20181

BIOPHYSICAL SURVEYS AND EVALUATIONS OF ENHANCEMENT OPPORTUNITIES FOR STREAMS TRIBUTARY TO LAKE REVELSTOKE

Volume 1

TRITON
Environmental Consultants Ltd.

2098/WP 4421

BIOPHYSICAL SURVEYS AND EVALUATIONS OF ENHANCEMENT OPPORTUNITIES FOR STREAMS TRIBUTARY TO LAKE REVELSTOKE

Volume 1

Prepared for:

Mica Fisheries Technical Committee
B.C. HYDRO/B.C. MINISTRY OF ENVIRONMENT, LANDS AND PARKS
c/o 1312 - 808 Nelson Street
Vancouver, B.C.
V6Z 2H2

April 1992

Prepared by:

TRITON
Environmental Consultants Ltd.
120-13511 Commerce Parkway
Richmond, B.C., Canada
V6V 2L1
(604) 279-2093 - Fax: (604) 279-2047

EXECUTIVE SUMMARY

Bio-reconnaissance was conducted on 23 tributaries flowing into Lake Revelstoke, a run of the river reservoir located between the Revelstoke and Mica Dams in southeastern British Columbia. These streams were assessed for enhancement opportunities of both stream resident and adfluvial (lake resident) species of sports fish. Eight tributaries, Bigmouth, Scrip, Kirbyville, Ruddock, Carnes, Downie, La Forme and Nagel Creeks offer the most potential for enhancement of adfluvial fish species. These streams have extensive habitat accessible to lake resident fish with the exception of Nagel Creek, which could provide over 20 km of habitat if a migrational impasse near its outlet is removed.

Bull trout were the most frequently encountered sports fish species within these 8 streams, although, no fish were captured in Nagel Creek. Rainbow trout were also found in Downie, Scrip and Kirbyville Creek. The largest tributary entering Lake Revelstoke, the Goldstream River, offers opportunities to enhance a resident cutthroat trout population since this stream is inaccessible to adfluvial fish species, but contains extensive habitat which is accessible to the indigenous cutthroat trout population.

Lowered escapement of spawning adults is hypothesized as the main factor limiting fish production within the 9 primary streams. Degradation of the remaining available spawning and rearing habitat, primarily a result of logging, likely adversely effects fish populations presently utilizing some of these streams. Habitat degradation may also impact upon proposed enhancement strategies. Enhancement should focus on bull trout and rainbow trout species, but not kokanee. Suggested enhancement techniques include habitat creation and rehabilitation, outplanting of hatchery reared juvenile fish, barrier removal, stream fertilization and management of existing resources. Prior to initiating an enhancement program on the nine identified primary streams, it is recommended that a long term study plan be developed. This plan would include the establishment of an integrated forestry fisheries management plan and further studies to collect baseline biological data for the 9 primary streams. After further investigations are completed, initiation of a pilot enhancement program on 2 of the primary tributaries could commence. Continued monitoring of streams after pilot enhancement projects have begun is critical to determine the success of enhancement procedures and will help determine if changes in enhancement strategies are required.

ACKNOWLEDGEMENTS

Triton Environmental Consultants acknowledges the contributions to this project by:

H. A. Smith	B. C. Hydro and Power Authority
J. O. Flemming	B. C. Hydro and Power Authority
B. Gadbois	B. C. Hydro and Power Authority
R. A. Lindsay	B.C. Ministry of Environement, Nelson Office.
I. McGreggor	B.C. Ministry of Environement, Nelson Office
J. Blake	B.C. Forest Service, Revelstoke Office
R. Mohr	B.C. Forest Service, Revelstoke Office
B. Wagner	Downie Street Sawmills, Revelstoke B.C.
J. Archer	Beaumont Timber Co. Ltd. Sicamous, B.C.
V. Scherm	Owner/Operator, Monashee Outfiiting
D. Monk	Owner/Operator, Downie R.V. Resort

STUDY TEAM

The study team was composed of the following personnel from Triton Environmental Consultants Ltd:

T.A. Watson	Project Director
A.C. Mitchell	Senior Engineer
M.M. Galesloot	Project Biologist, Author
B. Mattock	Technician, field and office support
B. T. Guy	Senior Hydrologist
H. D. Warburton	Quick Map Specialist
F. A. Lebrero	Engineer
R. B. Burko	dBase Specialist
D. T. Tesch	Office Support
R. V. Bogdonov	Office Support

TABLE OF CONTENTS

		Page
Executive Summary		i
Acknowledgments		ii
Study Team		iii
List of Figures		vii
List of Tables		x
List of Photographs		xv
List of Appendices		xxiii
1.0	INTRODUCTION	1
2.0	STUDY AREA	3
3.0	METHODS	5
3.1	Physical Studies	5
3.1.1	Survey Sites	5
3.1.2	Data Compilation	7
3.1.3	Hydrology	7
3.2	Biological Studies	8
4.0	RESULTS	12
4.1	Fish	12
4.1.1	Resident versus non-Resident fish	16
4.2	Hydrology	17
4.3	Logging	24
4.4	Priorizing Tributaries Entering Lake Revelstoke for Enhancement Potential	26
4.5	Stream Descriptions	32

TABLE OF CONTENTS
(CONTINUED)

Page

"A" CATEGORY STREAMS

4.5.1	Scrip Creek	32
4.5.2	Kirbyville Creek	42
4.5.3	Ruddock Creek	51
4.5.4	Carnes Creek	58
4.5.5	Bigmouth Creek	67
4.5.6	La Forme Creek	83
4.5.7	Downie Creek	92
4.5.8	Goldstream River	112
4.5.9	Nagel Creek	133

"B" CATEGORY STREAMS

4.5.10	Soards Creek	142
4.5.11	Mica Creek	149
4.5.12	Nicholls Creek	157
4.5.13	Park Creek	165
4.5.14	Pat Creek	171
4.5.15	Horne Creek	179
4.5.16	Hoskins Creek	185
4.5.17	Birch Creek	193

"C" CATEGORY STREAMS

4.5.18	Mars Creek	198
4.5.19	Big Eddy Creek	204
4.5.20	Frisby Creek	210
4.5.21	Pitt Creek	216
4.5.22	Seymour Creek	222
4.5.23	Bourne Creek	229

5.0 DISCUSSION 234

5.1 Historical Utilization of Tributary Habitat by Sports Fish Species 234

5.2 Factors Limiting Production in Revelstoke Tributaries 236

TABLE OF CONTENTS
(CONTINUED)

			Page
	5.3	Enhancement Opportunities	238
	5.3.1	Hatchery Raised Fish and Outplanting	239
	5.3.2	Barrier Removal	242
	5.3.3	Rehabilitation and Creation of Habitat	242
	5.3.4	Stream fertilization	243
	5.3.5	Management of Existing Resources	244
	5.4	Long Term Strategy	245
	5.5	Estimated Costs	248
	5.5.1	Barrier Removal	248
	5.5.2	Collection of Baseline Biological Data	252
	5.5.3	Hatcheries and Outplanting	255
6.0	CONCLUSIONS		259
7.0	REFERENCES		262

LIST OF FIGURES

		Page
Figure 1	The Revelstoke Lake Study area, identifying the streams surveyed during the course of field investigations.	4
Figure 2	Stream survey cards used during assessments of Revelstoke Lake tributaries.	6
Figure 3	Streams from which Water Survey of Canada gauging station data were used.	10
Figure 4	Histograms showing the age weight relationships for 1, 2, 3, and 4 year old bull trout captured above and below barriers on tributaries entering Revelstoke Lake.	18
Figure 5	Histograms showing the age length relationships for 1, 2, 3, and 4 year old bull trout captured above and below barriers on tributaries entering Revelstoke Lake.	19
Figure 6	Histograms showing the age weight relationships for 1, 2, 3, and 4 year old rainbow trout captured above and below barriers on tributaries entering Revelstoke Lake.	20
Figure 7	Histograms showing the age length relationships for 1, 2, 3, and 4 year old rainbow trout captured above and below barriers on tributaries entering Revelstoke Lake.	21
Figure 8	The stream profile for Scrip Creek.	36
Figure 9	A map of the Scrip Creek watershed, showing reach breaks and fish species distributions.	37
Figure 10	A map of Kirbyville Creek showing reach breaks, barriers and fish species distribution.	45
Figure 11	A stream profile of Kirbyville Creek.	46
Figure 12	The stream profile for Ruddock Creek.	53

LIST OF FIGURES
(CONTINUED)

		Page
Figure 13	A map of Ruddock Creek, showing reach breaks, lakes and fish species distributions.	54
Figure 14	A map showing sample sites, reach breaks, and species distribution for Carnes Creek.	62
Figure 15	The stream profiles for Carnes, Kelly and Mckinnon Creeks.	63
Figure 16	A map of the Bigmouth watershed, showing potential barriers, reach breaks, and species distributions.	72
Figure 17	The stream profiles for Bigmouth, Stitt and Carnes Creek.	73
Figure 18	A map of the La Forme Creek watershed, showing sample sites, reach breaks, barriers and fish species distribution.	86
Figure 19	The stream profile for La Forme Creek.	87
Figure 20	A map of the Downie Creek watershed, showing barriers, reach breaks, sample sites and distribution of fish species in both mainstem and tributaries.	100
Figure 21	A stream profile of Downie, Standard and Sorcerer Creeks.	101
Figure 22	A map of the Goldstream watershed, showing tributaries, barriers, sample sites, and reach breaks.	119
Figure 23	The stream profile for the Goldstream River.	120
Figure 24	The stream profiles for Old Camp, Brewster and McCulloch Creeks.	121
Figure 25	The stream profiles for French, Norman Woods and Stitt Creeks.	122

LIST OF FIGURES
(CONTINUED)

		Page
Figure 26	A map of Nagel Creek, showing reach breaks, sample sites and barrier locations.	136
Figure 27	The stream profile for Nagel Creek.	137
Figure 28	The stream profile for Soards Creek.	144
Figure 29	The stream profile for Mica Creek.	152
Figure 30	The stream profile for Nicholls Creek.	160
Figure 31	The stream profile for Park Creek.	167
Figure 32	The stream profile for Pat Creek.	174
Figure 33	The stream profile for Horne Creek.	181
Figure 34	The stream profile for Hoskins Creek.	188
Figure 35	The stream profile for Birch Creek.	195
Figure 36	The stream profile for Mars Creek.	200
Figure 37	The stream profile for Big Eddy Creek.	206
Figure 38	The stream profile for Frisby Creek.	212
Figure 39	The stream profile for Pitt Creek.	218
Figure 40	The stream profile for Seymour Creek.	224
Figure 41	The stream profile for Bourne Creek.	231

LIST OF TABLES

		Page
Table 1	A list of Water Survey of Canada gauging stations used to develop estimates of mean monthly flows.	9
Table 2	Mean lengths, weights and ranges of all fish species sampled during surveys of tributaries entering Revelstoke Lake in the fall of 1991.	13
Table 3	The mean weights, lengths and conditions factors of various ages classes of bull trout sampled from above and below barriers, as well as for all aged fish samples.	14
Table 4	The mean weights, lengths and conditions factors of various ages classes of rainbow trout sampled from above and below barriers, as well as for all aged fish samples.	15
Table 5	Estimation models developed for estimation of monthly discharge on ungauged study area streams.	22
Table 6	Estimated mean monthly discharge of 17 of 23 surveyed tributaries entering Revelstoke Lake.	23
Table 7	Measured discharges from tributaries entering Revelstoke Lake, fall , 1991.	25
Table 8	Future logging activities within the watersheds of tributaries entering Revelstoke Lake from 1991 to 1995.	27
Table 9	Summary of habitat and fish information gathered during surveys of Revelstoke Lake tributaries.	29
Table 10	Summary of biophysical habitat parameters for Scrip Creek.	38
Table 11	Electroshocking results (a), as well as fish size and age data (b) for Scrip Creek.	39

LIST OF TABLES
(CONTINUED)

		Page
Table 12	Summary of biophysical habitat parameters for Kirbyville Creek.	47
Table 13	Electroshocking results (a), as well as fish size and age data (b) for Kirbyville Creek.	48
Table 14	Summary of biophysical habitat parameters for Ruddock Creek.	55
Table 15	Electroshocking results (a), as well as fish size and age data (b) for Ruddock Creek.	56
Table 16	Summary of biophysical habitat parameters for Carnes Creek.	64
Table 17	Electroshocking results (a), as well as fish size and age data (b) for Carnes Creek.	65
Table 18	Summary of biophysical habitat parameters for Bigmouth Creek.	74
Table 19	Electroshocking results (a), as well as fish size and age data (b) for Bigmouth Creek.	76
Table 20	Summary of biophysical habitat parameters for La Forme Creek.	88
Table 21	Electroshocking results (a), as well as fish size and age data (b) for La Forme Creek.	89
Table 22	Summary of biophysical habitat parameters for Downie Creek.	102
Table 23	Electroshocking results (a), as well as fish size and age data (b) for Downie Creek.	104

LIST OF TABLES
(CONTINUED)

		Page
Table 24	Summary of biophysical habitat parameters for Goldstream River.	123
Table 25	Electroshocking results (a), as well as fish size and age data (b) for Goldstream River.	125
Table 26	Summary of biophysical habitat parameters for Nagel Creek.	138
Table 27	Electroshocking results (a), as well as fish size and age data (b) for Nagel Creek.	139
Table 28	Summary of biophysical habitat parameters for Soards Creek.	145
Table 29	Electroshocking results (a), as well as fish size and age data (b) for Soards Creek.	146
Table 30	Summary of biophysical habitat parameters for Mica Creek.	153
Table 31	Electroshocking results (a), as well as fish size and age data (b) for Mica Creek.	154
Table 32	Summary of biophysical habitat parameters for Nicholls Creek.	161
Table 33	Electroshocking results (a), as well as fish size and age data (b) for Nicholls Creek.	162
Table 34	Summary of biophysical habitat parameters for Park Creek.	168
Table 35	Electroshocking results (a), as well as fish size and age data (b) for Park Creek.	169
Table 36	Summary of biophysical habitat parameters for Pat Creek.	175

LIST OF TABLES
(CONTINUED)

		Page
Table 37	Electroshocking results (a), as well as fish size and age data (b) for Pat Creek.	176
Table 38	Summary of biophysical habitat parameters for Horne Creek.	182
Table 39	Electroshocking results (a), as well as fish size and age data (b) for Horne Creek.	183
Table 40	Summary of biophysical habitat parameters for Hoskins Creek.	189
Table 41	Electroshocking results (a), as well as fish size and age data (b) for Hoskins Creek.	190
Table 42	Summary of biophysical habitat parameters for Birch Creek.	196
Table 43	Electroshocking results (a), as well as fish size and age data (b) for Birch Creek.	197
Table 44	Summary of biophysical habitat parameters for Mars Creek.	201
Table 45	Electroshocking results (a), as well as fish size and age data (b) for Mars Creek.	202
Table 46	Summary of biophysical habitat parameters for Big Eddy Creek.	207
Table 47	Electroshocking results (a), as well as fish size and age data (b) for Big Eddy Creek.	208
Table 48	Summary of biophysical habitat parameters for Frisby Creek.	213
Table 49	Electroshocking results (a), as well as fish size and age data (b) for Frisby Creek.	214

LIST OF TABLES
(CONTINUED)

		Page
Table 50	Summary of biophysical habitat parameters for Pitt Creek.	219
Table 51	Electroshocking results (a), as well as fish size and age data (b) for Pitt Creek.	220
Table 52	Summary of biophysical habitat parameters for Seymour Creek.	225
Table 53	Electroshocking results (a), as well as fish size and age data (b) for Seymour Creek.	226
Table 54	Summary of biophysical habitat parameters for Bourne Creek.	232
Table 55	Cost estimate for the removal of Nagel Creek Waterfall.	249
Table 56	Standard costs and life expectancies for enhancement facilities.	250
Table 57	Expenditures from the Habitat Conservation Fund from 1981 to 1991.	251
Table 58	Estimated cost to build and monitor 2 adult trapping fences.	253
Table 59	Estimated cost for a juvenile out migration program.	254
Table 60	Cost to conduct water samples at 1 stream 3 times at one site.	256
Table 61	Estimated costs to complete intensive habitat inventories during low and high water flow regimes.	257

LIST OF PHOTOGRAPHS

		Page
Photo 1	A typical stretch of Scrip Creek within reach 1.	40
Photo 2	Sample site 2 in reach 3 of Scrip Creek (9.8 km upstream). Both rainbow and bull trout were captured in this section of stream.	40
Photo 3	Despite the apparent lack of cover, yearling bull trout were abundant at site 3 (reach 4) of Scrip Creek. No trout were captured in this section of stream.	41
Photo 4	Severe erosion is occurring along the banks at the mouth of Kirbyville Creek.	49
Photo 5	Reach 1 of Kirbyville Creek flows through a steep sided canyon where numerous eroding streambanks are common.	49
Photo 6	A typical example of reach 2 habitat on Kirbyville Creek.	50
Photo 7	The side channel sampled in reach 3 of Kirbyville Creek.	50
Photo 8	Reach 1 of Ruddock Creek. Good riparian and boulder cover provides rearing habitat for bull trout.	57
Photo 9	Bull trout density at sample site 2 of Ruddock Creek (6 km upstream) was amongst the highest of all sites surveyed.	57
Photo 10	Reach 3 of Carnes Creek has the best habitat within the system. Turbid water seen in the foreground of the photo is run-off from new road construction.	66
Photo 11	Cover in reach 1 of Kelly Creek is provided mainly by boulders and turbulent water.	66
Photo 12	A set of rapids near the outlet of Bigmouth Creek (centre of photo) may be a barrier when lake levels are low.	78

LIST OF PHOTOGRAPHS
(CONTINUED)

		Page
Photo 13	Long stretches of slow moving turbid water and some boulders near stream margins provided cover for both bull trout and whitefish captured at site 4, 13.5 km upstream.	78
Photo 14	Whitefish and bull trout were abundant in pool habitat within reach 5 of Bigmouth Creek.	79
Photo 15	Gravel dominated the substrate in reach 8 of Bigmouth Creek, although little off channel was present.	79
Photo 16	This stretch of Louis Lee Creek, near its confluence with Bigmouth Creek, was home to numerous bull trout yearlings.	80
Photo 17	Although steep in gradient, reach 1 of Big Fish Creek rises in a series of steps which facilitate upstream movement of bull trout.	80
Photo 18	The mouth of Argonaut Creek contains expansive gravel beds, although most of the gravel was compacted.	81
Photo 19	Despite its size and lack of cover, this small tributary entering Bigmouth Creek at km 13.5 had the highest concentrations of yearling bull trout of all sites sampled during field surveys.	81
Photo 20	Extensive logging has occurred on private land adjacent the lower 6 km of Bigmouth Creek, leaving little in the way of a green strip.	82
Photo 21	A constriction at the mouth of La Forme Creek has potential to collect debris, but is passable to fish migrating from Lake Revelstoke.	90
Photo 22	An old waterworks dam 5.0 km upstream on La Forme Creek may be a partial barrier to fish migration, although a small side channel (right of the structure) probably allows fish passage upstream.	90

LIST OF PHOTOGRAPHS
(CONTINUED)

		Page
Photo 23	A closer view of the dam shown in photo 39.	91
Photo 24	Healthy riparian vegetation and extensive surface ice provide good cover at site 3 (Reach 3) on La Forme Creek for rearing bull trout.	91
Photo 25	A series of chutes at km 16.5 of Downie Creek probably limits upstream access for all species of fish. The pictured chute is the largest of 3 in a short section of stream.	106
Photo 26	This chute is located approximately 100 m upstream of the chute in the preceding photo.	106
Photo 27	Reach 5 of Downie Creek flows through extensive alder marsh.	107
Photo 28	The narrow gorge in the first reach of Sorcerer Creek, contains 2 barriers within 100 m of each other. This 3 m falls, located 500 m upstream is the second barrier.	107
Photo 29	A downstream view of the massive logjam at km 8.3 of Sorcerer creek creates 2 and 2.5 high falls across the entire channel. Note the person standing in the middle of the photo.	108
Photo 30	This 2.5 m high logjam, located 650 m upstream of the Standard Creek mouth was the observed limit of kokanee migration, although it may be passable during high water.	108
Photo 31	Bull trout can easily migrate upstream through the stepwise pool and cascade sections in reach 2 of Standard Creek, although it is unknown if a barrier exists upstream of this area.	109

LIST OF PHOTOGRAPHS
(CONTINUED)

		Page
Photo 32	Culverts like the one shown here on an unnamed tributary (25.2 km upstream) are common to many Downie Creek tributaries. Such culverts may form a barrier to adult fish at high water, and likely restrict upstream movement of juvenile salmonids	109
Photo 33	This small unnamed tributary, which enters the Downie Creek mainstem at km 4.9, is still running despite a cold snap which has resulted in ice formations on many larger streams.	110
Photo 34	Unlike the small tributary in the preceding picture, Long Creek (entering Downie Creek at km 7.9) is almost completely frozen over with surface and anchor ice	110
Photo 35	Debris and slash was sidecast during road construction into Sorcerer Creek approximately 2.3 km upstream of the mouth.	111
Photo 36	The area beyond the gravel bar on the far side of Downie Creek has been proposed as a potential site for a spawning channel.	111
Photo 37	The falls at the mouth of the Goldstream River has a series of 3 drops, ranging from approximately 1.5 m to 4 m high. The pictured falls is about 3.0 m high.	128
Photo 38	Reach 5, like reach 2, of the Goldstream River meanders through alder marsh.	128
Photo 39	This chute and falls on Norman Woods Creek is located at km 2, the upstream end of this creek's canyon. It is unknown if other barriers exist downstream of this chute in the canyon.	129
Photo 40	The valley above the Norman Woods canyon broadens and stream gradient becomes reduced as the creek meanders through alder marsh.	129

LIST OF PHOTOGRAPHS
(CONTINUED)

		Page
Photo 41	Reach 5 of French Creek, like the upper reaches of Norman Wood Creek meanders through swamp. Extensive uncompacted gravel and undercut banks provide good salmonid habitat.	130
Photo 42	Camp Creek near the bridge crossing, 1 km upstream from its confluence with the Goldstream River. Underlying bedrock prevents scouring, so few deep pools have formed and little gravel is retained.	130
Photo 43	Placer activity, logging, and large fluctuation in flows have contributed to the condition of McCulloch Creek in reach 2.	131
Photo 44	Despite the condition of McCulloch Creek, the unconfined channel pictured here produced numerous yearling cutthroat trout.	132
Photo 45	The falls at the mouth of Nagel Creek.	140
Photo 46	Diverse cover is present in reach 4 of Nagel Creek, although substrate consists mainly of fines.	140
Photo 47	Reach 5 of Nagel Creek seen from the air, looking upstream.	141
Photo 48	The sample site at reach 5. Extensive gravel and low gradient provides good spawning habitat for salmonids.	141
Photo 49	This 6 to 8 m falls is located 370 m upstream of the mouth of Soards Creek.	147
Photo 50	Slow water near stream margins and good riparian cover provides reach 3 of Soards Creek with good rearing habitat for juvenile trout.	147
Photo 51	Side channel habitat in reach 4 of Soards Creek.	148

LIST OF PHOTOGRAPHS
(CONTINUED)

		Page
Photo 52	A 5 m falls located 9.5 km upstream divides the upper and lower halves of Soards Creek. The area above this second falls was not surveyed.	148
Photo 53	Bull trout were observed attempting to jump this 2.5 m falls located approximately 650 m upstream on Mica Creek.	155
Photo 54	Extensive frazzle, anchor and surface ice made sampling at reach 3 of Mica Creek difficult, and reduced available habitat for rearing bull trout.	155
Photo 55	A drainage ditch which parallels the highway near the mouth of Mica Creek could be made into a spawning channel.	156
Photo 56	A large pool between the highway and the mouth of Nicholls Creek probably provides good rearing habitat for salmonids. Note the extensive floating debris in the proximity of submerged culverts.	163
Photo 57	Numerous small barriers exist in reach 2 of Nicholls Creek, but this 5 m falls, located 2 km upstream, is a definite migrational impasse to lake resident fish.	163
Photo 58	Rearing habitat in reach 3 of Nicholls Creek is supplemented by LOD and pool cover.	164
Photo 59	This 2 m high debris jam at the mouth of Park Creek is accessible, and could be easily removed.	170
Photo 60	A broad uncontained flood plain with extensive cobble and boulder substrate suggests Park Creek is subject to large fluctuations in discharge.	170
Photo 61	This 10 m falls (est.), approx. 4.0 km upstream at the top end of the canyon, is the last and largest of many barriers encountered on Pat Creek.	177

LIST OF PHOTOGRAPHS
(CONTINUED)

		Page
Photo 62	Deep pools, extensive gravel substrate and large accumulations of LOD provide reach 3 of Pat Creek with good spawning and rearing habitat.	177
Photo 63	Reach 4 of Pat Creek has a slightly higher gradient, but still provides good habitat for resident rainbow trout.	178
Photo 64	This 6 m falls (est.) is one of 3 obstructions to fish migration on Horne Creek, located between 800 and 850 m upstream (Note the 1.7 m high dip net at the right of the photo).	184
Photo 65	Looking upstream at Horne Creek valley towards site 3.	184
Photo 66	This 5 m high x 35 m chute, preceded by a 2.5 m falls, represents the upstream limit of migration into Hoskins Creek for lake resident fish.	191
Photo 67	Reach 2 of Hoskins Creek is short in length but has good habitat.	191
Photo 68	Stream gradient becomes steeper upstream of the barrier on Hoskins Creek, but off channel habitat and boulders provide refuge for resident bull trout population.	192
Photo 69	Logging on private land has left reach 1 of Hoskins Creek with no green strip, but alder scrub still affords some cover for rearing fish.	192
Photo 70	This 2.5 m high debris jam is one of numerous obstructions encountered within the first 2.8 km of the Mars Creek mouth.	203
Photo 71	A short gorge 2.5 km upstream has a gradient of approximately 17.5%, and probably presents an impassable barrier to migrating fish. No fish were captured upstream of this gorge.	203

LIST OF PHOTOGRAPHS
(CONTINUED)

		Page
Photo 72	A 7 m falls located 270 m upstream of the mouth of Big Eddy Creek.	209
Photo 73	Looking upstream through sample site 3 of Big Eddy Creek, 2.2 km upstream. Side channels have good pool and riparian cover.	209
Photo 74	This 25 m falls (est.) at the mouth of Frisby Creek prevents fish access to upstream areas.	215
Photo 75	Reach 2 of Frisby Creek had the best habitat within this system, although only sculpins were captured here.	215
Photo 76	LOD and large substrate provide suitable for cover resident rainbow trout rearing in reach 2 of Pitt Creek, but numerous barriers and a steep gradient restrict upstream movement of lake resident spawners. The dip net in the centre of the photo is 1.7 m high.	221
Photo 77	A 2 m falls marks the start of a steep, narrow gorge located in reach 2 of Seymour Creek. It is unlikely fish can migrate past this gorge.	227
Photo 78	Numerous barriers in reach 1 of Seymour Creek prevent lake resident fish from migrating upstream.	227
Photo 79	Partially plugged culverts at the mouth of Seymour Creek may limit access of lake resident fish into this stream. Similar to Nicholls Creek, a small pond has formed between the submerged culverts and the mouth of Seymour Creek.	228
Photo 80	This 5 m falls at km 1.16 is the last of three barriers on Bourne Creek which start at km 0.2.	233
Photo 81	Excellent habitat is located upstream of barriers, in reach 3 of Bourne Creek.	233

LIST OF APPENDICES

Appendix 1	A photographic catalogue of sample sites of all streams surveyed during the Revelstoke Lake tributary assessment in the fall of 1991.
Appendix 2	Data compiled on stream survey forms.
Appendix 3	Hydrological data for Lake Revelstoke area tributaries.
Appendix 4	Mean lengths, weights, and condition factors of all fish sampled during bio-physical surveys of Lake Revelstoke tributaries. Ages are included for fish from which scales were taken.

