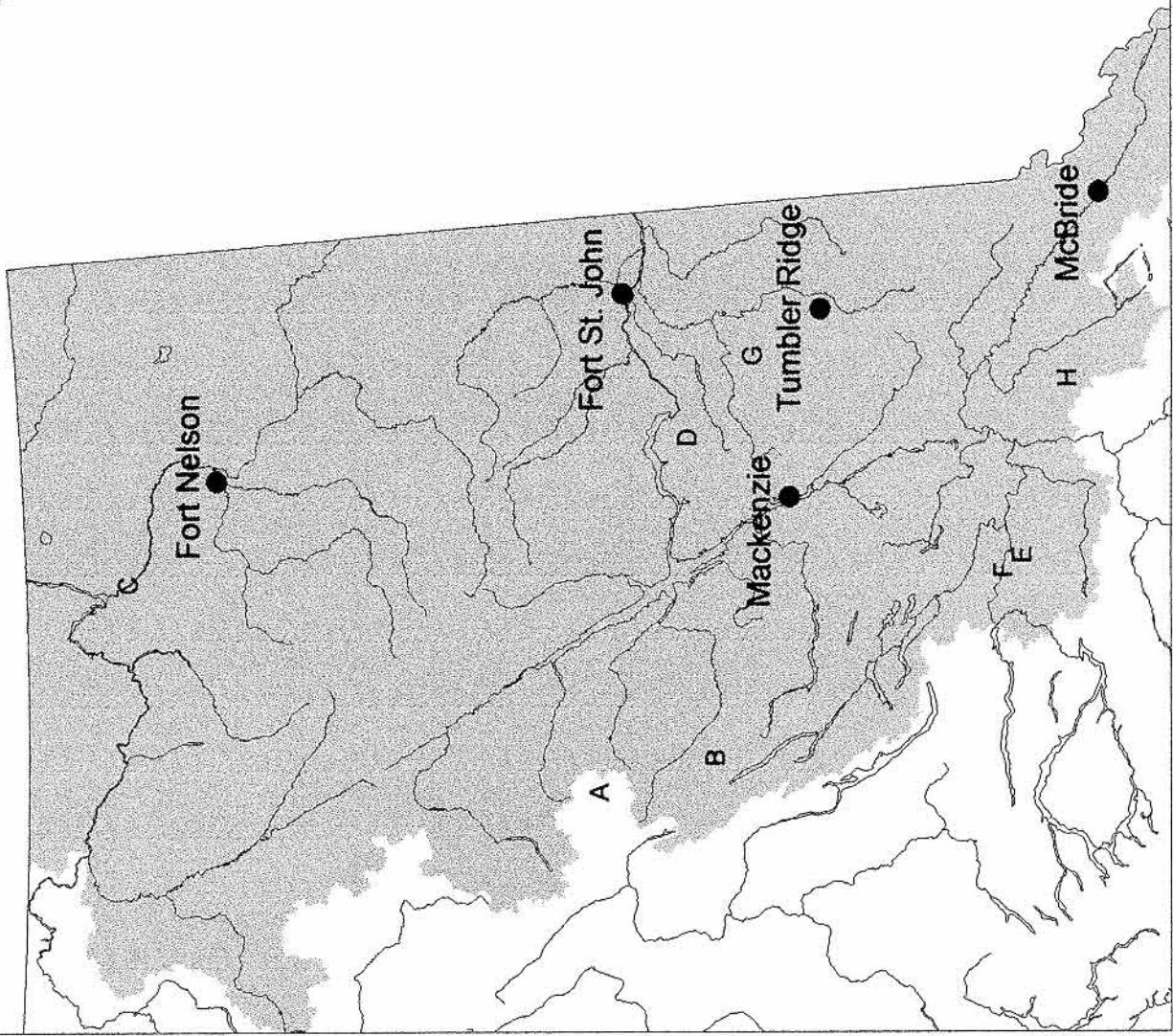
Omineca - Peace Region

Region 7. Omineca-Peace



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
	Chilako River	McPhee Creek		10	5979287	503653	180-039000-00000	00000LCHL
	Fort Nelson River	Stubby Creek		10	6582036	448357	212-083400	00000LFRT
	Halfway River	Blue Grave Creek		10	6272533	535089	235-371300	00000UHAF
	Nulkati-Tachick Lakes	Corkscrew Creek		10	5973076	442082	180-271000-56200	00000NECR
	Nulkati-Tachick Lakes	Stoney Creek		10	5985923	432056	180-271000	00000NECR
	Sukunka River	Martin Creek		10	6150032	585514	234-443900-14100	00000PINE
	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 km². 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 m³·s⁻¹. Return rates Q50, Q100 are 8.92 m³·s⁻¹ and 9.8 m³·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 m² of habitat whereas triple pass population surveys indicate that less than 10 rainbow fry per 100 m² 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

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Proponent

Ministry of Environment, Lands and Parks.

Watershed

McPhee Creek (Lower Chilko 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 km², 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.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™ 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 7-9. 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 7-8. 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 7-11. 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

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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 m² 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 ($1.0\text{-}1.9 \text{ m}\cdot\text{s}^{-1}$) 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 (Armetec 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 $1.3 \text{ m}\cdot\text{s}^{-1}$). 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

<u>Crossing</u>	<u>#4</u>	<u>Bioengineering</u>
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 m² 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.

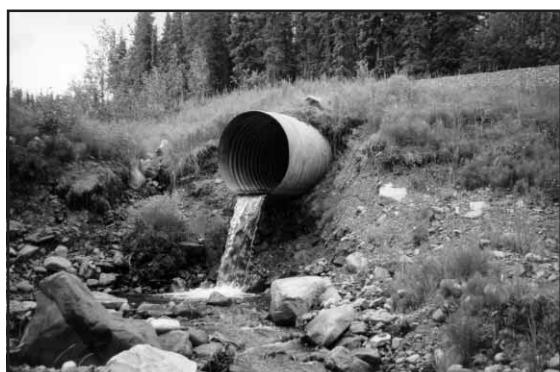


Figure 7-18. Upstream view of crossing #4 before restoration. Note the 1.5 m drop at the outfall.



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

Scott McIntosh and Cam Irvine.

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 H₆₀ 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 montane 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 gravelly 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 7-24b. Anchoring LWD structures.



Figure 7-24a. 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

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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 m³ 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 m² 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 · 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 7-27. 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 7-26. Upstream view of channel (from FSR bridge) before riffle-pool construction and LWD placement.



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

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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 km² 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 m³.s⁻¹ and 71.2 m³.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.

1998-99 Prescriptions

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 armour 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.