1.0 INTRODUCTION

In an effort to mitigate the loss of sports fish stocks in Revelstoke Lake, Triton Environmental Consultants Ltd. was retained by the Mica Technical Committee (comprised of B.C. Hydro and Ministry of Environment officials) to conduct bio-physical assessments and evaluate enhancement potential of tributaries entering Lake Revelstoke.

Both the Columbia River mainstem and tributary habitat utilized by spawning and rearing sports fish species within the Columbia River and migrating from the Arrow Lakes was lost with the creation of Revelstoke Lake (reservoir) in 1984 (Mason, 1985; Lindsay, 1977; Martin 1976; and ERC 1974). These species include kokanee, bull trout, rainbow trout, burbot, mountain whitefish plus other non-sports species. Some streams, such as Downie, Bigmouth, Carnes, Scrip, Hoskins, and La Forme Creek still do provide substantial amounts of available habitat to species migrating from the Revelstoke Lake reservoir.

Reduced recruitment of spawners due to the migrational barriers formed by the Revelstoke and Mica Dams, has resulted in an overall reduction in sports fish species, particularly rainbow trout and white fish, present in Lake Revelstoke (Fleming and Smith in prep.). This reduction is compounded by a change from a riverine to reservoir type habitat and the associated changes in water quality and temperature regime common to run-of-the river type reservoirs (Hirst 1991).

Degradation of remaining available spawning and rearing habitat in streams tributary to Revelstoke Lake is an ongoing process, primarily due to past and present resource use activities such as logging and mining. Recreational fishing has created additional pressure upon the remaining stock of sports fish within Revelstoke Lake.

The specific objectives of this project were to:

1) Assess and document habitat within streams tributary to Lake Revelstoke,

2) Investigate opportunities for enhancement for spawning and/or rearing of adfluvial (lake resident), fish (primarily kokanee, bull trout and rainbow trout) and,

3) Investigate opportunities for enhancement for stream resident stocks such as rainbow and cutthroat trout.

Most of the field work for this project began in late September and continued through to November 1, 1991. Two streams, Nagel and Birch Creeks were assessed in July to determine the feasibility of removing barriers by local members of the Revelstoke Rod and Gun Club on these streams prior to kokanee spawning in the fall. Creating additional kokanee spawning habitat by placement of gravel at the base of Mica Dam was also addressed during this field trip. Two interim reports, Field Assessment and Enhancement Possibilities for Nagel and Birch Creeks and the Mica Tailrace and Estimates of Costs for Enhancement Possibilities for Nagel and Birch Creeks and the Mica Dam Tailrace, (prepared for the Mica Fisheries Technical Committee by Triton Environmental Consultants Ltd.) summarize the results of the July field trip.

2.0 STUDY AREA

Lake Revelstoke, part of the Columbia River system, is a run of the river Reservoir with a flushing rate of approximately 4.2 times/year (Smith 1990). It is located in south eastern British Columbia, near the town of Revelstoke. The 128 km long lake was created in 1984, after the completion of B. C. Hydro's Revelstoke Dam and is situated between the previously created Kinbasket (north) and Arrow Lakes (south) reservoirs. Over 40 tributaries enter the Columbia River within the area which was eventually impounded. Most are of steep gradient and have some form of barrier within the first few hundred m of their confluence with the reservoir. Twenty three of these streams were surveyed during the course of field work (Fig. 1).

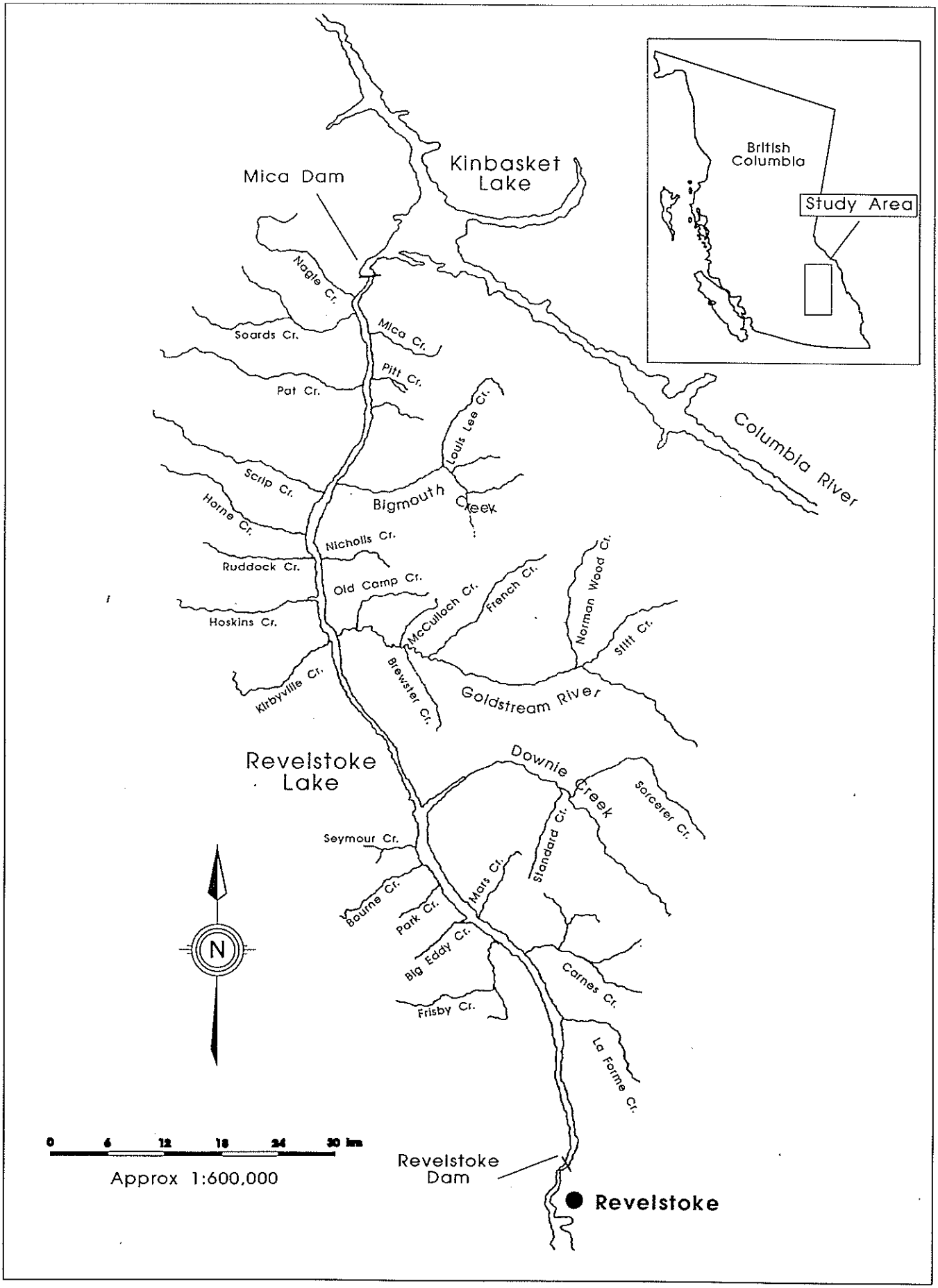


Figure 1: Streams Surveyed During Revelstoke Tributary Assessement

3.0 METHODS

Tributary survey sites were usually accessed via foot or vehicle. Some of the streams on the east and west side of Lake Revelstoke were accessible by vehicle, but ferries (operated by the local logging firms) were necessary to transport the vehicle to west side tributaries. Often, a combination of vehicular transport and hiking was employed to reach the mid-reaches of a stream. Where road systems did not exist, streams were first accessed by a 16 ft Lund outboard, and then hiked. A helicopter was used to access the upper reaches of selected tributaries on October 30, 31 and November 1. Sample sites and corresponding upstream distance was measured by hipchain and/or vehicle odometer, or in the case of the helicopter, by observations of landmarks seen from the air and verified on a 1:50,000 topographic map.

3.1 Physical Studies

3.1.1 Survey Sites

Physical studies were limited to in situ measurements of bio-physical parameters outlined in the Fish Habitat Inventory & Information Program's Stream Survey Form (Fig. 2). Data collected during stream surveys includes gradient, average channel and wetted width, percent cover and cover type, substrate material, stream bank characteristics, average water velocity and water temperature. One Stream Survey Card was filled out at each sample site.

Photographs were taken of survey sites, barriers as well as other physical and biological parameters encountered during field studies. Some photos are included in the text, however, a complete catalogue of photos taken are provided in appendix 1, volumes 1 and 2.

Data collected on stream survey cards were used to estimate total wetted areas within reaches, from which total substrate type, total cover etc. was calculated. The scope of this project permitted only one sample site within individual reaches of most streams surveyed. Individual stream survey cards are summarized in appendix 2.

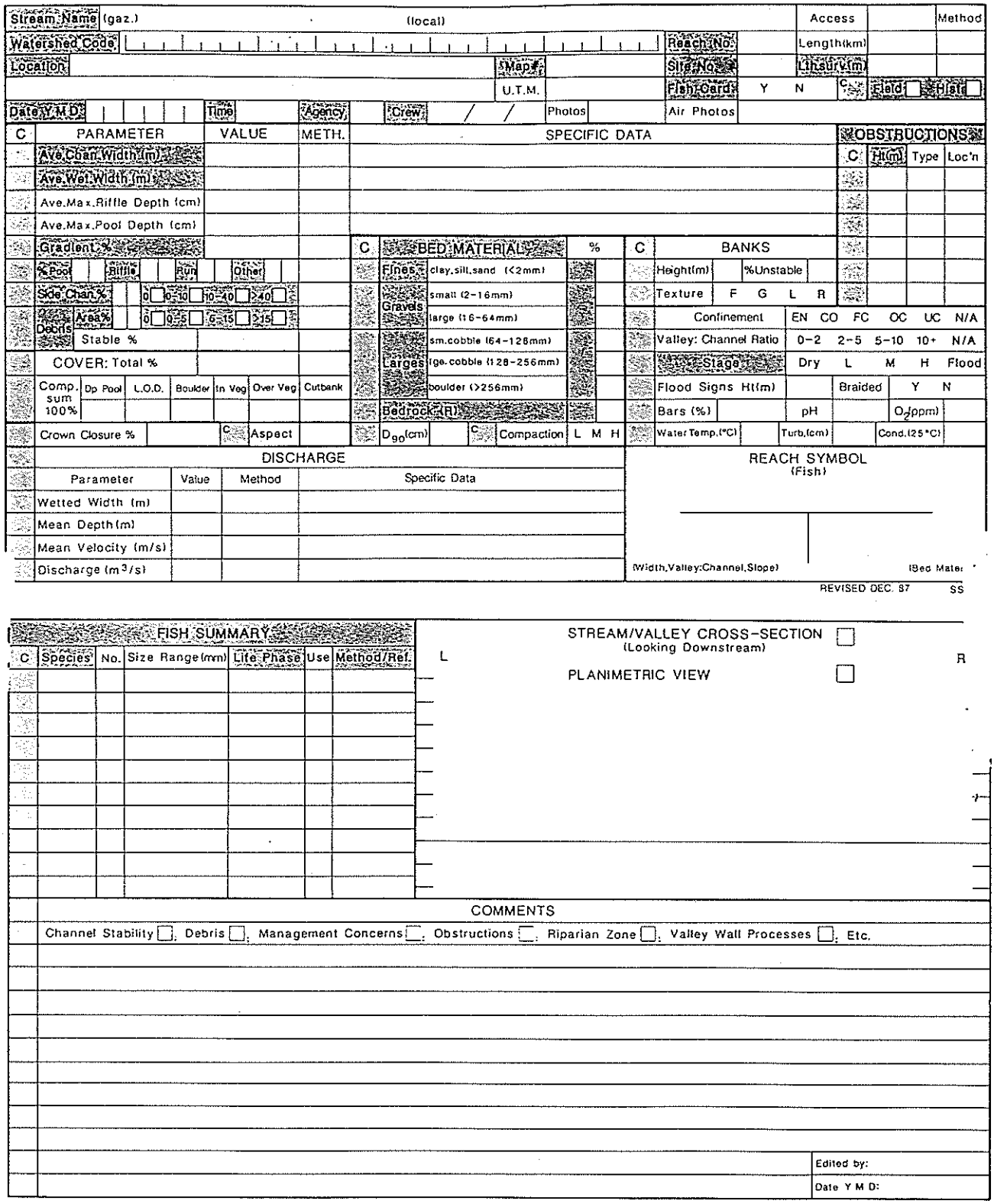


Figure 2: Stream survey cards used during assessments of Revelstoke Lake tributaries.

Sample sites were selected from different reaches (areas of similar gradient and habitat) within each stream, however, not every reach was sampled. Larger streams were generally sampled more frequently than smaller streams. Tributaries of larger streams were also sampled, but, similar to mainstem sampling, the number of survey sites for tributaries of these streams varied depending on the size of the tributary; small tributaries were usually sampled at only one site whereas large tributaries were sampled more frequently.

3.1.2 Data Compilation

Data collected on the Stream Survey Forms was complied into a dBASE-4 formatted data base, provided by the Ministry of Environment. A key code was assigned to each Stream Survey Form as a reference to the information compiled from individual sites and linked to the computerized mapping program QUIK-MAP. These sites were then plotted into existing digitized maps depicting the tributaries of Lake Revelstoke, also known as bluelines.

3.1.3 Hydrology

Hydrological analysis was conducted on streams entering Revelstoke Lake to provide estimates of mean monthly discharge. Data collected from stream discharges was incorporated into the development of a model to predict monthly discharges for each creek sampled.

Most study area streams have no hydrological record, thus, it was necessary to develop estimation techniques to provide the required information. The analysis was conducted by assessing regional hydrological characteristics, as determined by analysis of published data. Following this assessment, appropriate prediction models were developed for the estimation of discharges on ungauged streams in the study area. On the basis of discharge measurements performed during the summer and fall of 1991, these predictions were checked on 14 study area streams.

Based on initial evaluation of the records of 20 hydrological stations in the upper Columbia watershed operated by the Water Survey of Canada (WSC - a department of Environment Canada), a short list of 6 stations most relevant to the study area was determined. These stations, and relevant characteristics of each, are listed in

Table 1. Station locations are shown on Figure 3. Drainage areas of these 6 predictor stations range from 112 to 1170 km^2. The group includes 3 stations located on study area streams: Kirbyville Creek, Goldstream River, and Downie Creek. Record lengths range from 17 to 37 years.

Mean monthly runoff (i.e. discharge per unit area) for these 6 stations was plotted against drainage area for each of the 12 months of the year. For each month, the most appropriate mathematical model representing the data was determined through visual and statistical analysis. With the exception of Kirbyville, Goldstream, and Downie Creeks (for which actual hydrological records were used), monthly flows on study area streams were estimated on the basis of the most appropriate mathematical model representing the regional data.

Monthly discharge estimates were checked by comparing them with measured discharges on 14 streams in the study area, which were measured using a Swoffer model 2100 current meter, following standard methodology (Terzi, 1981). In evaluating this comparison, consideration was given to the flows recorded at nearby Water Survey of Canada stations on the same days as the measurements were made on study area streams.

3.2 Biological Studies

Electroshocking was the predominant method used to capture fish during stream surveys. Total shocking time was recorded so relative effort could compared between sites in the form of fish captured/sec. Only one pass was made at each electrofishing site. Area shocked was also measured to provide an estimate of $fish/m^2$. Electrofishing would normally encompass the entire cross-section of a stream within a sample area, except where currents were too fast and/or where water was too deep. In such cases, one or both stream margins within the sample area was shocked. Electrofishing always proceeding in an upstream to downstream direction. All fish captures as well as fish observations (escapees) were documented.

Where the physical characteristics of a site precluded the use of an electroshocker (usually sites which were too deep or too turbid), minnow traps and/or beach seines were utilized to obtain fish samples. All fish captured were weighed to the nearest

Table 1: Regional hydrological stations used to estimate monthly flows for Revelstoke Lake tributaries

Station Name	Station Number	Drainage Area (km^2)	Period of Record
Illecillewaet R. at Greeley	08ND013	1170	1963-present
Incommapleux R. near Beaton	08NE001	1020	1914, '15, '52-present
Goldstream R. below Old Camp Cr.	08ND012	938	1955-'57, '63-present
Downie Cr. near Revelstoke	08ND009	655	1953-'83
Jordan R. above Kirkup Cr.	08ND014	272	1963-'88
Kirbyville Cr. mear the Mouth	08ND019	112	1973 - present

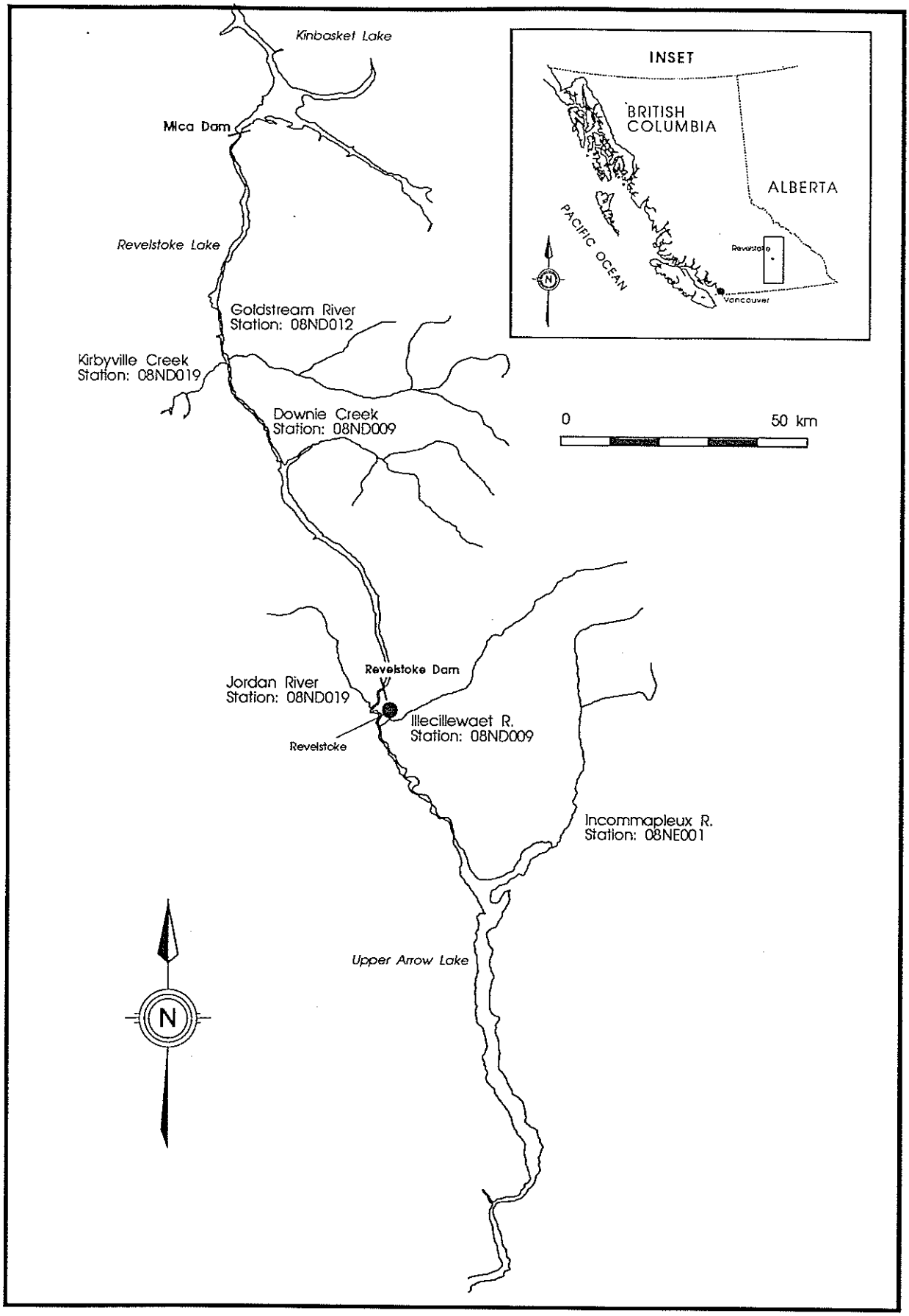


Figure 3: Locations of streams with hydrological stations (WSC) used to estimate monthly discharges for Lake Revelstoke tributaries.

0.01 g, and measured to the nearest mm. Scales were also taken from the right and left sides of randomly selected samples. Scale analysis was conducted in the lab, however, not all scales were readable.

Selected specimens sampled from various sites were preserved in a 5% formalin 95% water solution to provide a catalogue of species found in those streams surveyed.

4.0 RESULTS

4.1 Fish

An overview of rainbow and bull trout sampled during stream surveys is presented in this section, whereas detailed information regarding the results of fish sampling for specific streams is included in individual stream descriptions in section 4.3.

Nine species of fish were sampled from tributaries entering the Revelstoke Lake, including:

Bull trout	(*Salvelinus confluencus*)
Rainbow trout	(*Oncorhynchus mykiss*)
Yellowstone cutthroat trout	(*Oncorhynchus clarkii*)
Kokanee	(*Oncorhynchus nerka*)
Mountain whitefish	(*Prosopium williamsoni*)
Lake chubb	(*Couesious plumbeus*)
Cottids	
Torrent sculpin	(*Cottus rhotheus*)
Slimy sculpin	(*C. cognatus*)
Bridgelip Sucker	(*Catostomus columbianus*)

The most commonly sampled species were bull trout and rainbow trout, constituting 75% of all fish sampled (Table 2). Certain species, such as the lake chub, the bridgelip sucker and yellowstone cutthroat trout were found only in the Goldstream river. It should be noted that schools of kokanee and white fish were observed, but no fish were captured from these schools, hence no samples were taken.

Very few adult fish were captured during sampling. Most of the fish sampled were rearing juveniles. The mean size of bull trout sampled was 109 mm and 110 mm for rainbow trout. This may reflect the inefficiency of electroshocking as a method to capture adult fish, however, large (presumably adult) fish were occasionally captured although seldom seen escaping. Large fish should be noticed during shocking even if they were able to escape, however, such observations were infrequent.

Table 2: Mean lengths, weights and ranges of all fish sampled during surveys of tributaries entering Revelstoke Lake in the fall of 1991.

SPECIES	MEAN LENGTH (mm)	RANGE (mm)	MEAN WEIGHT (g)	RANGE (g)	N	% of OF N
BT	109	31 - 283	21.28	0.25 - >120.00	224	55.0%
RBT	110	29 - 380	24.41	0.23 - >120.00	86	21.1%
WF	100	44 - 238	19.06	1.09 - >120.00	35	8.6%
CC	83	25 - 110	7.20	0.12 - 13.61	27	6.6%
LKC	56	30 - 77	2.33	0.26 - 6.49	19	4.7%
CT	137	98 - 229	32.14	9.22 - >120.00	11	2.7%
KO	343	331 - 332	>120.00	-	4	1.0%
SKR	131	-	28.51	-	1	0.2%

Species:

BT = bull trout
RBT = rainbow trout
CC = cottid
CT = rainbow trout
WF = mountain whitefish
KO = kokanee
LKC = lake chuub
SKR = sucker

Table 3: The mean weights, lengths, and condition factors of various ages classes of bull trout sampled from above and below barriers, as well as for all aged fish samples.

CATAGORY	AGE CLASS (yrs)	MEAN WEIGHT (g)	RANGE (g)	MEAN LENGTH (mm)	RANGE (mm)	MEAN CONDITION (K)	Range	N
above	0+	6.25	5.96 - 6.53	87	86 - 87	0.96		3
below	1+	12.63	6.61 - 25.16	108	81 - 142	0.96	0.72 - 1.24	27
above		16.98	8.16 - 28.79	116	94 - 146	0.98	0.93 - 1.05	9
overall		**13.01**	**6.61 - 28.79**	**109**	**81 - 146**	**0.97**	**0.72 - 1.24**	**36**
below	2+	34.23	14.15 - 85.41	156	116 - 199	0.94	0.77 - 1.20	28
above		28.44	21.9 - 36.54	144	130 - 158	0.93	0.92 - 1.05	6
overall		**33.59**	**14.15 - 85.41**	**150**	**116 - 158**	**0.94**		**34**
below	3+	63.35	21.4 - >120	179	103 - 241	1.08	0.81 - 1.96	12
above		59.49	41.65 - 82.44	182	163 - 202	0.97	0.83 - 1.06	9
overall		**61.70**	**21.4 - >120.00**	**180**	**103 -241**	**1.03**	**0.81 - 1.96**	**21**
below	4+	111.85	100.69 - >120.00	241	213 - 283	0.88	0.81 - 1.96	3
above		103.51	-	211	-	1.10	-	1
overall		**109.76**	**100.69 - >120.00**	**234**	**211 - 283**	**0.94**	**0.81 - 1.96**	**4**

Table 4: The mean weights, lengths, and condition factors of various ages classes of rainbow and cutthroat trout sampled from above and below barriers, as well as for all aged fish samples

CATAGORY	AGE CLASS (yrs)	MEAN WEIGHT (g)	RANGE (g)	MEAN LENGTH (mm)	RANGE (mm)	MEAN CONDITION (K)	Range	N
	Rainbow Trout							
above	0+	3.12	-	63	-	1.25	-	1
below	1+	13.91	8.26 - 24.04	97	90 - 105	1.63	0.94 - 3.30	4
above		12.86	4.41 - 18.26	104	73 - 125	1.11	0.93 - 1.24	7
overall		**13.01**	**4.41 - 24.04**	**108**	**73 - 105**	**0.97**	**0.93 - 3.30**	**11**
below	2+	24.51	9.67 - 39.33	125	90 - 145	1.21	1.03 - 1.53	9
above		28.28	14.00 - 52.00	131	108 - 146	1.20	0.97 - 1.32	7
overall		**26.00**	**9.67 - 39.33**	**128**	**90 - 146**	**1.20**	**0.97 - 1.52**	**16**
below	3+	46.58	24.71 - 76.12	156	129 - 183	1.19	0.92 - 1.36	8
above		53.50	-	158	-	1.36	-	1
overall		**46.58**	**24.71 - 53.50**	**156**	**129 - 183**	**1.19**	**0.92 - 1.36**	**9**
below	4+	110.16	-	211	-	1.16	-	1
above		111.00	-	209	-	1.22	-	1
overall		**110.58**	**110.16 - 111.00**	**210.00**	**209 - 211**	**1.19**	**1.16- 1.22**	**2**
below	5+	>120	-	234	-	0.94	-	1
	Cutthroat Trout							
above	1+	19.83	15.77 -25.63	122	112 - 132	1.08	0.96 - 1.17	5
above	2+	89.04	58.07 - >120.00	204	735	1.01	1.00 - 1.03	2

Scale samples were taken from bull, rainbow and cutthroat trout as well as whitefish, although not all scales were readable. Results of scale analysis show an age range of 0+ to 4+ for bull trout and 0+ to 5+ for rainbow trout within the tributaries sampled (Table 3 and 4).

4.1.1 Resident versus non-Resident fish

A common problem encountered during tributary sampling was determining if rainbow and bull trout were stream or lake resident stocks. Determining whether observed obstructions in some tributaries, such as Mars, Downie and Mica Creeks were actually barriers to fish migration is a difficult task. In other instances, historical data which suggested resident populations of fish (such as for rainbow trout found in Kirbyville Creek) may have been based on subjective rather than objective observations.

Scales were examined from fish which were captured above and below barriers to determine if differences existed in patterns between what were presumed as resident (above barriers) and non resident (below barriers) fish. Intraspecific differences in scale patterns, such as the number and mean width of both summer circulli and winter annuli, may be used to distinguish allopatric populations when environmental conditions affecting productivity are large enough to cause unique seasonal growth patterns in scales typical of each population.

Unfortunately, there was insufficient scale samples to make valid comparisons. For example, the scales studied from La Forme, Kirbyville and Downie Creeks in the best case, provided only 4 individuals of the same age class from each of the alternate habitats to be compared within each species. Measurements of the summer circulli and winter annuli for these samples showed wide overlap between the individuals from the different habitats within each stream. Samples were not large enough in most cases for statistical cortisones to be made with respect to the mean numbers and widths of circulli. No significant difference was noted in cases where a statistically minimum number (N=4) of samples were available. Statistical analysis not withstanding, no qualitative visual characteristics were observed that could be readily used to identify fish as originating from a specific stream environment.

Comparisons between mean lengths and weights of resident and non resident bull and rainbow trout shows little variation between age classes within these populations (Table 3 and 4). Histograms comparing age to lengths and weights for rainbow and bull trout show a large amount of overlap between presumed resident and non resident fish of each species (Fig. 4, 5, 6, 7).

Scott and Crossman (1973) state bull trout reach sexual maturity between 3 to 6 years of age. Similarly, rainbow trout usually mature between 3 and 5 years of age, although males often mature earlier than females. Ford et. al.(1992) reports bull trout may rear in streams as long as 3 or 4 years. Rainbow trout migrate from natal streams within 1 to 3 years of hatching (Scott and Crossman, 1973). Cold water streams, such as those sampled during the Revelstoke tributary survey, might be expected to have slower growth rates and perhaps older ages of maturity than warm water systems.

Considering these facts, it appears very few fish sampled from Revelstoke Lake Tributaries had reached sexual maturity, suggesting most were still rearing. This further complicates determining if fish are stream resident or not.

Age criteria, combined with the presence of an obvious migrational barrier, is likely the best means of determining if fish captured within the tributaries sampled this year are resident or non-resident.

4.2 Hydrology

With the exception of the months of June, July, October, and November, little trend in the monthly runoff data is apparent. Therefore the mean value of the monthly runoff was used for estimation of values on ungauged streams. For June, July, October, and November, trends in the data are apparent, and models incorporating these trends were developed. The estimation models for each month are presented in Table 5.

Estimated monthly discharges for study area streams are presented in Table 6. Values for Kirbyville Creek, Goldstream River, and Downie Creek have been made on the basis of the recorded database at these sites. For Downie Creek, the data have been prorated from the site of the old WSC station (now drowned by Lake

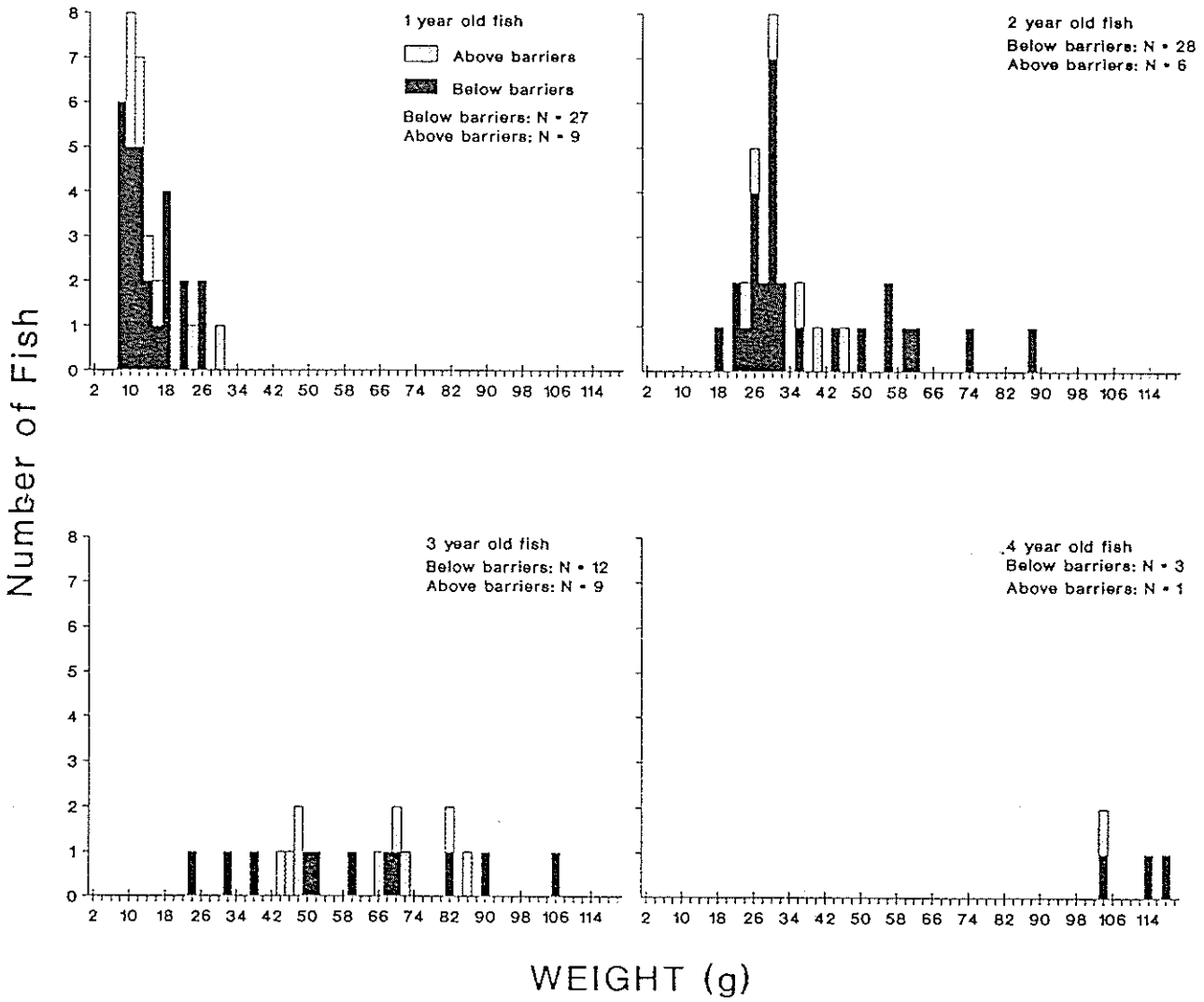


Figure 4: Histograms showing the age/weight relationships for 1, 2, 3, and 4 year old bull trout from above and below barriers on tributaries entering Revelstoke Lake.

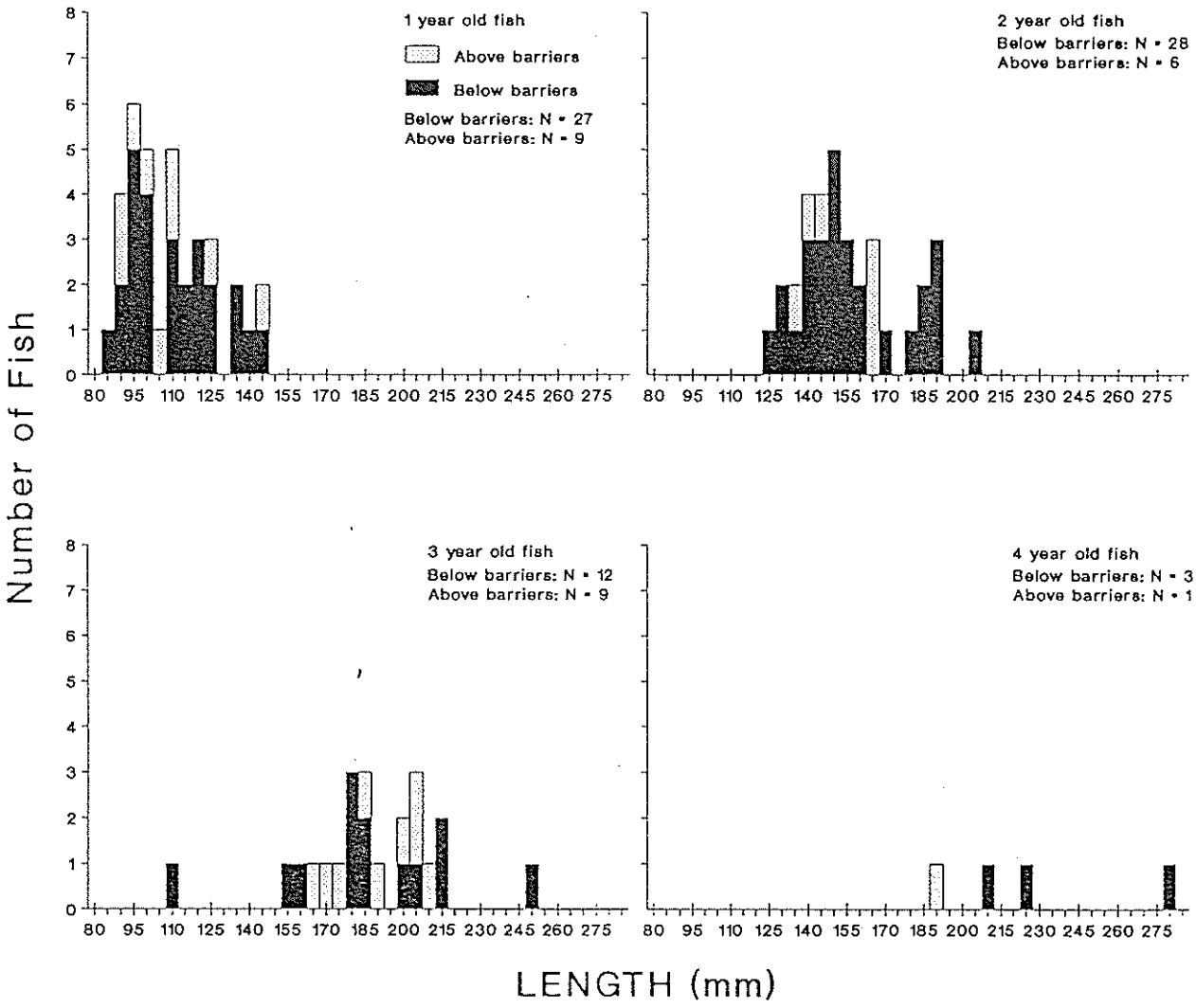


Figure 5: Histograms showing the age/length relationships of bull trout captured from tributaries entering Revelstoke Lake.

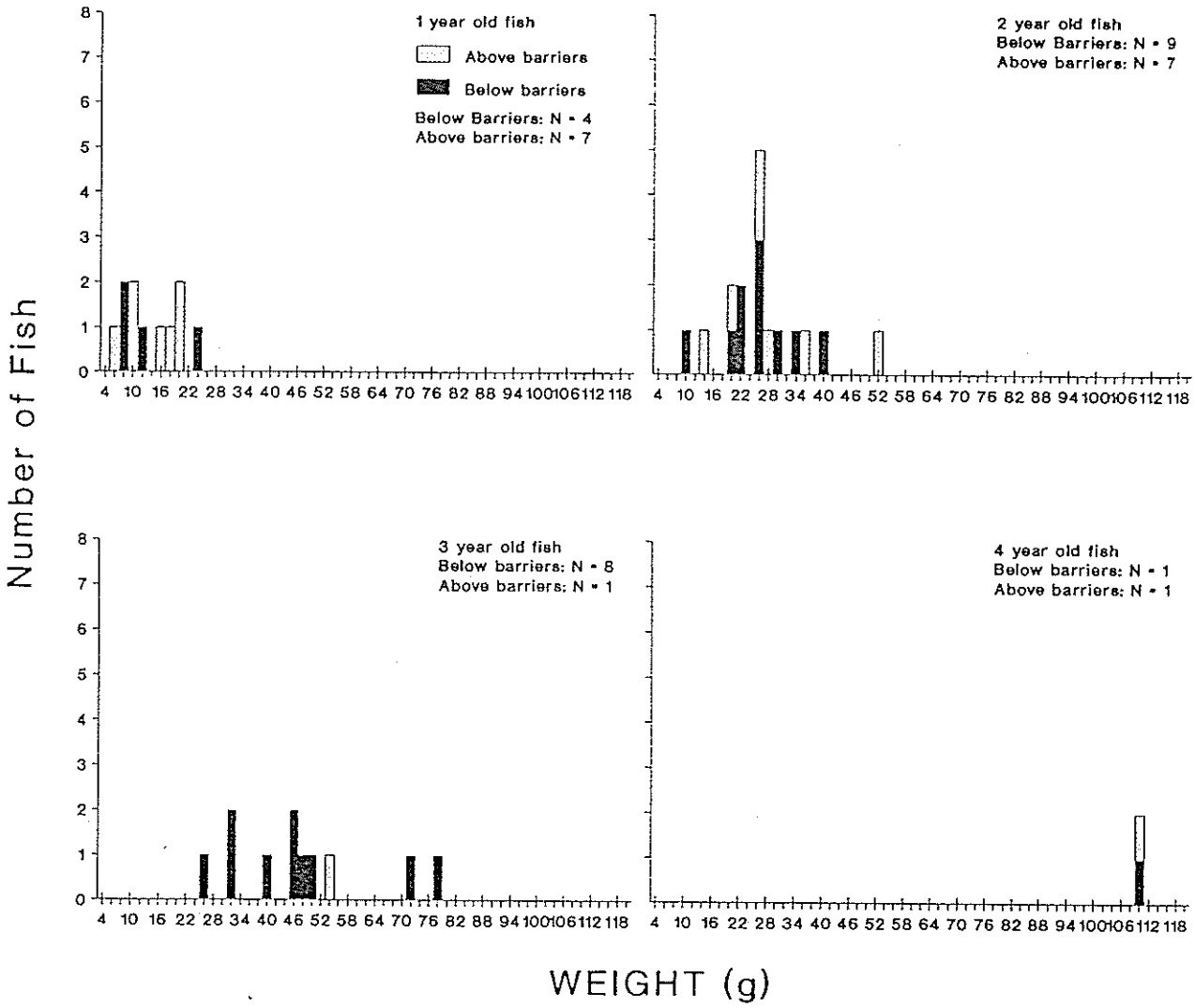


Figure 6: Histograms showing the age/weight relationship for 1, 2, 3, and 4 year old rainbow trout captured above and below barriers on tributaries entering Revelstoke Lake.

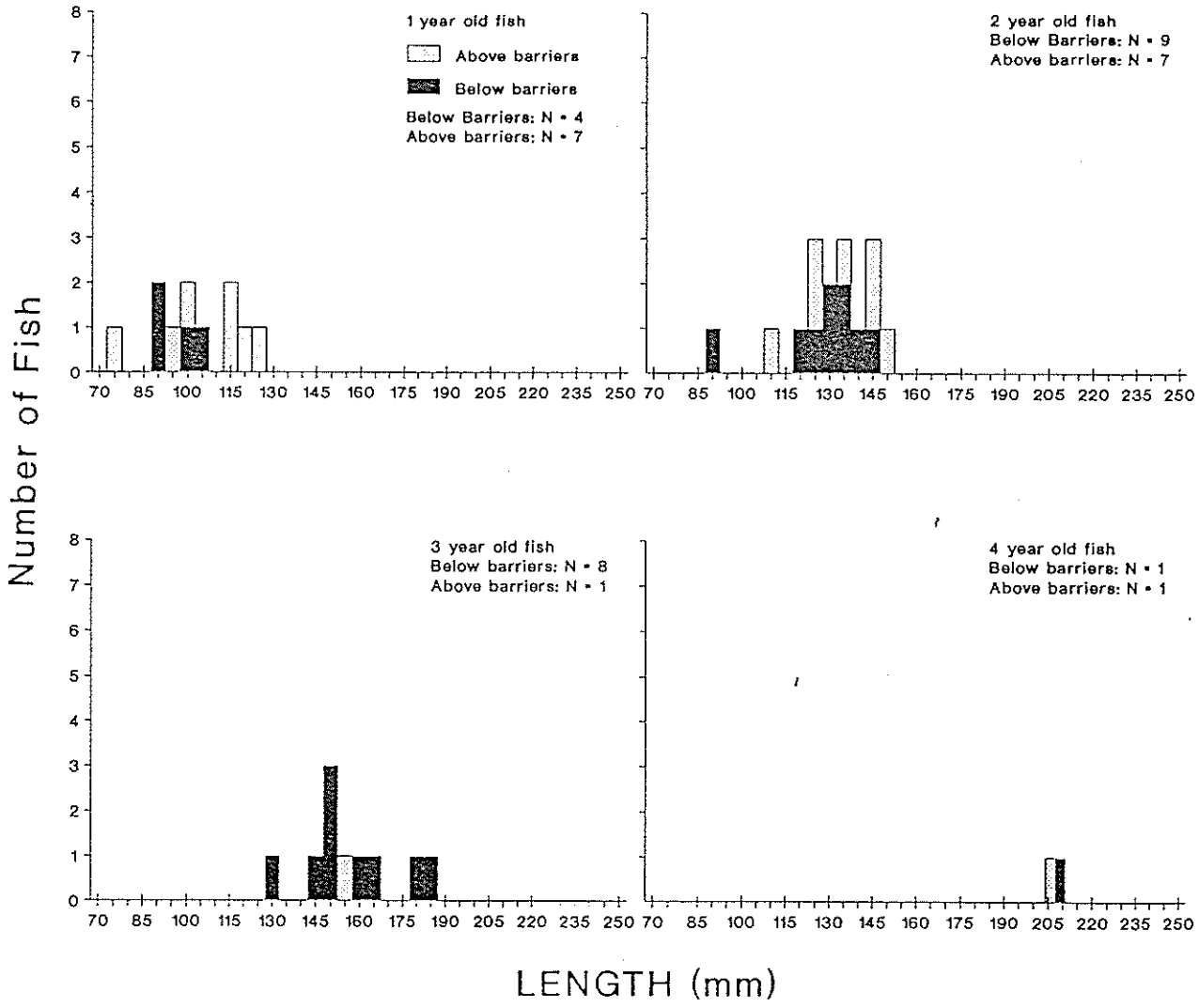


Figure 7: Histograms showing th age/length relationships for 1, 2, 3, and 4 year old rainbow trout captured above and below barriers on tributaries entering Revelstoke Lake.

Table 5: Estimation models developed for estimation estimation of monthly dicharge on ungauged study area streams.

Month	Log Runoff Runoff (L/s/km^2)
January	0.92
February	0.87
March	0.93
April	1.38
May	1.96
June	2.44 - 0.09 [log10(drainage area)]
July	2.36 - 0.09 [log10(drainage area)]
August	1.87
September	1.67
October	1.79 - 0.12 [log10(drainage area)]
November	1.68 - 0.14 [log10(drainage area)]
December	1.05

The above models are valid when drainage area is expressed in units of square km.

Table 6: Estimated mean monthly discharge for 17 of 23 Revelstoke Lake Tributaries

Watershed	Area (km^2)	Jan (m^3/s)	Feb (m^3/s)	March (m^3/s)	April (m^3/s)	May (m^3/s)	June (m^3/s)	July (m^3/s)	Aug (m^3/s)	Sept (m^3/s)	Oct (m^3/s)	Nov (m^3/s)	Dec (m^3/s)	Mean Annual (m^3/s)
Goldstream R*	934	6.65	6.13	6.60	17.20	69.30	128.00	104.00	58.10	34.00	21.00	14.20	8.85	39.20
Downie Ck.*	605	5.08	4.45	4.65	12.75	48.89	83.91	71.80	42.69	25.69	16.54	11.37	7.35	28.00
Bigmouth Ck.	591	4.92	4.38	5.03	14.18	53.89	91.64	76.23	43.81	26.40	16.94	11.58	6.63	29.66
Carnes Ck.	224	1.86	1.66	1.91	5.38	20.44	37.93	31.55	16.62	10.01	7.22	5.03	2.52	12.28
Scrip Ck.	161	1.34	1.20	1.37	3.87	14.72	28.13	23.40	11.97	7.21	5.41	3.79	1.81	9.10
Nagle Ck.	157	1.30	1.16	1.33	3.76	14.30	27.41	22.80	11.63	7.01	5.27	3.70	1.76	8.87
Horne Ck.	122	1.02	0.91	1.04	2.93	11.16	21.86	18.18	9.07	5.46	4.24	2.99	1.37	7.07
Kirbyville Ck.*	110	0.92	0.80	0.93	2.16	9.00	17.30	16.40	8.89	6.54	4.67	2.53	1.25	5.98
Hoskins Ck.	105	0.87	0.78	0.89	2.52	9.57	19.01	15.81	7.78	4.69	3.70	2.62	1.18	6.15
La Forme Ck.	80	0.66	0.59	0.68	1.91	7.27	14.81	12.32	5.91	3.56	2.91	2.07	0.89	4.79
Bourne Ck.	71	0.59	0.53	0.60	1.70	6.46	13.30	11.06	5.25	3.17	2.62	1.87	0.80	4.30
Ruddock Ck.	68	0.57	0.51	0.58	1.64	6.24	12.88	10.71	5.07	3.06	2.54	1.81	0.77	4.17
Seymour Ck.	42	0.35	0.31	0.36	1.01	3.83	8.26	6.87	3.11	1.88	1.65	1.19	0.47	2.67
Nicholls Ck.	42	0.35	0.31	0.36	1.01	3.82	8.25	6.86	3.11	1.87	1.65	1.19	0.47	2.67
Park Ck.	35	0.29	0.26	0.30	0.85	3.23	7.07	5.88	2.62	1.58	1.42	1.03	0.40	2.29
Birch Ck.	29	0.24	0.21	0.24	0.69	2.61	5.83	4.85	2.12	1.28	1.18	0.86	0.32	1.89
Pitt Ck.	8	0.07	0.06	0.07	0.19	0.71	1.79	1.49	0.58	0.35	0.38	0.28	0.09	0.58

* - based on recorded flow
All others estiated: June, July, Oct. , Nov., - usining regional trend,
All other months using average of regional values.

Revelstoke) to the current mouth of the creek. Hydrographs for study area streams are presented in Appendix 3.

Measured discharges on study area streams during summer and fall 1991 are presented in Table 7. With the exception of Nagel Creek on July 4, all measured values are lower than the estimated means for the respective month. These results were compared with data obtained at the four WSC stations of the group of six predictor stations operating on these dates (Kirbyville Creek, and Illecillewaet, Incommapleux, and Goldstream Rivers). The measured data are consistent with data obtained at these WSC stations, and confirm the suitability of the monthly estimation methods developed for the months of July, September, and October. This result suggests that the estimation models developed from regional data provide reliable estimates for study area streams.

4.3 Logging

Logging comprises an important part of the regional economy of the Revelstoke Lake area and most of the tributaries surveyed either showed signs of past logging or were being actively logged. Of the 23 tributaries surveyed, only La Forme Creek, had no previous or active logging occurring within its watershed, although many tributaries have only had limited logging within their drainages, such as near their outlets, to date. Specifics of logging within the watersheds surveyed are present in Section 4.4.

Records summarizing the extent of past logging within tributaries to Revelstoke Lake are not readily available. Some maps depicting harvested cutblocks were reviewed, but most of the information presented in this text concerning past logging activities within individual watersheds is based on field observations.

Three companies, Downie Street Sawmills, Westar and Joe Kozak Sawmills Ltd, plus a government administered small business program (The Small Business Forest Enterprise Program), are permitted to log one or more of the watersheds in the study area, and fall under the jurisdiction of the British Columbia Forest Service's (BCFS) Revelstoke District Office. In addition to these concerns, private land (owned by a German interest), is administered and logged by Beaumont Timber Co. Ltd. and is not within the jurisdiction of the BCFS. This private land follows either

Table 7: Measured discharges from tributaries entering Revelstoke Lake, fall, 1991.

Watershed	July 01 (m^3/s)	Sept. 27 (m^3/s)	Sept. 28 (m^3/s)	Oct. 1 (m^3/s)	Oct. 4 (m^3/s)	Oct. 7 (m^3/s)	Oct. 8 (m^3/s)	Oct. 9 (m^3/s)	Oct. 11 (m^3/s)	Oct. 22 (m^3/s)	Oct. 24 (m^3/s)	Oct. 26 (m^3/s)	Oct. 27 (m^3/s)
Birch Ck.	4.31												
Nagle Ck.	36.11												
Mica Ck.		2.36											
Nicholls Ck.			0.44										
Soards Ck.				4.02									
Pat Ck.				4.86									
Bigmouth Ck.					9.51								
Carnes Ck.					3.61								
Seymour Ck.						0.25							
Bourne Ck.							1.17						
Big Eddy Ck.								0.84					
Park Ck.								0.91					
Mars Ck.									0.54				
Frisby Ck.									4.57				
La Forme Ck.									0.91				
Horne Ck.										2.54			
Hoskins Ck.											2.5		
Scrip Ck.												2.72	
Ruddock Ck.												1.42	
Downie Ck.													8.44

side of the reservoir, from approximately the Goldstream River to Bigmouth Creek and extends as far as 6 km up some watersheds (Bigmouth Creek).

The largest of the permitted logging operators is Westar, which plans to clearcut 4019 ha of land within 6 separate watersheds between 1991 and 1995. The smallest operator within the Revelstoke Lake drainage is Joe Kozak Sawmills Ltd. which plans to clearcut 151 ha of land from 1 tributary watershed (Table 8).

It should be noted that actual cutting plans can, and often do change from that indicated in five year plans. These changes usually affect the time table for harvesting individual cutblocks, although the amount of timber to be harvested may also be affected (pers. comm., R. Mohr, BCFS). Such changes could become

particularly apparent with Westar, which is experiencing financial difficulties, and its parent company is looking to sell it's interests in Westar.

4.4 Priorizing Tributaries Entering Lake Revelstoke for Enhancement Potential

Based on the information presented in section 4.4, surveyed streams have been priorized into A, B, and C categories. The "A" category represents those streams with the greatest enhancement potential while "C" represents streams with little or no enhancement potential.

Nine streams have been categorized to have good enhancement potential (Table 9). Of these streams, Downie, Bigmouth, Carnes, Scrip, and Kirbyville Creeks have been identified as primary streams in past reports (Martin 1976, ERC 1976). Streams not included in the "A" category which were listed as primary streams in past reports are Horne and Pat Creek. The existence of substantial migratory barriers, limited habitat below these obstructions, as well as resident populations of fish preclude category Horne and Pat Creeks from a primary listing in this report. Streams included in Table 9 as primary streams but not considered as such in the earlier reports are La Forme, Ruddock and Nagel Creeks, as well as the Goldstream River.

Nagel Creek could provide a large amount of habitat if made accessible to lake resident fish although removing the on this stream would require a more detailed

Table 8: Future logging acitivities within the watersheds of tributaries entering Revelstoke Lake from 1991 to 1995.

Stream	Present Logging (field observations)	Logging Co.	PLANNED ACTIVITY Harvest (ha.)	Road Const. (km)	Year	Comments
Carnes Ck.	Limited to south side, to ~ km 12	JKS	151.0	10.4	1991 - 94	4 bridges and 9 cvs to be placed.
Bigmouth Creek						
mainstem	Mainly below km 18, N & S sides	SBFEP	173.5	20.1	1991, 93	3 temp. bridges to be placed
mainstem	see above	WSTR	311.1	25.9	1991 - 94	1 bridge on French m/l
Bigmouth Tributaries						
Louis Lee Ck.	None	DSS	62.0	7.4	1992 - 94	4 bridges to be placed
Big Fish Ck.	unknown	WSTR	104.6	?	1991	Road Construction?
Frisby Ck	Limited to S. side upper slopes of upper watershed	SBFEP	19.0	11.5	1995	1 cv to be placed
Goldstream River						
mainstem	Throughout watershed to ~ km 32	SBFEP	29.0	4.5	1993	3 bridges to be placed
mainstem	see above	WSTR	1194.9	26.5	1991-95	
Goldstream Tributaries						
Norman Wd. Ck.	Upper slopes, to ~ km 4 , E & W sides.	SBFEP	10.0	n/i	1992 - 94	
Norman Wd. Ck.	see above	WSTR	226.6	14.6	1991 - 93	
French Ck.	To ~ 2.5 km u/s of confl. with Goldstream R. Primarily W. side.	WSTR	561.5	25.8	1991 - 95	1 bridge to be placed
French Ck.	see above	SBFEP	14.0	n/i	1992	
Stitt Ck.	North side, to ~ 2.0 km u/s of confluence	WSTR	66.4	1.8	1993	
Camp Ck.	Throughout watershed to ~ km 4	WSTR	218.5	33.8	1994 - 95	Road Construction?
Hiram Ck.		WSTR	?	10.7		
	Total (tributaries):		1097.0	86.7		
	Total (mainstem):		1223.9	31.0		
	Total (system):		2320.9	117.7		

...continued

Sources: Five year plans submitted by indicated logging concerns to the BCFS.

Table 8: Future logging acitivities within the watersheds of tributaries entering Revelstoke Lake from 1991 to 1995.

Stream	Present Logging (field observations)	Logging Co.	PLANNED ACTIVITY Harvest (ha.)	Road Const. (km)	Year	Comments
Downie Creek						
mainstem	Throughout watershed to ~ km 25	SBFEP	66.4	n/i	1994	
mainstem	see above	WSTR	675.3	n/i	1991 - 94	Road Construction?
Downie Tributaries						
Sorcerer Ck	Limited, but road exists along most of Ck. length	WSTR	145.7	n/i	1991,92	Road Construction?
	Total (system):		**887.4**	**0.0***		
Big Eddy Ck.	To km 1.0, N. side.	SBFEP	50.0	n/i	1995	
Nagle Ck.	To ~ km 4.0, N&S side	SBFEP	25.0	n/i	1995	
Soards Ck.	Throughout watershed to ~ km 12.5	DSS	277.5	7.8	1991,92,94,95	
Ruddock Ck.	North bench, 2 km u/s	DSS	none	8.0	1995	Only road construction
Pat Ck.	Throughout watershed	DSS	322.0	15.5	1992, 94, 95	
Kirbyville Ck.	Throghout watershed to ~ km 10	DSS	247.9	9.4	1992, 93, 95	
Scrip Ck.	Limited. To ~ km 2.0.	DSS	85.0	n/i	1993	Road Construction?
Horne Ck.	In valley bottom to ~km 5.0	DSS	38.0	n/i	1993	Road Construction?
Laforme	None	DSS	87.0	6.2	1994, 95	Road construction in 1992
Mica Ck.	upper slopes to ~km 2 on south side.	WSTR	284.1	n/i	1991 - 93	Road Const. obs. on north slope
Birch Ck.	N & S sides to ~ km 2.0	WSTR	70.1	1.7	1993	Road Constructionin 1992
Nicholls Ck.	unknown	WSTR	186.1	n/i	1995	Road Construction?
	Total	WSTR	**4044.9**	**140.8**		
		DSS	**1119.4**	**54.3**		
		SBFEP	**386.9**	36.1		
		JKS	**151.0**	10.4		

n/i = not indicated .

Sources: Five year plans submitted by indicated logging concerns to the BCFS.

Table 9: Summary of habitat and fish information gathered during surveys of Revelstoke Lake tributaries. Streams are ranked for enhancement potential based on presence of barriers, fish densities, and available habitat.

STREAM	WATER	BARRIERS			WETTED AREA		FISH CAPTURED			ENHANCEMENT POT.	
	Type (glacial or clear)	Loct'n (km)	Type	Hght (m)	Above Barrier (m^2)	Below Barrier (m^2)	CPUE (#/sec)	Density (#/m^2)	Observed Spp.	Rating	Comments
CATAGORY "A" TRIBUTARIES											
Goldstream R.	glacial	0	F	5.0	>1,102,650	0	0.018	0.011	wf\cc\lkc	A	
McCulloch Ck.	clear		Cyn		?	> 2,160	0.035	0.039	ct		
Old Camp Ck	clear	2.3	F		?	12,200	0.006	0.005	cc/ct		
French Ck.	glacial		?		>64,000	> 24,890	0.002	.0.001	ct		No fish upstream of canyon
Brewster Ck.	clear		F		>15,000	20,000	0.002	>0.001	ct		No fish above barriers
Norman Wd Ck.	glacial	1.85	Ch			>65,000	0	0	0		
Bigmouth Ck.	glacial	none	-		-	>561158	0.018	0.008	cc/bt/wf	A	Rapids at mouth vary with lk. lvl.
13.5 km Trib.	clear		cyn		?	1,560	0.102	0.074	bt		culvert is possible barier
17.5 km Trib.	clear				?	2,500	0.066	0.037	bt		culvert is possible barrier
Louis Lee Ck.	glacial	none	cyn		-	>97,540	0.019	n/a	bt		
Big Fish Ck.	clear	?	?		?	>25410	0.018	n/a	bt		Not survied through canyon
Argonaut Ck.	clear	0.65	F		>16,500	3,600	0.004	n/a	u/s		No fish above barriers
Downie Ck	glacial	16.5	F/C	3.5	>380,000	370,000	0.002	0.002	t/rbt/wf/k	A	Resident bt u/s of barrier?
25.2 km Trib.	clear		cyn	?	?	1,600	n/s	n/s	-		Reach one surveyed
Pass Ck.	clear		cyn	?	?	1,800	0.032	0.034	bt		Reach one surveyed
Standard Ck.	clear	0.65	LJ	2.5	> 37,000	5000	0.028	0.015	bt/rbt/ko		Barrier in canyon?
Belcher Ck.	clear		cyn	?	?	3,700	0.004	0.004	bt		Reach one surveyed
4.9 km Trib.	clear*		cyn	?	?	330	0	0	-		Reach one surveyed
Long Ck.	clear*		cyn	?	?	1,900	0	0	-		Reach one surveyed
Sorcerer Ck.	glacial	0.5/8.3	C/LJ	3.5/3	>135,000	<2,000	0	0	-		Sampled to km 11
Carnes Ck.	glacial	none	-	-	-	>174,000	0.019	n/a	bt	A	Wate clear u/s of Mckinnon Ck.
Kelly Ck.	clear	3.8+	cyn	?	?	53,700	0.026	0.01	bt		Surveyed to km 3.8
Mckinnon Ck.	glacial	?	?	?	?	>23,800	0.014	n/a	bt		Reach one surveyed
Ruddock Ck.	clear*	~11.0	F	?	?	>80,000	0.23	0.016	bt	A	Glacial run-off moderated by lk. ?
La Forme Ck.	clear	5	D	~ 4.0	>52,500	59,500	0.037	n/a	bt	A	Dam at km 5 is partial barrier
Scrip Ck.	clear	none	-	-	-	>268,835	0.02	0.14	rbt/bt	A	Slight glacial influence
Kirbyville Ck.	clear	~8.5+	F	>2.0	>56,000	>124,000	0.014	0.025	bt/rbt/cc	A	Glacial run-off moderated by lk. ?
Nagle Ck.	glacial	0.4	F/C	3 + 2	>274,510	<1,000	<0.001	<0.001	u/s	A	

...continued

* = At time of survey

n/s = not shocked

Barriers Abbreviations: F = Falls, CV = Culvert, C = Chute, D = Dam, LJ = Log jam.

Fish Abbrevt'n: cc = Cottid, rbt = Rainbow trout, ct = Cutthroat trout, bt = bull trout, lkc = Lake Chubb, wf = Whitefish, u/s = unidentified salmonid

Table 9: Summary of habitat and fish information gathered during surveys of Revelstoke Lake tributaries. Streams are ranked for enhancement potential based on presence of barriers, fish densities, and available habitat.

STREAM	WATER	BARRIERS			WETTED AREA		FISH CAPTURED			ENHANCEMENT POT.	
	Type (glacial or clear)	Loct'n (km)	Type	Hght (m)	Above Barrier (m^2)	Below Barrier (m^2)	CPUE (#/sec)	Density (#/m^2)	Observed Spp.	Rating	Comments
CATAGORY "B" TRIBUTARIES											
Nicholls Ck.	clear	0+	lj/f/cv	2.5-5	>18,500	18,500	0.022	n/a	rbt/bt/cc	B	Resident rbt in reach 3?
Park Ck.	glacial	0.25	F/LJ	2.0	>21,000	2,700	0.021	0.013	bt	B	Resident bt?
Hoskins Ck.	glacial	2.3	F/C	7.5	>83,000	31,000	0.014	0.008	bt/rbt/cc	B	Resident bt u/s of barrier?
Horne Ck.	clear	0.8	F/C	~8.0	>211,000	~10,000	0.011	0.005	rbt	C	Resident rbt above barrier
Mica Ck.	clear	0.5+	F/C	2 - 3	>43,000	3,400	0.007	n/a	bt	B	Resident bt u/s cyn?
Pat Ck.	clear	0 & 4.0	F/C	1 - 10	>318,000	32,500	0.016	0.013	rbt	C	Resident rbt.
Soards Ck.	glacial	0.37+	F		>124,000	6,700	0.004	n/a	bt/rbt	B	Resident rbt u/s falls, falls at 7 k
Birch Ck.	clear	0.55	CV	1.5	>32,000	<1,000	n/a	n/a	cc/bt	B	Barrier removed.
CATAGORY "C" TRIBUTARIES											
Mars Ck.	clear	2.5	gorge	-	>12,000	10,500	0.044	0.046	rbt/bt	C	Resident rbt? Gorge grad. = 18%
Seymour Ck.	clear	0.25+	F/C	1.4-5	>2,500	1,800	0.023	0.013	rbt	C	Resident ?
Frisby Ck.	glacial	0+	F	25.0	>214,600	0	0.007	0.003	cc	C	Fish in R-1. 2 falls u/s, 7.6 &13.6
Pitt Ck.	clear	0.5+	CV	1.0	>12,400	1,800	0.01	n/a	bt/cc/rbt	C	Resident rbt us of cv?
Bourne Ck.	glacial	0.13+	F	2 - 8	>38,600	< 2,000	0	0	-	C	3 sets of falls 0.13 to 0.77 km
Big Eddy Ck.	glacial	0.2+	C/F	1 - 5	>52,000	2,400	0	0	-	C	3 separate barriers, 0.2 to 0.4 km

* = At time of survey

n/s = not shocked

Barriers Abbreviations: F = Falls, CV = Culvert, C = Chute, D = Dam, LJ = Log jam.

Fish Abbrevt'n: cc = Cottid, rbt = Rainbow trout, ct = Cutthroat trout, bt = bull trout, lkc = Lake Chubb, wf = Whitefish, u/s = unidentified salmonid

engineering study. The Goldstream River offers good potential to enhance resident cutthroat trout to benefit recreational fishing opportunities. La Forme and Ruddock Creeks, similar to the remaining 5 "A" category streams presented in Table 9 are all accessible to lake resident fish, and have substantial amounts of good rearing and spawning habitat.

These 9 tributaries, with the exception of Downie and Nagel Creeks, also have comparatively high CPUE's and fish densities. This suggests conditions which prevail in these streams are conducive to supporting spawning and rearing populations. It is unknown if the available habitat is underutilized, however, it is likely standing stocks are less than capacity and could probably be increased thorough a hatchery outplanting programs. Also, most of these creeks are either clear watered creeks or have clear water tributaries which flow into the mainstem. They also have considerable water storage capability (i.e. lake fed or have large water sheds).

Another factor considered in priorizing was vehicle access. Road access to complete habitat improvement, conduct further studies, initiate habitat improvement or to begin hatchery outplanting programs is an important consideration and will ultimately effect the cost required to conduct enhancement work. Ruddock, Scrip and La Forme Creeks are notable exceptions in the "A" list since there is limited access into these watersheds, however, there are indications that road networks may be expanded into the valleys of these creek within the next 5 years (Table 8).

The streams listed in the "B" category present opportunities for enhancement although they have been considered less important than "A" streams due to limitations in habitat, fish access, road access or discharge. The effects of low winter discharge was especially evident from ice formations observed in some of the "B" category streams during a brief cold spell. Still, opportunities do exist for improving these streams through small projects which might be easily accomplished by volunteers from the Revelstoke Rod and Gun Club. Also, they present alternatives which may be considered viable opportunities by both B.C. Hydro and or MOE. These include:

1) Removing small barriers (such as Nicholls and Mars Creek), to the benefit of lake resident fish,

2) Creating additional habitat by building spawning and/or side channels or complexes,

3) Enhancing resident fisheries (such as for Pat and Soards Creek),

4) Creating a resident stock for recreational fishing (such as Frisby Creek).

Tributaries within category "C" generally have limited enhancement potential due to a lack of available habitat. Some of these streams, although heavily utilized by rainbow and/or bull trout, require more than one barrier removed to gain access for lake resident fish but would provide only poor quality or limited habitat should obstructions be removed (such as Mars Creeks and Pitt Creeks). Other streams, such as Big Eddy and Bourne Creek have good habitat upstream of numerous barriers which is devoid of fish, however, there is too little of this habitat to warrant either barrier removal (each stream has 3 or more obstructions) or outplanting to create a viable resident fish population.

4.5 Stream Descriptions

Descriptions of the 23 tributaries surveyed include detailed results of both physical and biological parameters observed within each stream. The descriptions proceed from streams within the "A" category to streams within the "C" category (Section 4.4). Barriers (if any) on each stream surveyed are identified, followed by a general descriptive summary of the reaches and a summary of fish capture results, logging and/or mining activities. Enhancement opportunities are included with each stream description.

A CATEGORY STREAMS

4.5.1 Scrip Creek

The absence of any barriers to fish passage, and long stretches of low gradient channel makes over 20 km of Scrip Creek accessible to lake resident fish (Fig. 8). Water clarity was very good at the time of sampling. The presence of numerous

small lakes and the absence of any large icefields in the headwaters of Scrip Creek help maintain water clarity (Fig. 9).

Reach 1 of Scrip Creek extends through 2 kms of steep sided narrow valley and continues approximately 3.4 km upstream of its outlet (photo 1). Stream gradient becomes lower, the valley bottom broadens and the creek begins to meander in reach 2. Although reach 2 was not sampled, it probably represents some of the best rearing and spawning habitat in the Scrip system since it has a low gradient, and a helicopter overflight of these section revealed a meandering stream with a gravel substrate and numerous deep pools.

Reach three is characterized by a slight increase in gradient, and a high proportion of large substrate in the stream bed (photo 2). Gradient in reach 4 decreases and gravel content increases from that observed in reach 3 (Table 10). There is almost no cover in reach 4, although what cover does exist is restricted to overhead vegetation and cutbank (photo 3).

It should be noted that ice cover in Scrip Creek was limited to reach 2 and 3 during the cold snap at the end of October. The ice in reach 2 appeared to be surface ice only and probably added cover, whereas some frazzle ice was noted in reach 3. The head water areas (reach 4), where flow and depth was reduced, were free of ice.

Fish

Bull trout was the most commonly encountered species in Scrip Creek and was observed at all sites sampled, however, rainbow trout were also caught in reach 3 (Table 11a). The highest CPUE was calculated for reach 4, almost 20 km upstream. This conforms with observations in other reports which indicate bull trout utilize headwater areas of streams (Ford et al. 1992, Lindsay 1977). Still, this observation is somewhat surprising considering there was hardly any cover in reach 4 and water depths were very shallow. The mean length of bull trout in reach 4 was 92 mm, suggesting most fish were 1+ years old. This may indicate that reach 4 forms part of the natal rearing grounds for bull trout in Scrip Creek, even though gravel was found to be highly compacted in this section. Bull trout longer than 200 mm and

weighing over 80 g were also captured in reach 4, although the mean size of bull trout was larger in lower reaches (Table 11b).

Kokanee were not observed in Scrip Creek during helicopter or foot surveys. Lindsay (1977) speculates that Scrip Creek supported a large run of kokanee prior to the creation of the Revelstoke Reservoir, based on pre-impoundment observations of kokanee utilizing some of the smaller streams.

Logging

There is no logging presently occurring in Scrip Creek, although limited cutting has occurred near the stream mouth along Lake Revelstoke's foreshore. A road, accessible only by ferry, was constructed to access a forest fire which occurred in reach 1 and 2 of the Scrip watershed. The road follows the midslopes of the valley on the south side of the stream and descends to the valley floor approximately 2 km upstream of the mouth where it crosses Scrip Creek. This road is responsible for erosion into Scrip Creek along more than one section of reach one and one section is in danger of total collapse.Downie Street Sawmills plans to remove 85 ha of trees from reach 2 of the Scrip watershed in 1993.

Enhancement Opportunities

Scrip Creek provides extensive spawning and rearing habitat for both bull and rainbow trout. It is possible that Scrip Creek, is under utilized by both rainbow and bull trout and is capable of supporting higher densities of rearing juveniles and spawning adults, however, this would require further investigations before verification. This work would include detailed studies of Scrip Creek to determine seasonal use of habitat within reaches, the carrying capacity of Scrip Creek as well as collect biophysical information such as water quality and continuous temperature data. Determining the carrying capacity of Scrip Creek will determine which enhancement strategy is most appropriate. Since preliminary surveys indicate expansive spawning habitat is present in this stream (Reach 2 and 4 in particular), enhancement activities should concentrate on increasing rearing juvenile standing stocks.

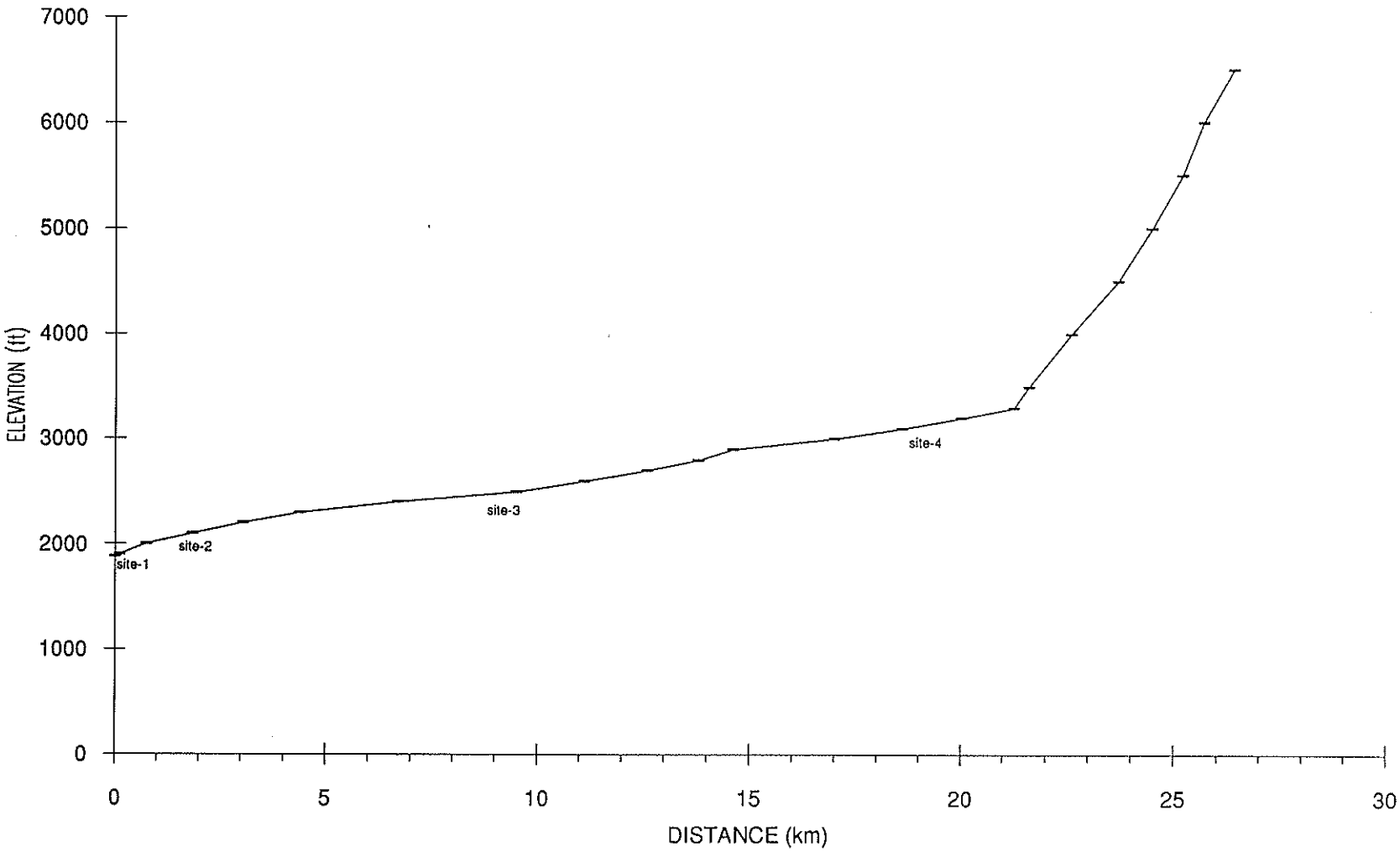
Should habitat be restricting juvenile production in Scrip Creek, expanding existing rearing habitat or increasing food sources via increases in limiting nutrients by stream fertilization may be warranted. Scrip Creek's valley broadens 2 km upstream of its mouth, which would aid creation of more rearing habitat via side channel development. Road access exists as far as km 3 (although it would require improvement) of Scrip Creek and would facilitate transport of equipment.

If adult recruitment is found to limit juvenile production within Scrip Creek, initiating a program of outplanting hatchery raised bull and rainbow trout juveniles may be explored. Scrip Creek may also have potential to provide brood stock for a hatchery program. Prior to beginning a hatchery outplanting program, preliminary investigations conducted this year should be supplemented with further studies to determine the number of adult bull and rainbow trout utilizing this stream for spawning.

Yearly monitoring of the stream both prior to and after enhancement is important to determine the success of habitat improvement or hatchery outplanting programs.

- requires temp, H_2O chem study.

Figure 8: The stream profile for Scrip Creek (not to scale)



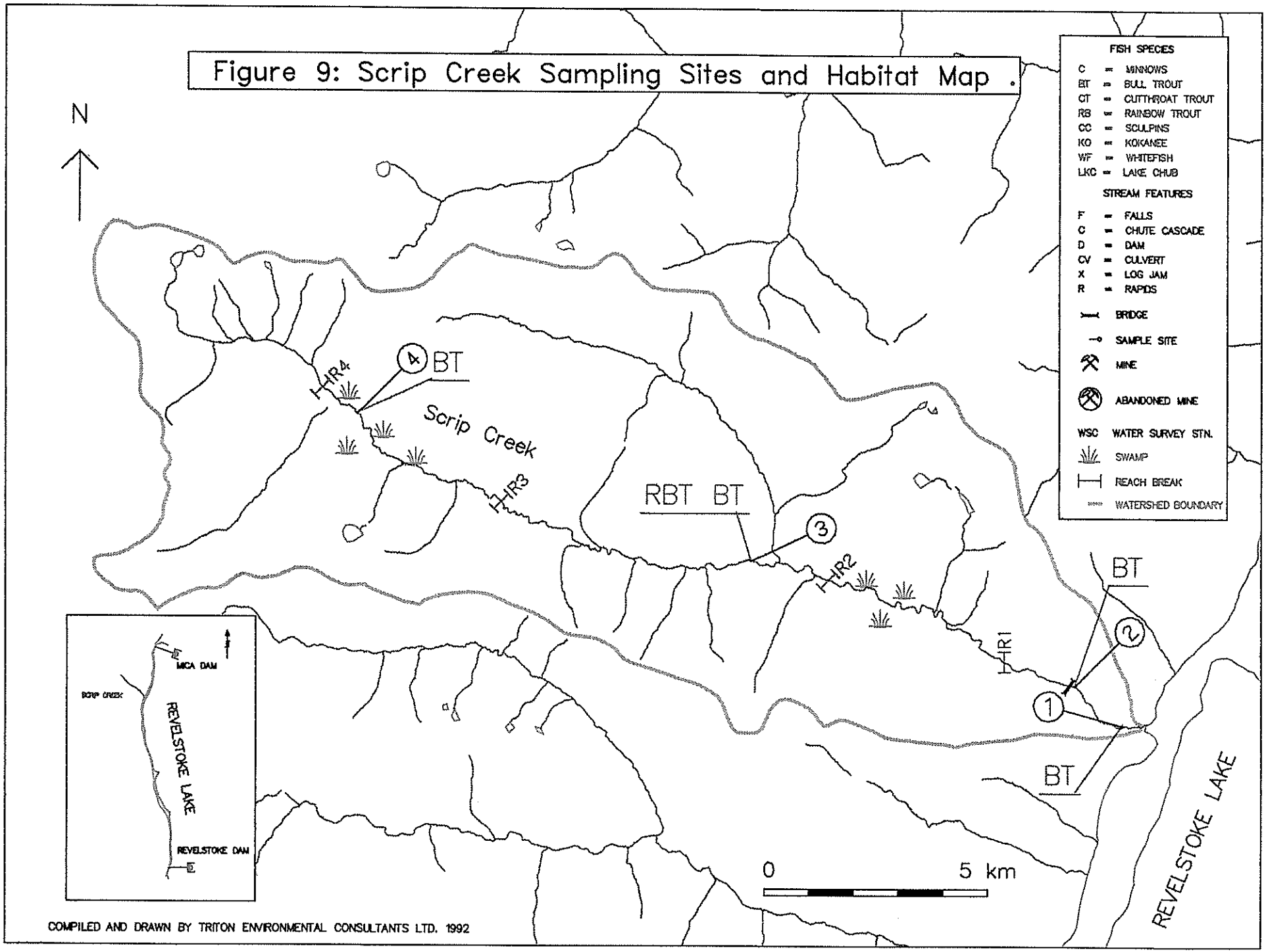

Figure 9: Scrip Creek Sampling Sites and Habitat Map .
N
FISH SPECIES
C = MINNOWS
BT = BULL TROUT
CT = CUTTHROAT TROUT
RB = RAINBOW TROUT
CC = SCULPINS
KO = KOKANEE
WF = WHITEFISH
LKC = LAKE CHUB
STREAM FEATURES
F = FALLS
C = CHUTE CASCADE
D = DAM
CV = CULVERT
X = LOG JAM
R = RAPIDS
BRIDGE
SAMPLE SITE
MINE
ABANDONED MINE
WSC WATER SURVEY STN.
SWAMP
REACH BREAK
WATERSHED BOUNDARY
4 BT
HR4
Scrip Creek
HR3
RBT BT
3
HR2
BT
2
HR1
1
BT
REVELSTOKE LAKE
0
5 km
MICA DAM
SCRIP CREEK
REVELSTOKE LAKE
REVELSTOKE DAM
COMPILED AND DRAWN BY TRITON ENVIRONMENTAL CONSULTANTS LTD. 1992

Table 10: Summary of biophysical habitat parameters for Scrip Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1,2	1	3.5	3.5	72,275	21,683	dp/b/l	4,156	20,326	23,039	23,039	5,871	14,455	14,455	L	145	CO	2 - 5
mainstem	3	3	1.8	7.8	113,100	16,965	b/ov/dp	1,131	11,310	45,240	50,895	5,655	5,655	33,930	L	90	OC	5 - 10
mainstem	4	4	0.5	7.8	83,460	4,173	ov/cb	835	16,692	41,730	25,038	0	8,346	41,730	H	70	UC	10 +
Total 1+3+4:				19.1	268,835	42,821		6,122	48,328	110,009	98,972	11,526	28,456	90,115		158		

Summary of geographical parameters.

Location:	North central area of resevoir, west side.
Length:	26 km
Barriers:	None
No. of Reaches:	5
No. of Reaches Sampled:	3
Length of stream below barriers	Minimum of 19.1 km
Major Tributaries:	1 unamed trib entering the north side of Scrip Ck. at km 9.
Water Source:	Numerous small and moderate sized lakes, slight glacial influence.
Resource use:	Logging limited to valley bottom and mid-slopes in reach 1. An old fire has burned the north slope of the upstream section of reach 1 and the downstream section of reach 2.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 11: **Electroshocking results (a), as well as fish size and age data (b) for Scrip Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	1	4	1	BT	f/p	0.016	0.004	0.020	0.010	0.003	0.013
mainstem	1	1	1	BT	f	0.003	0.003	0.005	0.001	0.001	0.001
total, reach 1:		**5**	**2**	**Mean**		**0.009**	**0.003**	**0.012**	**0.005**	**0.002**	**0.007**
mainstem	3	2	2	RBT	p	0.005	0.005	0.010	0.006	0.006	0.013
mainstem	3	2	1	BT	p	0.005	0.003	0.008	0.006	0.003	0.010
total, reach 3:		**4**	**3**	**mean:**		**0.005**	**0.004**	0.009	**0.006**	**0.005**	0.011
mainstem	4	8	6	BT	p/f	0.022	0.017	0.039	0.013	0.010	0.023
Total, 1+3+4:		17	11	Mean		0.012	0.008	0.020	0.008	0.005	0.014

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yr)	N
1	BT	107	51 - 182	16.47	1.36 - 46.36	0.84	5	2+	2
3	RBT	150	149 - 150	37.99	31.19 - 44.78	1.14	2	3+	2
3	BT	150	139 - 161	33.51	25.32 - 41.69	0.97	2	2+	2
4	BT	92	50 - 206	19.72	1.27 - 87.48	1.01	8	3+	2
1+3+4	BT	105	50 - 206	20.47	1.27 - 87.48	0.95	17	2- 3+	8

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available



Photo 1 A typical stretch of Scrip Creek within reach 1.

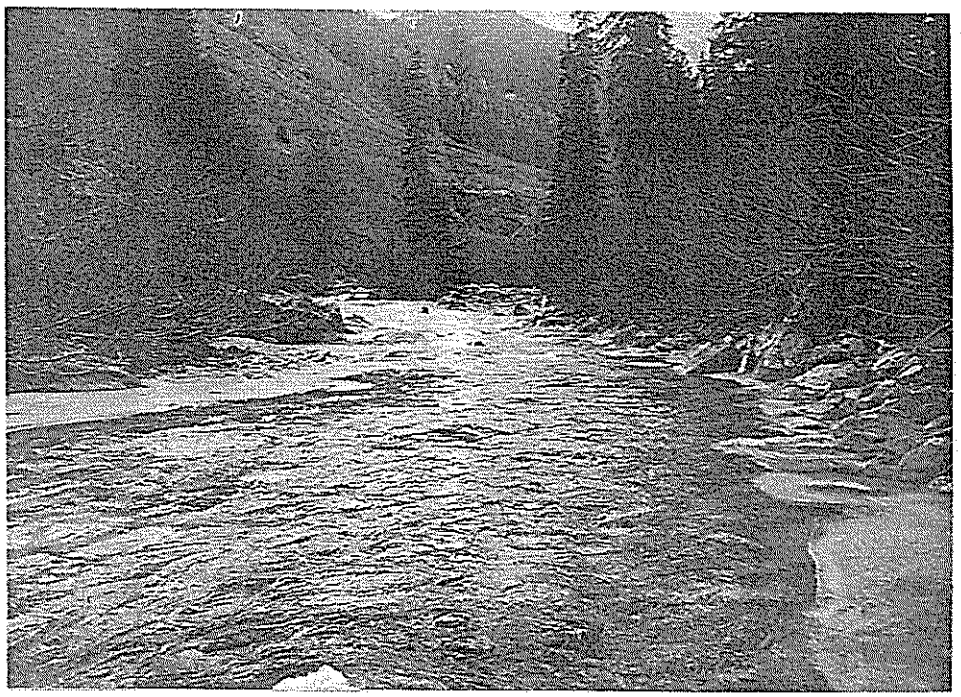


Photo 2 Sample site 2 in reach 3 of Scrip Creek (9.8 km upstream). Both rainbow and bull trout were captured in this section of stream.

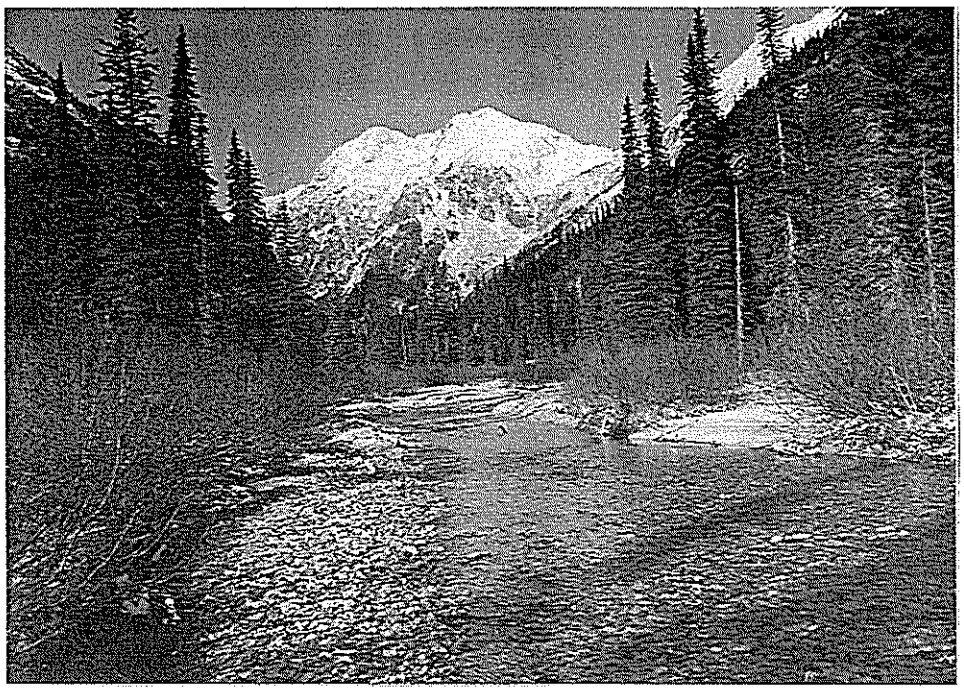


Photo 3 Despite the apparent lack of cover, yearling bull trout were abundant at site 3 (reach 4) of Scrip Creek. No trout were captured in this section of stream.

4.5.2 Kirbyville Creek

Kirbyville Creek is accessible for approximately 8 km of its length. Numerous small falls were observed during a helicopter overflight of the stream, the first of which occurred approximately 8 km upstream of the mouth. A single large falls approximately 150 m high is located 11 km upstream, isolating Kirbyville Lake from downstream reaches (Fig. 10).

A large protected lagoon marks the entrance to Kirbyville Creek. The lower sections of reach 1 show evidence of extensive flooding. Streambank erosion is common throughout reach 1, including a number of banks within 700 m of the creek mouth (photo 4, 5). Much of this erosion maybe attributable to severe floods which occurred in the Revelstoke area in 1983. Scrip creek is confined to a steep sided valley in reach 1, with rapids occurring at the creek mouth as well as upstream areas of this reach (Fig. 10), however, these rapids did not appear to be barriers to fish migration during low water conditions.

Reaches 2 and 3, of 4 surveyed, had the most quality spawning and rearing habitat (Table 12). Gradient varied between 1.0% in reach 2 and 1.6% in reach 3 (Fig 11). Reach 2 meanders through alder marsh, whereas reach 3 is braided with LOD frequenting the sidechannel margins (Photo 6). The mainstem of reach 3 has numerous large accumulations of LOD which provide superb cover for rearing juvenile fish. Reach 4 is likely unaccessible to lake resident fish because of numerous water falls in this section of stream, although bull trout were captured upstream of these falls.

Fish

Similar to Scrip Creek, both rainbow trout and bull trout were captured in Kirbyville Creek. Both species were present in relatively equal numbers, although there was a tendency for one species to dominate in a particular reach. For example, rainbow trout were most prevalent in reaches 1 and 3 whereas bull trout were more common in reaches 2 and 4 (Table 13). Partitioning of habitat within streams which contain these 2 species is not uncommon, bull trout usually utilize slower water sections whereas rainbow trout use faster water areas (Ford et al, 1991).

An unnamed lake, draining into the eastern side of Kirbyville Lake has been stocked with rainbow trout (Pers. comm. R. Lindsay, Biologist, MOE Nelson). Lindsay (1977) reports rainbow trout captured in Kirbyville Creek are resident fish, however it is unlikely Kirbyville Lake is the source of many of the rainbow trout observed in reach 3, since a 150 m falls (approx.) at km 11 separates Kirbyville lake from the lower river. Like other streams entering Revelstoke Lake, it is difficult to determine if rainbow trout found in reach 3 of Kirbyville Creek are resident since no barriers exist to prevent lake stock from migrating into this area. The presence of bull trout upstream of barriers observed in reach 4 suggests some of this species captured in Kirbyville Creek may be resident fish, however, high water conditions in the spring may facilitate larger juvenile bull trout to migrate past barriers which are otherwise not negotiable.

Logging

The Kirbyville drainage has been extensively logged on both south and north sides of the valley, to approximately 10 km upstream of the creek mouth. This includes valley bottom, midslope areas, and some upper elevation sections of the watershed. It is likely that the water quality of Kirbyville Creek has been affected by past logging activities.

A road network on either side of the Kirbyville Creek facilitate vehicle access between km 4 and km 10 of the mainstem, but ferry transportation is necessary to access these logging roads. Similar to Pat and Scrip Creeks, these roads are a source of erosion within the watershed. The main road was littered with rocks which fell from up-slope areas in one section. Another road accessing lower reach 2 on the south side of the creek was inaccessible due to bank collapse.

Enhancement Opportunities

Kirbyville Creek, like Scrip Creek, is probably an important producer of lake resident rainbow and bull trout. Also similar to Scrip Creek, Kirbyville Creek appears to have extensive spawning habitat which may be under-utililized due to a lowered of recruitment of pre-impoundment migratory adult spawners. The presence of a large lake (Kirbyville lake) probably reduces sedimentation from

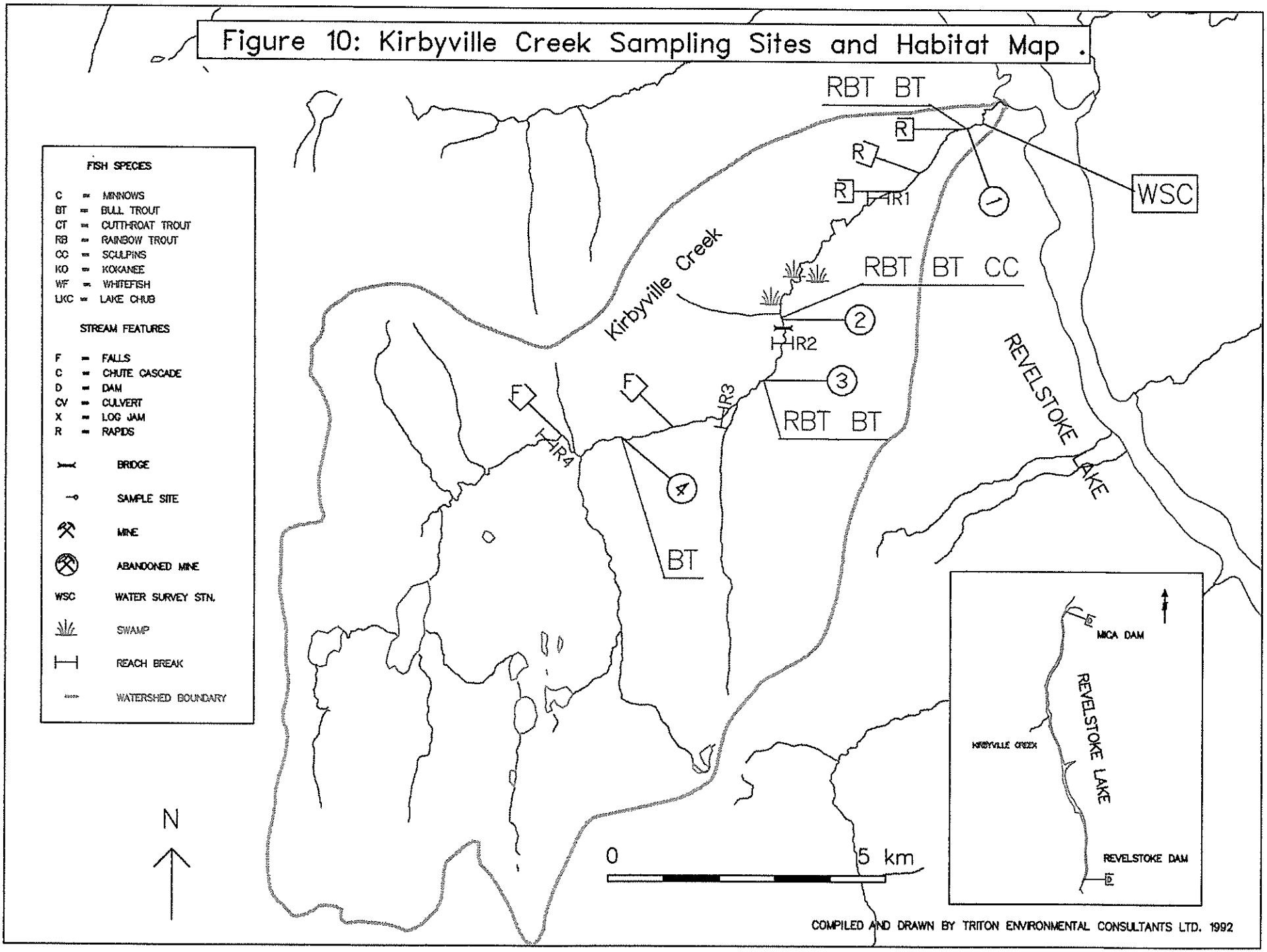
glacial melt as well as providing a more stable flow regime, both factors are advantageous to incubating salmonid eggs.

Increasing spawner escapement through increased juvenile production from Kirbyville Creek is recommended. Further investigations are necessary to determine which parameters may limit juvenile production in Kirbyville Creek, however, a broad valley bottom in reach 2 and 3, combined with extensive road access would facilitate habitat enhancement projects such as side channel development, hatchery outplanting programs, or incubation boxes.

There are no indicated plans to conduct further logging in the Kirbyville Valley, however, the present condition of the watershed may impact upon habitat available to both rearing juvenile and spawning adult salmonids. Severe naturally occurring erosion along banks in reach 1 is probably amplified by the effects of a logged watershed on this streams hydrology, specifically, increased peak in discharge but over a shorter duration. Eroding banks within reach 1 may lead to mass wasting, and possibly the creation of a migrational impasse. For this reason, bank stabilization via revegetation should be considered. Another concern linked to the status of logging in the Kirbyville watershed is the transport of large organic debris from upstream reaches and (such as reach 3) into the canyon of reach 1. Road failure, although not severe at the time of surveys, has the potential of creating mass wasting on the south side of reach 2. Input of debris may cause logjams that create effective barriers to fish migration. Special attention should be given to monitoring the canyon in Kirbyville Creek to ensure blockages which may occur are cleared, until the system becomes stabilized.

Finally, there is potential to develop the lagoon at the mouth of Kirbyville Creek. Good littoral habitat within Lake Revelstoke is almost non-existent (Smith 1990). This lagoon may provided important transitional habitat for sports fish migrating out of Kirbyville Creek. Provision of cover, planting of sedges as well as shore vegetation, and placement of habitat complexes (such as floating cover) in the Kirbyville lagoon would provide valuable littoral habitat within this area.

Figure 10: Kirbyville Creek Sampling Sites and Habitat Map .



COMPILED AND DRAWN BY TRITON ENVIRONMENTAL CONSULTANTS LTD. 1992

Figure 11: The stream profile for Kirbyville Creek (not to scale)

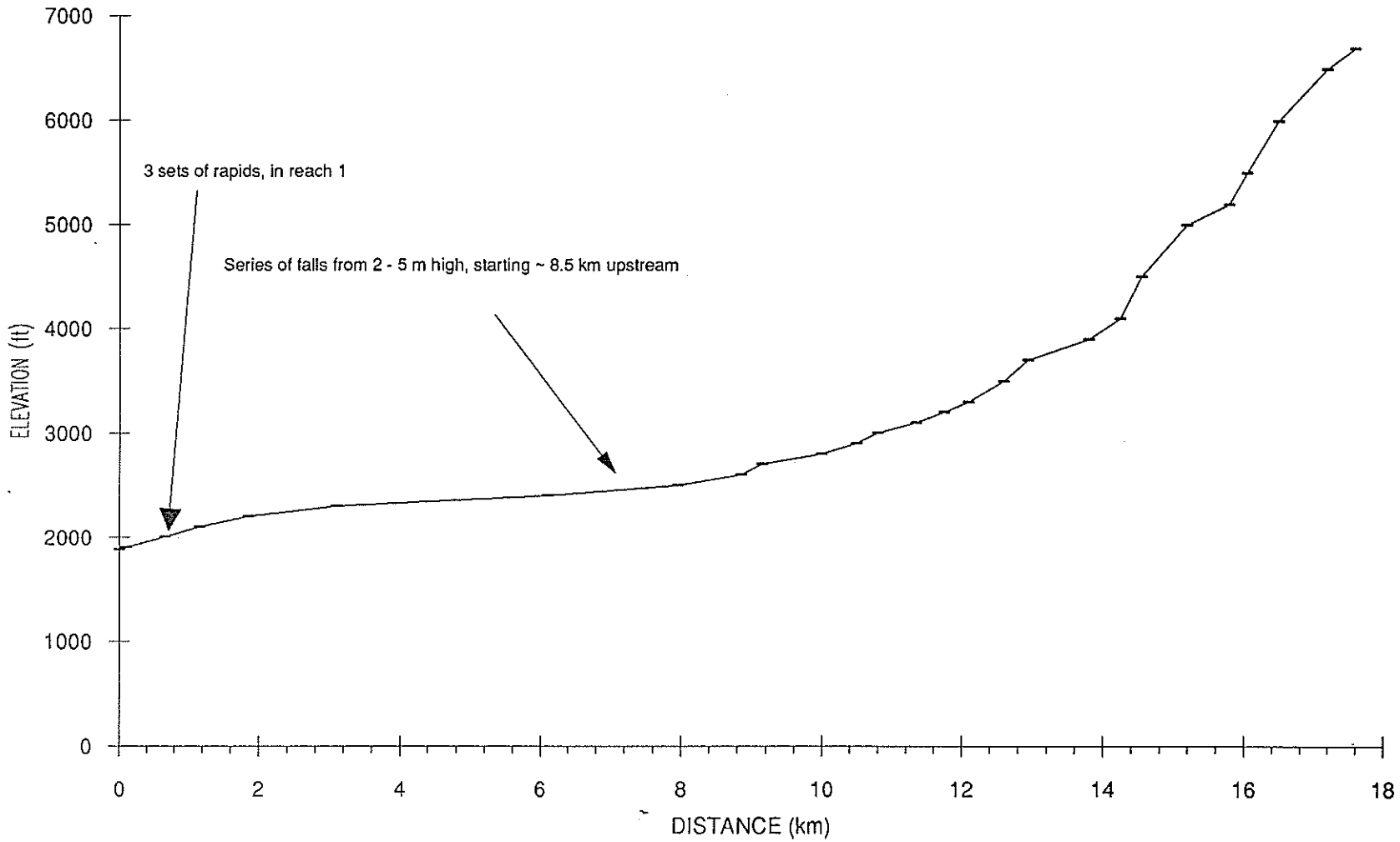


Table 12: Summary of biophysical habitat parameters for Kirbyville Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	4.1	4.1	44,000	8,800	b/dp	2,200	8,800	17,600	13,200	4,400	4,400	11,000	M	100	CO	0 - 2
mainstem	2	2	1.0	1.0	57,090	11,418	dp/cb	4,567	11,418	22,836	22,836	0	8,564	34,254	L	100	OC	5 - 10
side channel	3	3	1.6	1.6	23,100	5,775	l/dp/ov/cb	1,155	4,620	9,240	9,240	0	3,465	11,550	M	70	OC	5 - 10
mainstem	4	4	5.5	5.5	56,100	22,440	b/dp/l	5,610	11,220	16,830	16,830	11,220	5,610	14,025	L	160	CO	0 - 2
Total				12.2	180,290	48,433		13,532	36,058	66,506	62,106	15,620	22,039	70,829		430		

Summary of geographical parameters.

Location:	Central area of resevoir, west side.
Length:	17.6 km
Barriers:	Starting at km 8
No. of Reaches:	5+
No. of Reaches Sampled:	4
Total length of stream below barriers:	~8.0 km
Major Tributaries:	1 unamed trib entering the south side of the mainstem at km 10 (approx).
Water Source:	Numerous small and moderate sized lakes.
Resource use:	Logging throuhgout valley bottom and mid-slopes to km 10. Road networks exist on south and north side of the Creek.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 13: Electroshocking results (a), as well as fish size and age data (b) for Kirbyville Creek.

(a) Electroshocking results,

Site	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE Esc. or Obs.	CPUE Total	DENSITY (Fish/m^2) Caught	DENSITY Esc. or Obs.	DENSITY Total
mainstem	1	1	1	BT	p	0.003	0.003	**0.006**	0.002	0.002	**0.005**
mainstem	1	3	1	RBT	p	0.009	0.003	**0.012**	0.007	0.002	**0.010**
total, reach 1:		**4**	**2**	**mean:**		**0.006**	**0.003**	**0.009**	**0.005**	**0.002**	**0.007**
mainstem	2	7	0	RBT	p	0.019	0.000	**0.019**	0.050	0.000	**0.050**
mainstem	2	7	0	BT	p	0.019	0.000	**0.019**	0.050	0.000	**0.050**
mainstem	2	1	0	CC	a	0.003	0.000	**0.003**	0.007	0.000	**0.007**
total, reach 2:		**15**	**0**	**mean:**		**0.013**	**0.000**	**0.013**	**0.036**	**0.000**	**0.036**
side ch.	3	4	3	RBT	p	0.010	0.008	**0.018**	0.008	0.006	**0.013**
side ch.	3	1	1	BT	f/p	0.003	0.003	**0.005**	0.002	0.002	**0.004**
total, reach 3:		**5**	**4**	**mean:**		**0.006**	**0.005**	**0.011**	**0.005**	**0.004**	**0.009**
mainstem	4	3	2	BT	p	0.014	0.009	**0.023**	0.029	0.019	**0.048**
Total, system:		27	8	Mean:		0.010	0.004	0.014	0.018	0.006	0.025

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yr)	N
1	RBT	117	90 - 211	44.96	1.47 - 109.31	1.88	3	1 - 4+	2
2	RBT	87	83 - 90	7.45	6.64 - 8.26	1.15	2	1+	1
3	RBT	126	102 - 152	23.37	9.96 - 40.58	1.09	5	1 - 2+	4**
2	BT	99	52 - 174	13.79	1.35 - 48.09	0.90	11	1 - 3+	6*
4	BT	117	107 - 144	20.23	11.48 - 27.23	0.93	3	2+	2***
2	CC	66	-	3.36	-	1.17	1	-	-
1 + 2 + 3	RBT	116	83 - 211	26.66	1.47-109.31	1.34	10	1 - 4+	7
2 + 4	BT	103	52 - 174	14.11	1.35-48.09	0.90	14	1 - 3+	8

* 1 scale sample unreadable, all scales from fish > 98 mm long.

** Scales from 152 mm RBT were regenerated.

*** Scales from 107 mm BT were unreadable.

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available



Photo 4 Severe erosion is occurring along the banks at the mouth of Kirbyville Creek.



Photo 5 Reach 1 of Kirbyville Creek flows through a steep sided canyon where numerous eroding streambanks are common.

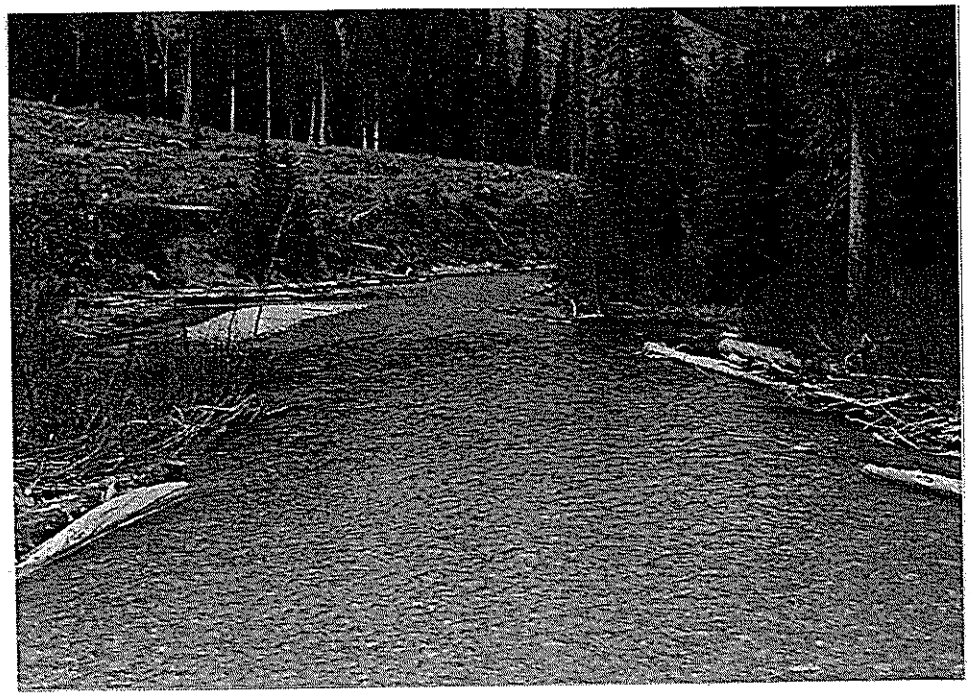


Photo 6 A typical example of reach 2 habitat on Kirbyville Creek.

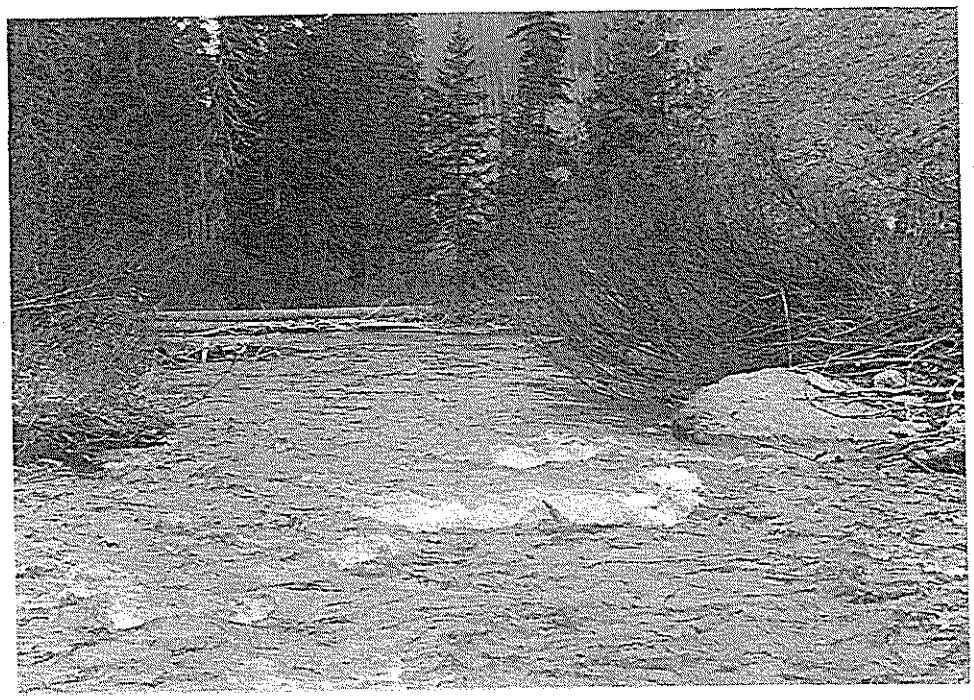


Photo 7 The side channel sampled in reach 3 of Kirbyville Creek.

4.5.3 Ruddock Creek

Ruddock Creek is a comparatively flat stream, accessible to fish for over 10 km of its length. Ground surveys 1 km upstream of the lake and a helicopter overflight of the entire stream did not reveal any barriers on Ruddock Creek although a steep section of stream exists in reach 2 (Fig 12).

Water clarity was very high at the time of the surveys, as would be expected during low flow conditions, even though over 13% of Ruddock's watershed is comprised of glaciers. Two small lakes at the headwaters of this stream probably moderate the effects of turbid spring and summer runoff originating from the numerous icefields in the Ruddock watershed (Fig 13).

Reach 1 and 3 provide the majority of quality spawning habitat in Ruddock Creek. Each reach has similar gradients although substantially more gravel, and slower water velocities provide reach 3 with better spawning habitat (photo 8, 9). Total cover did not vary between each reach, although it was more diverse in reach 3. Table 14 indicates more pool habitat exists in reach 1, but this is an anomaly due to the infrequency of reach sample sites. The helicopter overflight suggested reach 3 had more pool habitat.

Fish

Higher densities of bull trout towards the upstream limits of migration is a commonly observed for stream rearing bull trout. This was a re-occurring observation for most of the streams which enter Revelstoke Lake, and Ruddock Creek was not an exception. Bull trout were captured in both of the reaches sampled, however, CPUE and fish density were higher in reach 3 than in reach 1 (Table 15a). Adult bull trout and spawning activities were not observed by field crew during sampling, but a local guide observed large bull trout holding in a pool below a falls in the uppermost section of reach 3 during late September, 1991 (pers. comm. Volker Scherm, Owner Operator, Monashee Outfitting).

Logging

Aside from one cutblock on a bench above the stream on the north side, near the mouth of Ruddock Creek, there has been no logging in the Ruddock drainage. A road accesses the cutblock for approximately 1 km upstream, but it does not drop into the Ruddock valley floor. There is no indication of any planned logging activities for the Ruddock drainage over the next 5 years, however, a logging road extending into the valley is proposed to be constructed in 1995 (Table 8).

Enhancement Opportunities

The relatively high densities of rearing bull trout captured in Ruddock Creek, specifically in reach 3, suggests this stream is an important bull trout producing stream. Again, similar to Kirbyville and Scrip Creeks, further studies should be conducted on Ruddock Creek to determine carrying capacity, productivity and seasonal variations in habitat utilized by fish. The results of such work will allow a better understanding of this stream and aid in determining the best enhancement strategy. Similar to most of the other tributaries which enter Lake Revelstoke but have no obstructions to fish migration, increasing production of bull trout from Ruddock Creek could be achieved by hatchery outplanting. Again, detailed studies are necessary to determine if this stream has reached its carrying capacity. If so, the provision of additional spawning and rearing habitat through spawning or side channel development in reach 3 is an option. However, this area is presently inaccessible to machinery, although, there are plans to increase the road network presently accessing Ruddock Creek.

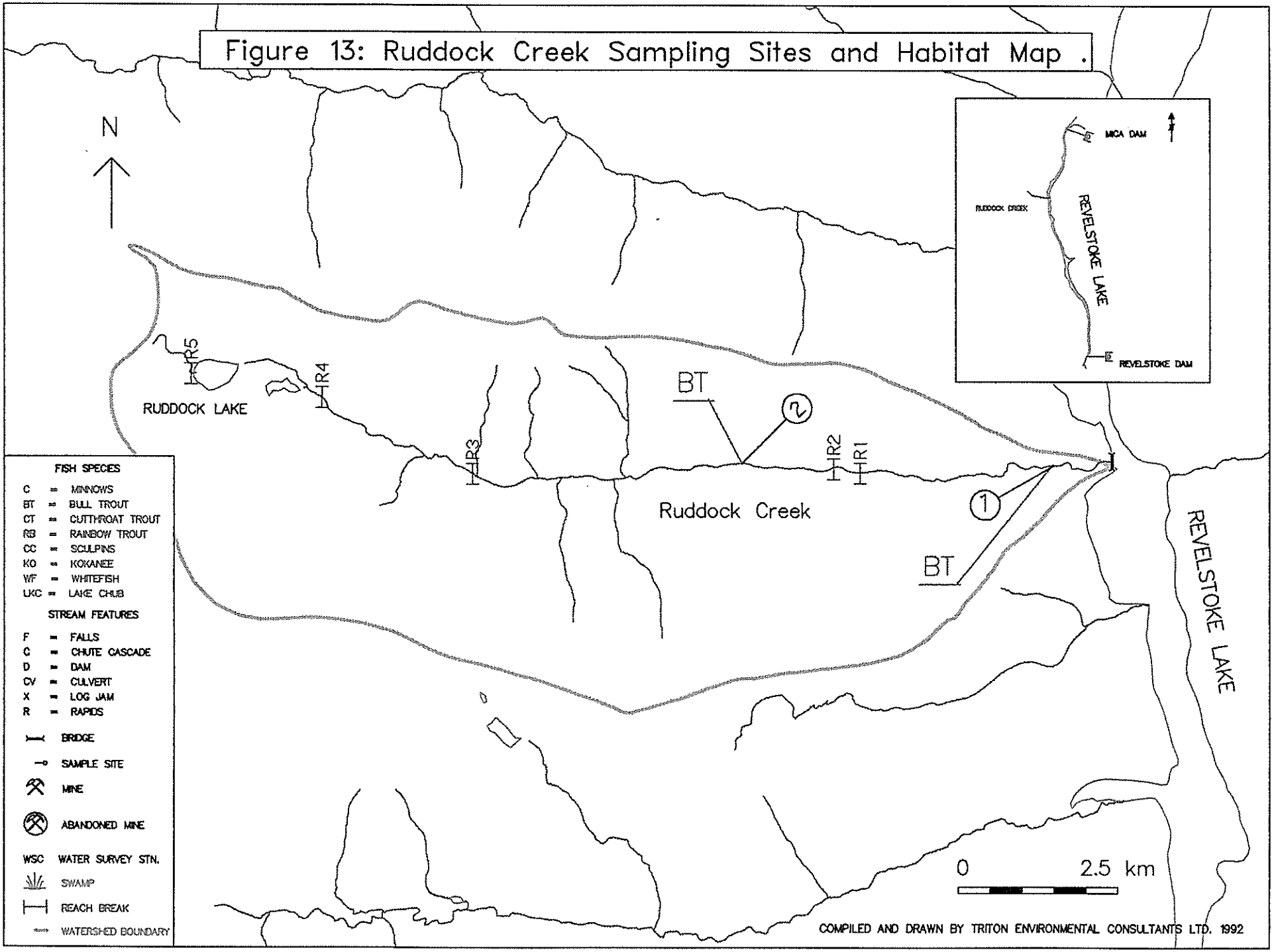

Figure 13: Ruddock Creek Sampling Sites and Habitat Map .
N
MICA DAM
RUDDOCK CREEK
REVELSTOKE LAKE
REVELSTOKE DAM
R5
R4
R3
R2
R1
RUDDOCK LAKE
BT
2
1
BT
Ruddock Creek
REVELSTOKE LAKE
FISH SPECIES
C = MINNOWS
BT = BULL TROUT
CT = CUTTHROAT TROUT
RB = RAINBOW TROUT
CC = SCULPINS
KO = KOKANEE
WF = WHITEFISH
LKC = LAKE CHUB
STREAM FEATURES
F = FALLS
C = CHUTE CASCADE
D = DAM
CV = CULVERT
X = LOG JAM
R = RAPIDS
BRIDGE
SAMPLE SITE
MINE
ABANDONED MINE
WSC WATER SURVEY STN.
SWAMP
REACH BREAK
WATERSHED BOUNDARY
0 2.5 km
COMPILED AND DRAWN BY TRITON ENVIRONMENTAL CONSULTANTS LTD. 1992

Figure 12: The stream profile for Ruddock Creek (not to scale)

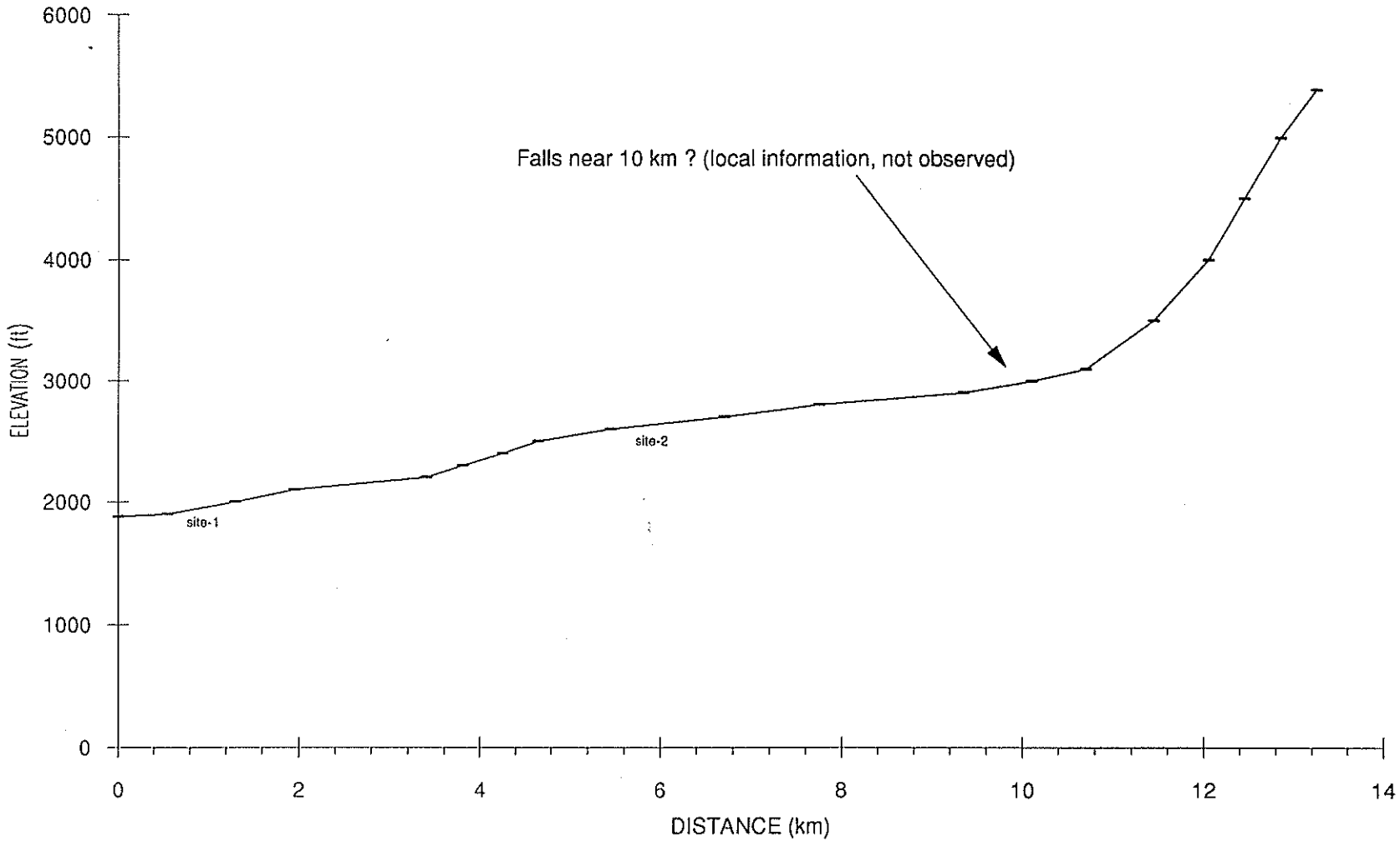


Figure 13: A map of Ruddock Creek, showing reach breaks, lakes and fish species distributions.

Table 14: Summary of biophysical habitat parameters for Ruddock Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	2.8	3.6	37,080	7,416	b/dp/ov	371	11,124	14,832	11,124	0	3,708	12,978	L	120	FC	2 - 5
mainstem	3	3	2.1	5.4	43,200	8,640	ov/cb	1,296	6,480	10,800	25,920	0	4,320	23,760	L	90	FC	5 - 10
Total (1+3:				9.0	80,280	16,056		1,667	17,604	25,632	37,044	0	8,028	36,738		105		

Summary of geographical parameters.

Location:	Central area of resevoir, west side.
Length:	15.0 km
Barriers:	Falls at km ~10 (local information, not viewed)
No. of Reaches:	6
No. of Reaches Sampled:	2
Total length of stream below barriers	Minimum of 9 km, possibly 11 km (approx.)
Major Tributaries:	none
Water Source:	2 moderate sized lakes at the headwaters of the creek.
Resource use:	Logging in mid-slope area within first km of the creek mouth. south and north side of the Creek.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 15: Electroshocking results (a), as well as fish size and age data (b) for Ruddock Creek.

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	1	3	3	BT	f/p	0.004	0.004	**0.009**	0.003	0.003	**0.005**
mainstem	3	16	4	BT	f/p	0.030	0.008	**0.038**	0.022	0.006	**0.028**
Total 1+3:		19	7	Mean:		0.017	0.006	0.023	0.012	0.004	0.016

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yr)	N
1	BT	102	55 - 107	13.81	1.72 - 27.93	0.97	3	1 - 2+	2*
3	BT	106	57 - 151	13.47	2.01 - 33.58	0.98	16	0 - 2+	11
1 + 3	BT	105	55-151	13.53	1.72-33.58	0.98	19	0 - 2+	13

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available



Photo 8 Reach 1 of Ruddock Creek. Good riparian and boulder cover provides rearing habitat for bull trout.



Photo 9 Bull trout density at sample site 2 of Ruddock Creek (6 km upstream) was amongst the highest of all sites surveyed.

4.5.4 Carnes Creek

A 2 km long inlet leading from Revelstoke Lake precedes the mouth of Carnes Creek. This creek had no observed barriers on it and access to fish is only limited to the last reach of the stream where it climbs to its headwaters. The first 2 reaches of Carnes Creek flows through a steep sided, narrow Canyon for approximately 7.5 km before the valley bottom broadens upstream of the confluence with McKinnon Creek.

Reach 1 is a short flat section of stream limited to the mouth of Carnes Creek (Fig. 14)

Water velocity increases in reach 2 and gradient averages between 2.0% and 3.0%. Little off channel habitat is found in this reach but there is considerable pool area (Table 16). A large portion of low to moderately compacted gravel in the substrate provides a good spawning medium for fish, however, silt deposits from McKinnon Creek, a glacial tributary, were evident downstream from the Mckinnon/Carnes confluence. Siltation became reduced as the distance downstream from the Mckinnon/Carnes confluence increased, particularly below Kelly Creek, a lake fed tributary which had clear water at the time of sampling. Boulders and pools are the predominant form of cover in lower Carnes Creek, supplemented by turbid water.

Reach 3, the area upstream of the Mckinnon Creek confluence, represents the section of Carnes Creek with the best spawning and rearing habitat (photo 10). The stream is comprised of long runs separated by short riffles and/or pools. The bed material consists of 50% loose to moderately compacted gravel, and the cover is predominantly LOD and deep pools. Water was very clear in reach 3 at the time of sampling, and is expected to remain relatively clear during the summer since most glacial run-off is contributed from Mckinnon Creek.

Two major tributaries, Mckinnon Creek and Kelly Creek, flow into Carnes Creek at km 4.2 and km 9.1. The extent to which fish can access these tributaries is unknown, since barriers were not observed in the surveyed sections of these 2 streams.

A narrow, steep sided canyon extends about 0.5 kms upstream from the mouth of Kelly Creek. No obvious barriers were noted during the helicopter overflight of this

section although the stream climbs steeply from its confluence with Carnes Creek to the sample site (Fig. 15). Cover is provided mainly by boulders and pools (photo 11). Despite a gradient of 8.0% at the Kelly Creek sample site, loose gravel substrate commonly occurred between large boulders and cobble to form numerous "pockets" of spawning habitat. Water clarity is high, probably due to the low flows at the time of sampling and the presence of 2 small lakes on tributaries entering Kelly Creek.

Mckinnon Creek is a glacial stream, and was very turbid at the time of sampling. Accumulations of silt were evident between gravel and cobble interstices, reducing the spawning potential in reach one since gravel became compacted.

Fish

Kokanee were first observed on October 5, in reach 2, during foot surveys of Carnes Creek. Kokanee were observed again during helicopter surveys 3 weeks later in the lower portion of reach 3. Bull trout were the only other species of fish captured or observed in the Carnes system, found in both major tributaries as well as the mainstem. The highest CPUE was observed in reach 2 of Carnes Creek, although little variation existed between mainstem reaches or tributaries (Table 17a).

Griffing (unpub. data) reports both whitefish and bull trout in Carnes Creek. He also notes bull trout were captured in Mckinnon Creek upstream of reach 1.

The mean size of bull trout was larger in reach 3 than reach 2 and largest fish were found in Kelly Creek (Table 17b). Local fisherman have indicated that rainbow trout have been stocked into the lake which feeds Burke Creek, a tributary of Kelly Creek, but this can not be verified from survey results.

Scale analysis shows all fish aged from Carnes Creek were between 1 and 3 years old suggesting bull trout captured in this stream are rearing juveniles. Despite angling data collected by Griffing which suggests one bull trout, 180 mm long captured in the Carnes mainstem, was an adult (no age given), it is speculated that some, if not most, bull trout captured in the Carnes watershed are of lake stock origins.

Logging and Mining

Both logging and mining activities have and are presently occurring in the Carnes watershed. Kelly Creek had an old placer operation approximately 3 km upstream of the mouth, near site 2. Also, Jenny Gold (Cheni Mines Inc.) is presently operating an exploratory underground mine within the Mckinnon Creek drainage (Fig. 14).

Recently logged cutblocks exist on the upper slopes of the south side of Carnes Creek but are not extensive, however, logging activities are expanding into reach 3 of Carnes Creek. The five year plan submitted by Joe Kozak Sawmills indicates 151 ha of land is to be removed from the Carnes watershed by 1994, including the construction of 10.4 km of road and the placement of 4 bridges. Three of these bridges have already been placed. New road was being constructed at the time of stream surveys on the north side of Carnes Creek downstream towards Kelly Creek and also extending into upstream sections of reach 3, although, logging in each of these areas has not yet commenced. These new roads, plus the main road following the upper level of Carnes valley on the south side of the creek facilitate access to the upper watershed, but a two km long inlet preceding the mouth of Carnes Creek and the narrow steep valley in reach 1 and 2 limits access to the lower river to boat, foot or helicopter.

Enhancement Opportunities

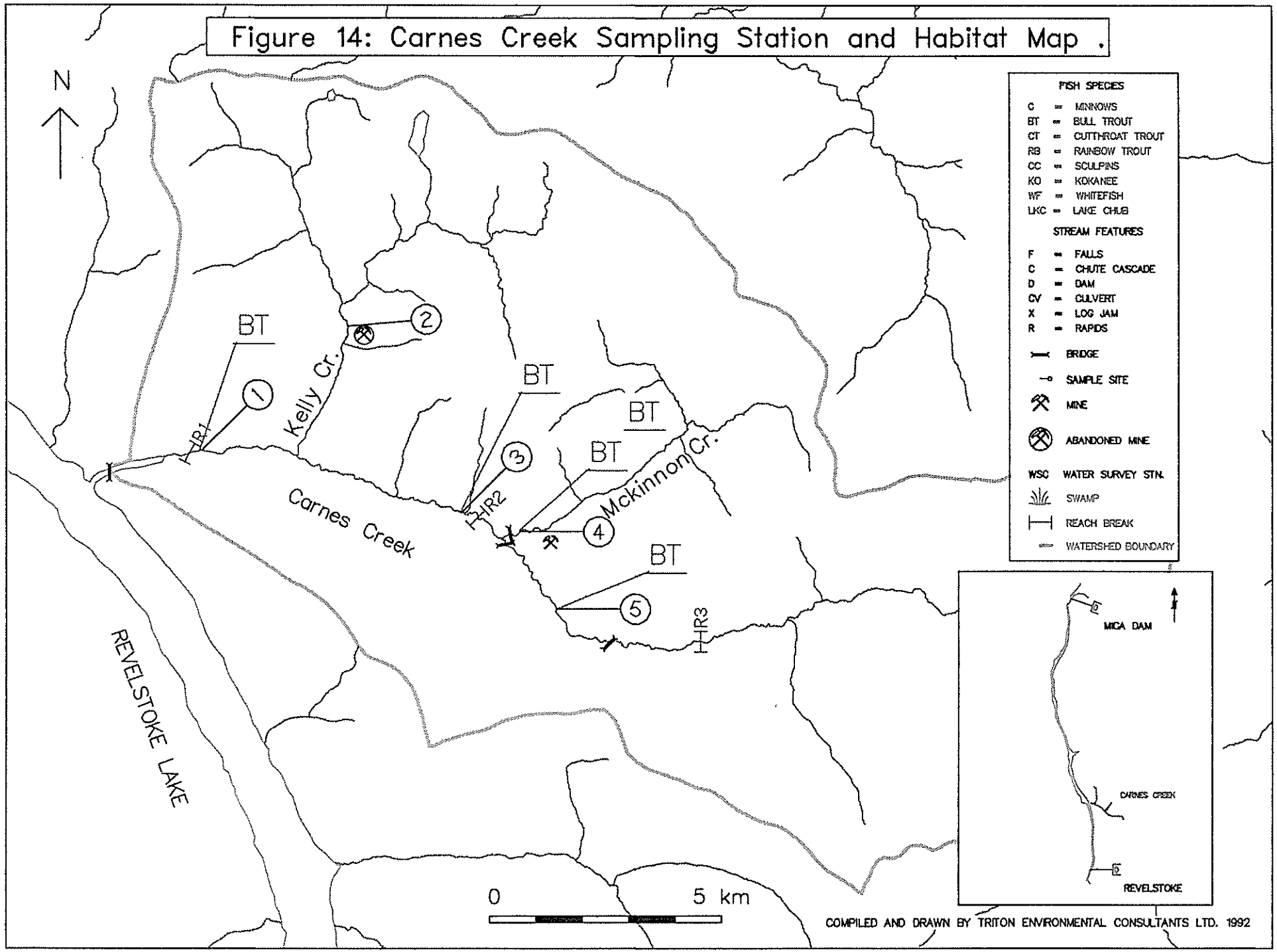
Carnes Creek is likely an important spawning and rearing stream for lake resident bull trout and kokanee. The absence of any barriers allows fish free access throughout it's length, and bull trout were observed to utilize all reaches and tributaries sampled. It is unknown if Carnes Creek, like many tributaries entering Revelstoke Lake, is being fully exploited by bull trout, but it is not unreasonable to assume that bull trout may be on the increase within this stream since the initial loss of adult spawner recruitment after the completion of the Revelstoke Dam.

Outplanting bull trout may speed the recovery of bull trout populations utilizing the Carnes system and thereby increase juvenile input into Lake Revelstoke. Increasing

rearing and spawning habitat via side channel development in reach 3 may also be considered.

The encroachment of human activities such as logging and mining may create undesired pressures upon existing habitat within Carnes Creek and thereby have detrimental effects on present fish stocks and the potential for these stocks to recover to pre-impoundment levels. For this reason, it is prudent to consider a co-operative effort between interested parties to minimize habitat degradation as an effective method to maintain fish stocks within Carnes Creek.

Figure 14: Carnes Creek Sampling Station and Habitat Map .



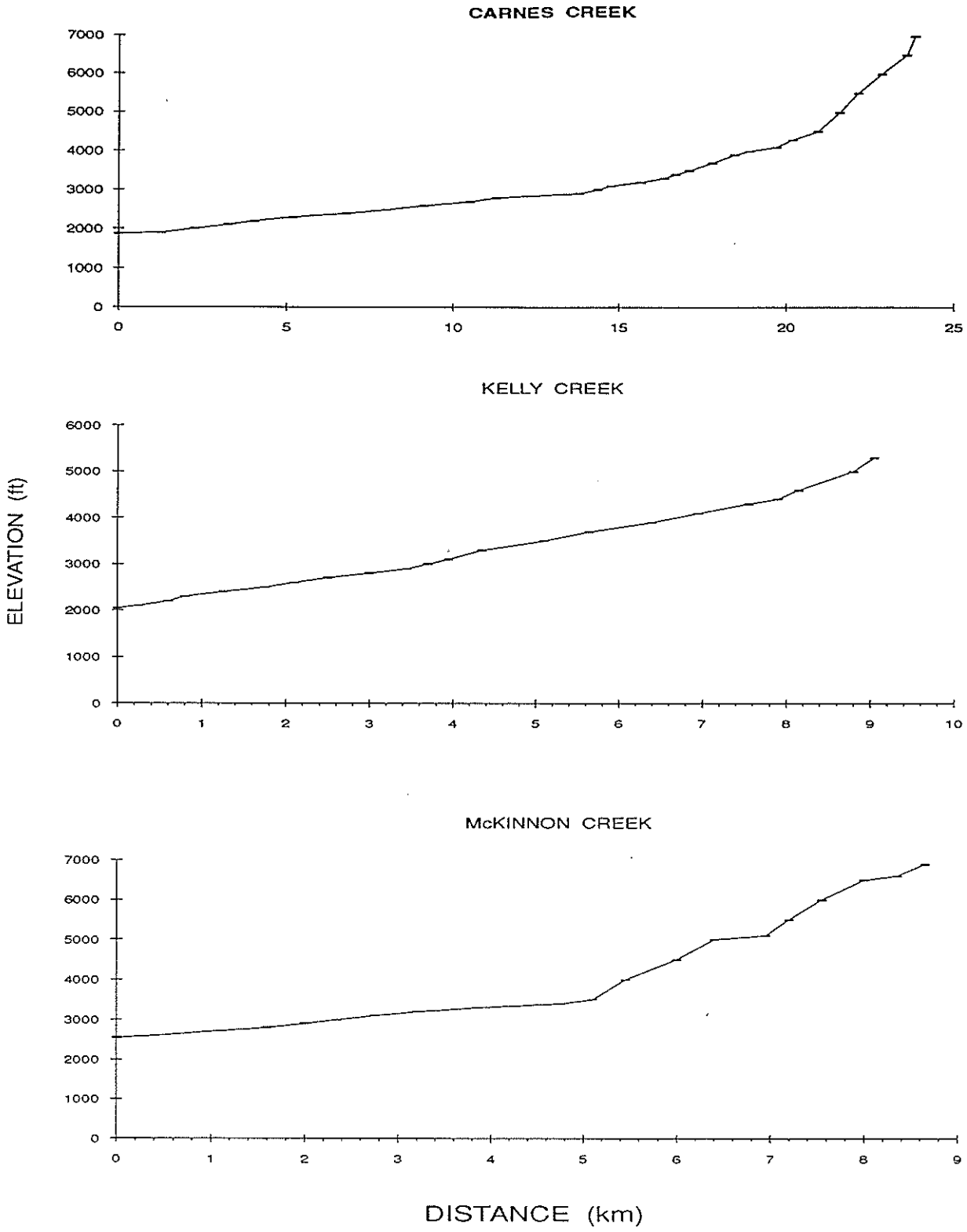


Figure 15: Stream profiles for Carnes, Kelly and McKinnon Creeks (not to scale)

Table 16: Summary of biophysical habitat parameters for Carnes Creek and its tributaries.

						COVER			STREAM CHARACTER				SUBSTRATE			VALLEY CHAR.		
Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1,3	2	2.3	7.5	110,625	44,531	dp/b/l	9,281	22,125	40,594	44,156	3,750	22,125	40,594	L	75	CO	0 - 2
mainstem	5	3	2.6	6.8	63,240	15,810	dp/b	6,324	18,972	12,648	31,620	0	15,810	31,620	M	100	UC	10 +
Total 2+3				14.3	173,865	60,341		15,605	41,097	53,242	75,776	3,750	37,935	72,214		87		
Kelly CK	2	1	8.0	3.3	53,790	16,137	dp/b	538	16,137	13,448	16,137	8,069	5,379	21,516	L	110	CO	0 - 2
McKinnon Ck.	4	1	6.6	1.6	23,840	13,112	l/b	5,960	2,384	14,304	4,768	2,384	8,344	4,768	L - M	50	OC	5 - 10
Total tributaries				4.9	77,630	29,249		6,498	18,521	27,752	20,905	10,453	13,723	26,284				
Total all sites				19.2	472,745	178,653		40,666	103,868	162,181	184,994	21,703	85,908	179,685				

Summary of geographical parameters.

Location:	Southern area of Revelstoke Lake, east side.
Length:	23.85 km
Barriers:	none
No. of Reaches:	4+
No. of Reaches Sampled:	2
Length of stream below barriers:	At least 14.3 km
Major Tributaries (in order of size):	Mckinnon Creek., Kelly Creek.
Water Source:	McKinnon Ck. = glacial, Kelly Ck. = lake & glacier CArnes Ck. = Small lakes, some glaciars.
Resource use:	Limited logging in McKinnon Creek area and upper slopes of reach 2. An exploratory mine (Jenny Gold) is presently operating in the upper slopes adjacent reach 1 of McKinnon Ck.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined; N/A = not applicable.

Table 17: **Electroshocking results (a), as well as fish size and age data (b) for Carnes Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	2	3	1	bt	f	0.006	0.002	**0.009**	n/a	n/a	**n/a**
mainstem	2	1	2	bt	p	0.011	0.022	**0.033**	n/a	n/a	**n/a**
total, reach 2		4	3	mean:		0.009	0.012	**0.021**	n/a	n/a	**n/a**
mainstem	3	4	0	bt	p	0.017	0.000	**0.017**	n/a	n/a	**n/a**
Total Mainstem:		8	3	Mean:		0.013	0.006	0.019	n/a	n/a	n/a
Kelly Ck.	1	5	3	bt	f/p	0.016	0.010	**0.026**	0.006	0.004	**0.010**
Mckinnon Ck.	1	3	2	bt	f/p	0.008	0.006	**0.014**			
Total (tributaries):		8	5	Mean:		0.012	0.008	0.020	0.006	0.004	0.010
Total Carnes System:		16	8	Mean:		0.013	0.007	0.020	n/a	n/a	n/a

Note: 30 kokanee (approx.) were observed at site 3, reach 2, during fooot surveys on Sept. 30.
Aproximately 100 kokanee were observed during a helicopter overflight on Oct. 25, 1991 in lower reach 3. upstream of the confluence of Carnes and Mckinnon Creeks.

(b) Mean lengths, weights and conditions factors.

Site/Reach	Species	Mean (mm)	Range (mm)	Mean (g)	Range (g)	Conditon (k)	N	Age (yr)	N
Carnes Ck.									
2	BT	77	57 - 135	7.70	1.80 - 25.55	0.95	4	n/a	0
3	BT	124	91 - 146	19.60	6.93 - 29.61	0.97	5	1 - 3+	3
2+3	BT	103	57 - 146	14.31	1.80 - 29.61	0.96	9	1 - 3+	
Kelly Ck.	BT	153	62 - 206	49.75	2.52 - 91.45	1.06	5	2+	3
Mckinnon Ck.	BT	111	103 - 120	18.26	18.78 - 21.40	1.37	3	1 - 3+	2
Mean (Tribs):	BT	138	62 - 206	37.94	2.52 - 21.4	1.18	8	1 - 3+	5
Mean (system):	BT	119	57 - 206	25.43	1.80 - 91.45	1.06	17	1 - 3+	8

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available



Photo 10 Reach 3 of Carnes Creek has the best habitat within the system. Turbid water seen in the foreground of the photo is run-off from new road construction.

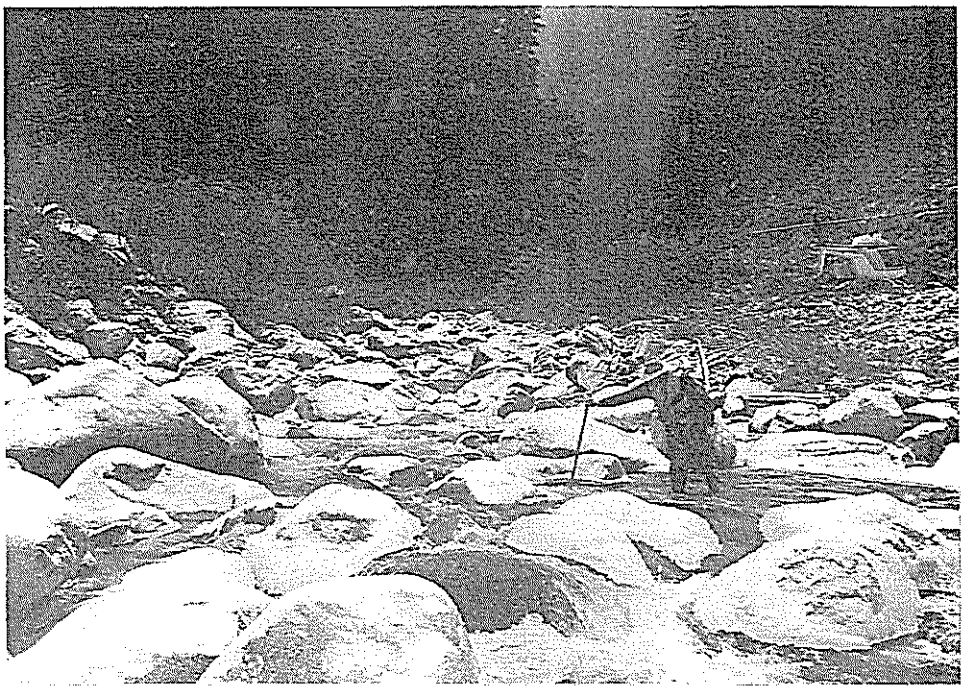


Photo 11 Cover in reach 1 of Kelly Creek is provided mainly by boulders and turbulent water.

4.5.5 Bigmouth Creek

Bigmouth Creek has the third largest watershed, behind the Goldstream River and Downie Creek, of all tributaries entering Revelstoke Lake (Table 18). It is a very turbid, glacially fed stream with numerous tributaries, the largest of which is Louis Lee Creek (Fig 16). Three smaller tributaries: Big fish Creek, Argonaut Creek and an unnamed creek (not sampled) enter the Bigmouth at km 6.3, 18.5 and 25.6 respectively. A total of 16 sites were sampled on Bigmouth Creek.

Reach one begins with a large broad flood plain prior to becoming entrenched in a short channel to create the Bigmouth estuary. Water levels in this section of stream are influenced by fluctuations in lake levels and likely effects the height of a set of rapids located 0.8 km upstream of the creek mouth (Photo 12).

Because of its length, reach 2 accounts for over 330,000 (65%) of the wetted area of those reaches sampled in Bigmouth Creek. Almost 140,000 m^2 of cover is present in this reach, primarily deep pools and LOD, complemented by turbid water (Table 18). There is considerable accumulation of fines in the bed material of reach 2. Sedimentation may detrimentally affect available spawning habitat in this reach, although loose to moderately compacted gravel occurs in the bed material of riffles. Extensive deep pool cover supplemented with boulder and LOD cover provides good habitat for rearing bull trout and white fish (photo 13).

Reach 3 is a short braided section of stream which was not sampled.

Gradient increases somewhat in reach 4 and a set of rapids and a small chute located 16.8 km upstream are located in this section, although they do not appear to be a barrier at low water.

Reach 5 flows through alder scrub marshes where off channel habitat is commonplace. This off channel habitat will likely increase in area during highwater. Deep pools substrates composed of silt and sand account for a third of the wetted area in reach 5. Riffles, which also occupy 33% of the wetted area] in reach 5. Loose to moderately compacted gravel is common to the riffles (Photo 14).

Reach 6 was not sampled.

Gradient does not vary much in reach 7 from reach 5, but the stream becomes more contained, with little side channel habitat. Pool habitat is sparse, but long riffles with loosely compacted gravel provides reach 7 with excellent spawning potential (photo 15).

Tributaries

Sedimentation due to the glacial nature of Louis Lee Creek accounts for the moderately to highly compacted substrate observed at all three sample sites on this stream. Cover at site 6 (reach 1) consisted of mostly overhead vegetation and some LOD whereas pools and large substrate were the primary cover in reach 2 (Photo 16). Cover was more sparse but also more diverse in reach 4 than reach 2. A helicopter overflight revealed a small chute about 4.8 kms upstream of the mouth of Louis Lee Creek, but it is unknown if this chute is a barrier.

Big Fish Creek was sampled near the logging road approximately 500 m upstream from its confluence with Bigmouth Creek. The gradient at this site is 8%, but numerous cascades separate small pools. Turbulence associated with cascades at the upstream ends of these pools provide good cover and the "stepwise" climb between pools facilitates upstream migration of fish (Photo 17). A substrate dominated by large cobble and boulder limits spawning habitat in reach 2 of Big Fish Creek, although the gravel which is present is loosely compacted and water is crystal clear. The upper reaches of Big Fish Creek were not explored, therefore it is unknown if a barrier exists on this stream, but reach 3 is flatter than reach 2, and presumably, has better spawning habitat.

Habitat on Argonaut Creek is limited by a 10 m falls 650 m upstream from its confluence with Bigmouth Creek. Clear water and a high proportion of gravel (50%) in the substrate provides good spawning habitat in the first 300 m of Argonaut Creek upstream of its mouth (photo 18). An extensive system of old channel beds and large amounts of LOD suggest channel course changes frequently in the lower 600 m of Argonaut Creek. Such unstable channel courses would have detrimental effects on fish utilizing the stream for rearing and/or spawning.

Numerous small tributaries flowing into Bigmouth Creek tributaries were also sampled (Table 18). Many of these tributaries, although small in size, had clear water and good gravel, however, most had culverts at road crossings. Many of the small tributaries within the first 6 km of the mouth of Bigmouth Creek are extensively in their lower reaches. Few green strips are in evidence amongst these logged tributaries. Bank erosion in logged sections of small tributaries was commonly observed. Available habitat in many of these streams is probably limited to sections prior to the start of canyons, although upstream areas were not explored to verify this.

Fish

Martin (1975) reports kokanee are the only species utilizing Bigmouth Creek, however, mountain whitefish and bull trout were encountered during sampling of this stream. Only bull trout were captured in streams tributary to the Bigmouth Creek. No kokanee were observed during field sampling or two helicopter overflights. Whitefish were observed in reach 2 and 5 but were most numerous in reach 5. Reach 2 and 5 also yielded the highest CPUE's for bull trout in Bigmouth mainstem (Table 19a).

Tributaries entering Bigmouth Creek had both a higher mean CPUE and mean density of bull trout than those found in the mainstem. The mean size of tributary fish was smaller and most were younger than fish sampled from the mainstem (Table 19b). Small tributaries likely provide important natal rearing and, presumably, spawning habitat. The importance of tributaries are rearing habitat for juvenile bull trout was especially evident in reach one of Louis Lee Creek and in the unnamed tributaries entering the Bigmouth at km 13.5 and km 17.5. In one instance (site Bgmth-5), 20 bull trout fry were captured and another 5 escaped during electroshocking an area less than 400 m^2. This represented some of the highest fish densities encountered during the course of field studies. This sample area was centered in a cutblock and streambanks were completely devoid of overhead vegetation (Photo 19). The average riffle was less than 10 cm, and like numerous small tributaries entering the Bigmouth, a culvert with a 40 cm drop to water level separated upstream and downstream sections of reach 1. Severe freezing was observed during the later part of October in this habitat, and no open water was observed. The effects of ice cover on the bull trout fry observed rearing in this

tributary earlier in the year are unknown, but high mortality is suspected. The lack of vegetative cover may have facilitated the observed freezing.

Logging

The Bigmouth Creek watershed has been extensively logged within the lower 10 km of the stream and a well developed network of roads accompanies this logging. The lower 6 km (approx) of Bigmouth Creek is within private land administered by Beaumont Timber Co. Ltd., while the upper watershed is being, or will be logged by Westar, Downie Street Sawmills and the Small Business Forest Enterprise Program. As yet, little logging has occurred within the Bigmouth drainage past km 16.5, however 5 year plans of the 3 different logging concerns utilizing the upper drainage indicate over 650 ha are to be clear-cut from the watershed between 1991 and 1993. Twenty km of new road and 3 bridges will accompany this development. New road has been constructed from approximately km 20 to km 29 and new bridges have already been placed across the Bigmouth at km 16.5, 18.5 and 29 off the main logging road, although logging has not yet begun at any of these sites.

Enhancement Opportunities

The set of rapids located 0.8 km upstream on Bigmouth Creek are within the influence of fluctuating lake levels. These rapids do not present a barrier to bull trout since reservoir levels are usually high during the period when bull trout migrate into the Bigmouth. The rapids could form a barrier to rainbow trout migration in the spring if lake levels are low. This may be, in part, one explanation why no rainbow trout were observed within the Bigmouth watershed. These rapids should be inspected at low reservoir levels. If these rapids are in fact a barrier, it is possible that minor alterations would facilitate access for rainbow trout.

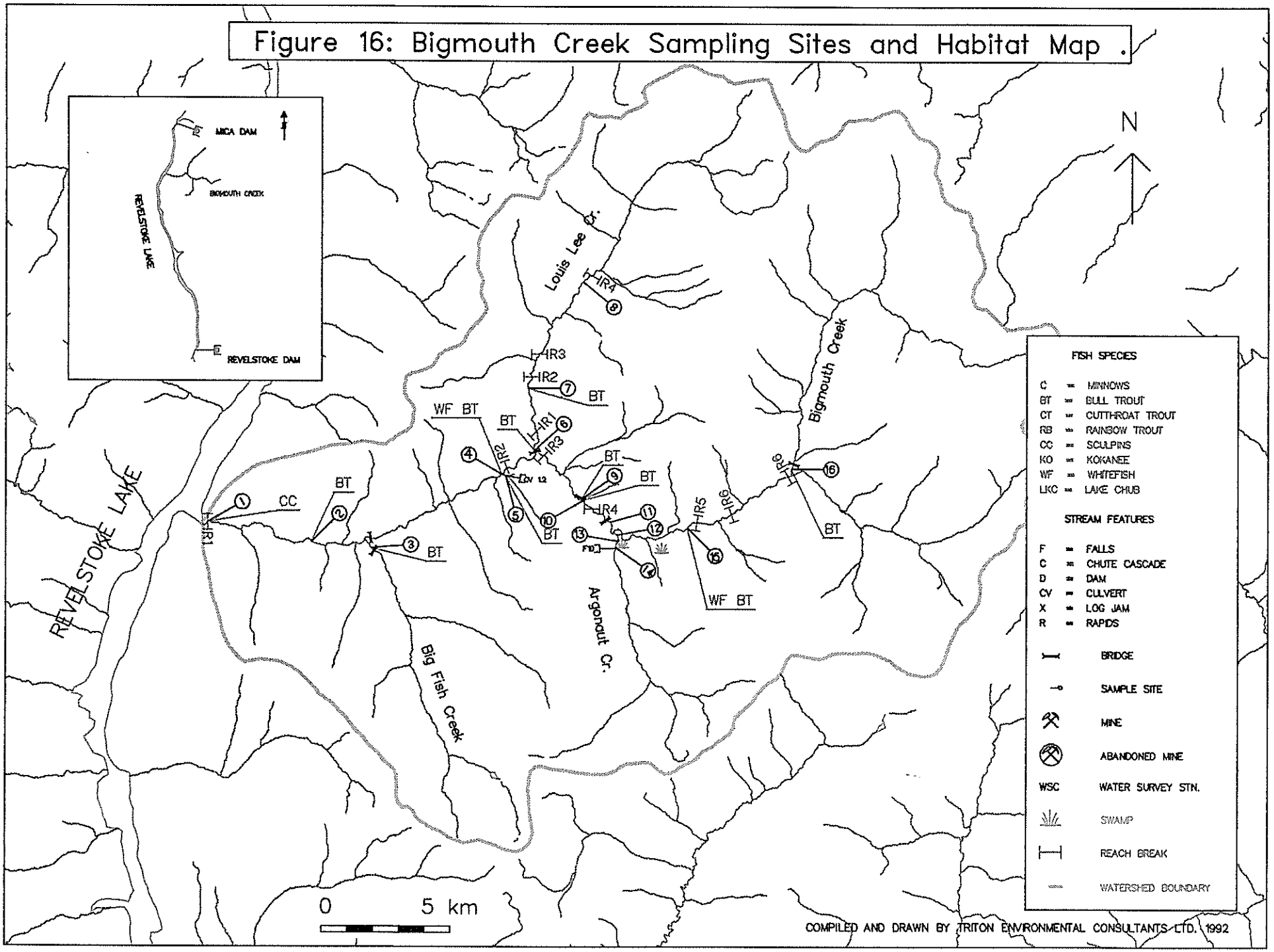
Bigmouth Creek, like Carnes Creek is probably an important bull trout producing stream. Considerable logging activity on private land within the first 6 km of this stream has all but denuded the land of vegetation (Photo 20). Numerous small clear water tributaries which enter the mainstem in this area as well as upstream areas have been left without green strips or riparian vegetation. Sampling has shown small tributaries on Bigmouth Creek provide productive natal rearing, and

consequently, spawning habitat for bull trout. This observation is consistent with the findings by Carl (1985).

Enhancement strategies should focus on identifying those small tributaries on the Bigmouth which provide or could provide habitat for bull trout. Enhancement projects should concentrate on rehabilitating these small tributaries. This rehabilitation could involve removing or modifying barriers, (such as culverts or logging slash) stabilizing banks by revegetation, and outplanting of yearling bull trout. Furthermore, it is important that companies logging within the jurisdiction of the BCFS are made aware of the importance of these small tributaries to minimize habitat degradation. One example is the use of a bulldozer to ford Louis Lee Creek in reach one at the site which was found to have some of the highest bull trout densities within the Bigmouth system. While no severe damage was done during the fording, an inquisitive worker at the site was quite surprised to learn the area of stream crossed had numerous bull trout rearing within it.

There is potential to develop estuary habitat at the outlet of Bigmouth Creek. A well developed estuary provides an important component of stream habitat available to rearing fish. The mouth of Bigmouth Creek is presently a broad flat plain, and wetted area will fluctuate with lake levels. Little natural vegetation exists in this area. This site has a low gradient and constant accretion of sediment, both of which are conducive to estuary development (Adams and Whyte, 1990). A seeding program to establish native sedges and shrubs could improve fish habitat, particularly for those juveniles species migrating into the lake from the creek. Considerable site planning should occur prior to initiating an estuary revitalization plan, the most important of which is to collect topographic data and relate this information to the cycle of fluctuation of water levels common to Lake Revelstoke.

Figure 16: Bigmouth Creek Sampling Sites and Habitat Map .



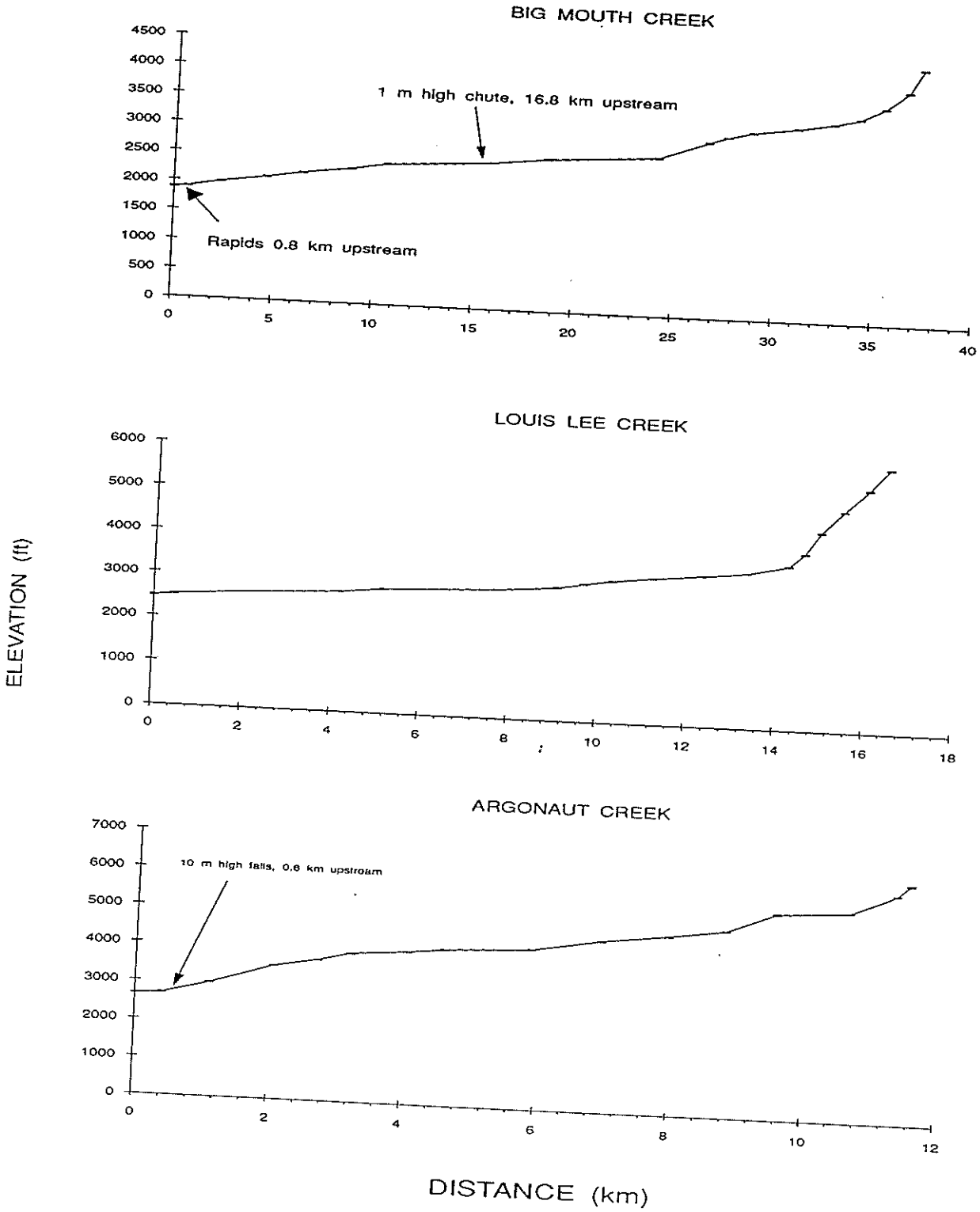


Figure 17: Stream profiles for Bigmouth, Louis Lee and Argonaut Creeks (not to scale)

Table 18: Summary of biophysical habitat parameters for Bigmouth Creek and it's tributaries.

						COVER			STREAM CHARACTER				SUBSTRATE			VALLEY CHAR.		
Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	0.8	0.8	20,800	6,240	dp/b	208	4,160	4,160	12,480	0	4,160	3,120	M	40	EN	2 - 5
mainstem	2, 4	2	1.3	12.7	365,125	138,113	dp/d/l/ov	25,400	76,994	110,331	177,800	0	127,800	65,088	L - M	40	CO-OC	2 - 5
mainstem	10	4	1.5	3.0	95,000	57,000	dp/b	2,850	9,500	57,000	28,500	0	14,250	23,780	L - M	40	CO	0 - 2
mainstem	11,15	5	1.0	5.0	133,780	66,875	dp/l/ov	14,900	40,700	48,400	45,250	0	24,200	47,800	L - M	43	OC-UC	2 - 5
mainstem	16	8	1.6	4.0+	54,400	8,160	ov	2,720	2,720	43,520	8,160	0	10,880	21,760	L	n/a	UC	10 +
Total, mainstem:				25.5	954,855	419,263		74,653	176,936	306,274	472,215	0	281,303	247,273		203		
Bigmouth Tributaries:																		
Big Fish Ck.	3	1	8.0	3.3	25,410	8,894	dp/l/b	2,541	6,353	7,623	6,353	5,082	1,271	6,353	L	100	FC	2 - 5
Trib 13.5 K	5	1	1.0	0.3	1,560	234	dp/ov/cb/l	78	234	156	234	0	156	936		70	UC	10 +
Louis Lee Ck.	6	1	0.5	0.9	8,550	1,710	ov/l	428	855	2,565	5,130	0	1,283	3,420	M	70	UC	5 - 10
Louis Lee Ck.	7	2	2.3	1.8	22,320	6,696	dp/b	2,232	5,580	5,580	11,160	0	4,464	6,696	M	75	FC	2 - 5
Louis Lee Ck.	8	5	2.3	3.7	66,600	6,660	dp/ov/l/cb	1,998	9,990	26,640	29,970	0	13,320	16,650	H	90	OC	5 - 10
Total					97,470	**15,066**		**4,658**	**16,425**	**34,785**	**46,260**	**0**	19,067	**26,766**		78		
Trib 17.5 K	9	1	9.5	0.5	2,500	1,250	dp/b	125	750	750	250	750	250	625	L	100	EN	0 - 2
Argonaut Ck.	12	1	0.5	0.3	2,520	756	cb	126	504	504	1,260	0	756	1,260	M	150	UC	5 - 10
Argonaut Ck.	13	2	2.5	0.3	1,060	424	l/dp/cb	318	424	318	318	0	212	265	L	130	UC	5 - 10
Argonaut Ck.	14	3	8.3	2.2	12,980	5,192	dp/b	649	5,192	2,596	2,596	2,596	1,298	2,596	M	150	EN	0 - 2
Total				2.8	**16,560**	**6,372**		**1,093**	**6,120**	**3,418**	**4,174**	**2,596**	**2,266**	**4,121**		143		
Total, Bigmouth Tributaries:				2.8	143,500	31,816		8,495	29,882	46,732	57,271	8,428	23,009	38,801				
Total, Bigmouth system				25.3	704,658	247,911		47,731	143,672	255,993	295,377	8,428	186,718	168,560				

...continued

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.

Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 18: Summary of biophysical habitat parameters for Bigmouth Creek and it's tributaries.

Summary of geographical parameters.

Location:	North central area of resevoir, east side.
Length:	37 km
Barriers:	Possibly at mouth (depending upon lake level), possibly at 16.5 km (seasonal?).
No. of Reaches:	9+
No. of Reaches Sampled:	5
Total Length of Sampled Reaches:	26
Major Tributaries (in order of size):	Louis Lee Ck., Argonaut Ck., Big Fish Ck.
Water Source:	Glacier
Resource use:	Mainly ds of km 16.5 but road network placed to km 29.

Table 19: **Electroshocking results (a), as well as fish size and age data (b) for Bigmouth Creek.**

Table 19 a: Electroshocking Results

Site	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE Esc. or Obs.	CPUE Total	DENSITY (Fish/m^2) Caught	DENSITY Esc. or Obs.	DENSITY Total
mainstem	1	1	0	cc	a	0.007	0.000	0.007	0.003	0.000	0.003
mainstem	2	8	5	bt	f/p	0.015	0.010	0.025	0.015	0.009	0.024
mainstem	2	7	7	bt	f/p	0.015	0.015	0.030	0.004	0.004	0.008
mainstem	2	1	0	wf	f	0.002	0.000	0.002	0.001	0.000	0.001
total, reach 2:		**16**	**12**	**Mean**		**0.011**	**0.008**	**0.019**	**0.006**	**0.004**	**0.011**
mainstem	4	1	2	bt	p	0.008	0.016	0.024	0.003	0.007	0.010
mainstem	5	5	5	wf	a?	0.012	0.012	0.025	n/a	n/a	n/a
mainstem	5	7	5	bt	a?	0.017	0.012	0.030	n/a	n/a	n/a
total, reach 5:		6	5	Mean		0.015	0.012	0.027	n/a	n/a	n/a
mainstem	7	0	5	bt	p/a	0.000	0.014	0.014			
Total (mainstem):		24	24	Mean:		0.008	0.010	0.018	0.004	0.004	0.008
BIGMOUTH TRIBUTARIES											
Big Fish	1	3	4	bt	p	0.008	0.010	0.018	0.002	0.006	0.009
13.5 km Trib	1	20	5	bt	f	0.081	0.020	0.102	0.059	0.015	0.074
Louis Lee	1	19	4	bt	f/p	0.029	0.006	0.035	n/a	n/a	n/a
Louis Lee	2	4	1	bt	f/p	0.016	0.004	0.020	n/a	n/a	n/a
Louis Lee	5	0	1	bt	p	0.000	0.003	0.003	0.000	0.001	0.001
Total(Louis Lee)		23	6	Mean		0.015	0.004	0.019	0.000	0.001	0.001
17.5 km Trib.	1	6	6	bt	f/p	0.033	0.033	0.066	0.018	0.018	0.036
Argonaut	1	1	0	bt	f	0.004	0.000	0.004	n/a	n/a	n/a
Argonaut	2	0	1	u/s	-	0.000	0.006	0.006	n/a	n/a	n/a
Total (Argonaut):		1	1	Mean		0.002	0.003	0.00466	n/a	n/a	n/a
Total (Tributaries):		53	22	Mean:		0.028	0.014	0.042	0.029	0.008	0.038

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb,
n/a = not available

Table 19 b: Size and age data for fish captured in Bigmouth Creek and its tributaries.

Site/Reach	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range	N
Bigmouth mainstem									
2	BT	79	40 - 145	7.50	0.59 - 31.84	0.98	8	1+	3*
2	WF	58	-	1.68	-	0.86	1	n/a	-
4	BT	86	-	6.11	-	0.96	1	n/a	-
5	BT	179	153 - 241	>62.77	34.93 - >120.00	1.04	7	3+	4
2+4+5	BT	110	40 - 241	24.26	0.59 - >120.00	0.99	16	1 - 3+	7
Tributaries									
Argonaut Ck.	BT	42	-	0.70	-	0.94	1	n/a	-
Louis Lee Ck.									
1	BT	84	43 - 124	7.22	0.80 - 1.55	0.99	19	n/a**	-
2	BT	92	45 - 125	9.77	0.82 - 18.53	0.93	4	2+	2***
Mean (1+2):		**86**	**43 - 125**	**7.66**	**0.80 - 1.55**	**0.98**	**23**	**2+**	**2***
13.5 km Trib.	BT	71	66 - 75	3.45	2.77 - 4.86	0.93	20	n/a	3****
17.5 km Trib	BT	75	53 - 100	5.16	1.42 - 10.4	0.96	6	1+	3
Big Fish Ck.	BT	152	-	28.38	-	0.81	1	2+	1
Mean all Tribs:	BT	79	43 -125	5.99	0.82 - 28.38	0.97	51	1 - 2+	9
Mean: Bigmouth system	BT	89	40 - 241	11.66	0.59 - >120.00	0.98	67	1 - 3+	16

* 5 of 8 scale sample were unreadable.
** 6 scale samples were unreabable
*** For fish > 116 mm only.
**** all scales samples were unreadable.
Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb,
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available

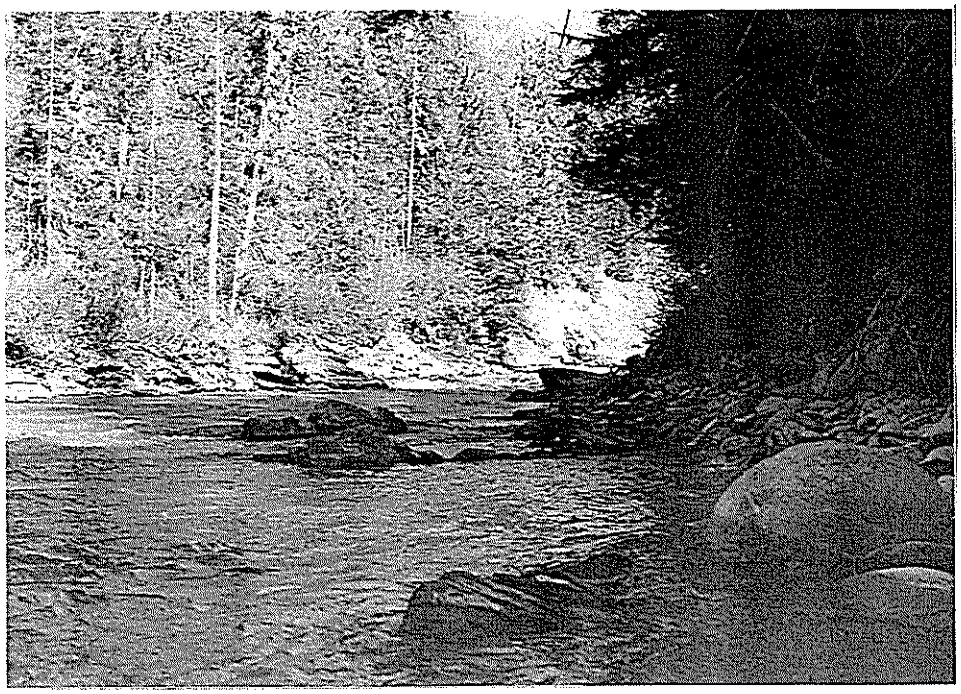


Photo 12 A set of rapids near the outlet of Bigmouth Creek (centre of photo) may be a barrier when lake levels are low.

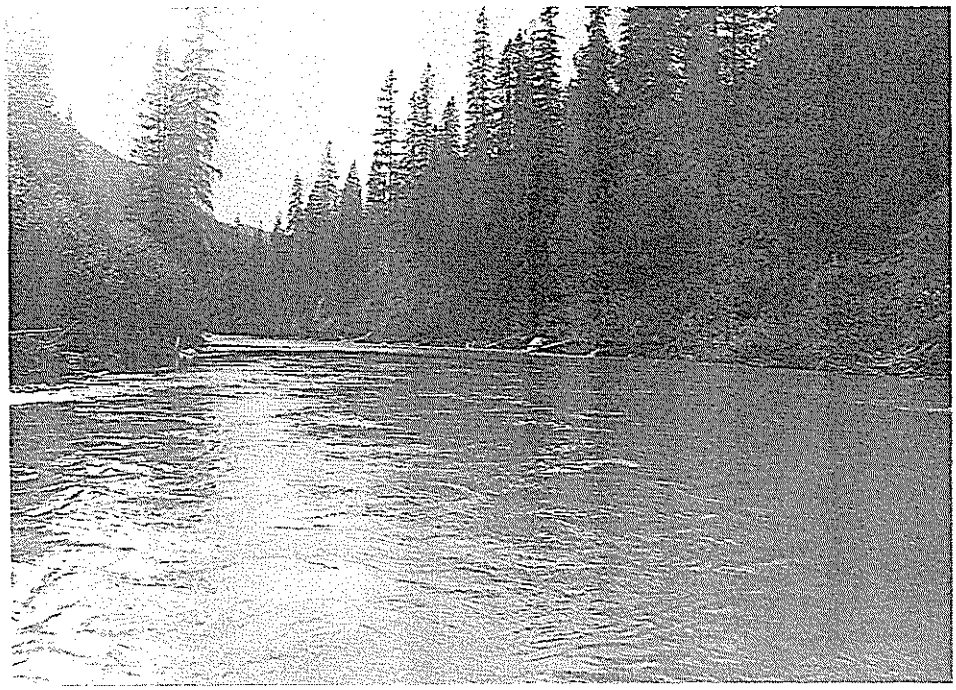


Photo 13 Long stretches of slow moving turbid water and some boulders near stream margins provided cover for both bull trout and whitefish captured at site 4, 13.5 km upstream.



Photo 16 This stretch of Louis Lee Creek, near its confluence with Bigmouth Creek, was home to numerous bull trout yearlings.



Photo 17 Although steep in gradient, reach 1 of Big Fish Creek rises in a series of steps which facilitate upstream movement of bull trout.



Photo 14 Whitefish and bull trout were abundant in pool habitat within reach 5 of Bigmouth Creek.



Photo 15 Gravel dominated the substrate in reach 8 of Bigmouth Creek, although little off channel was present.

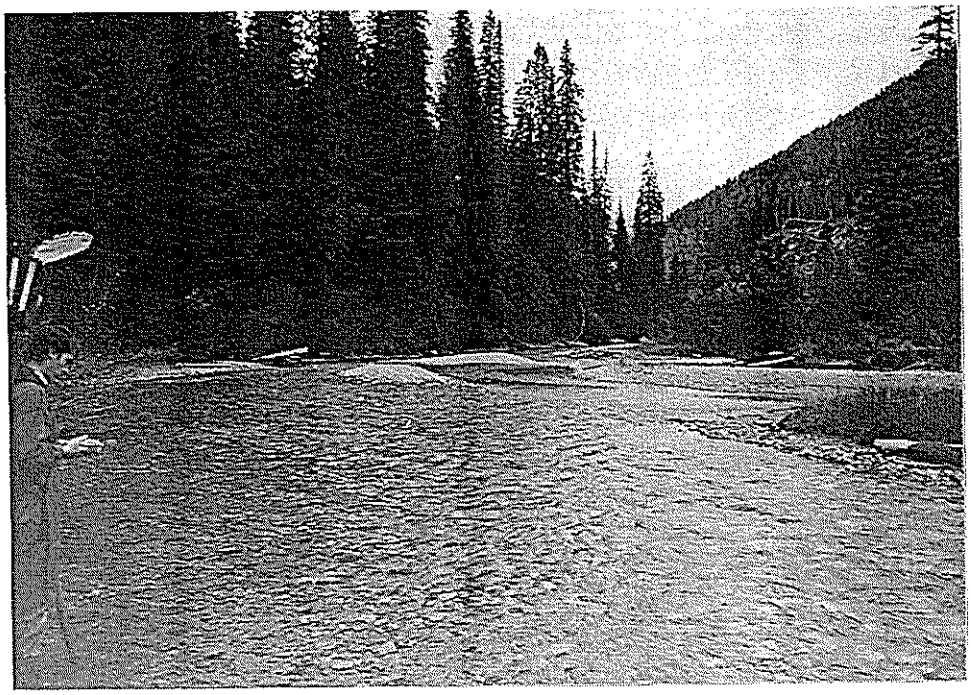


Photo 18 The mouth of Argonaut Creek contains expansive gravel beds, although most of the gravel was compacted.

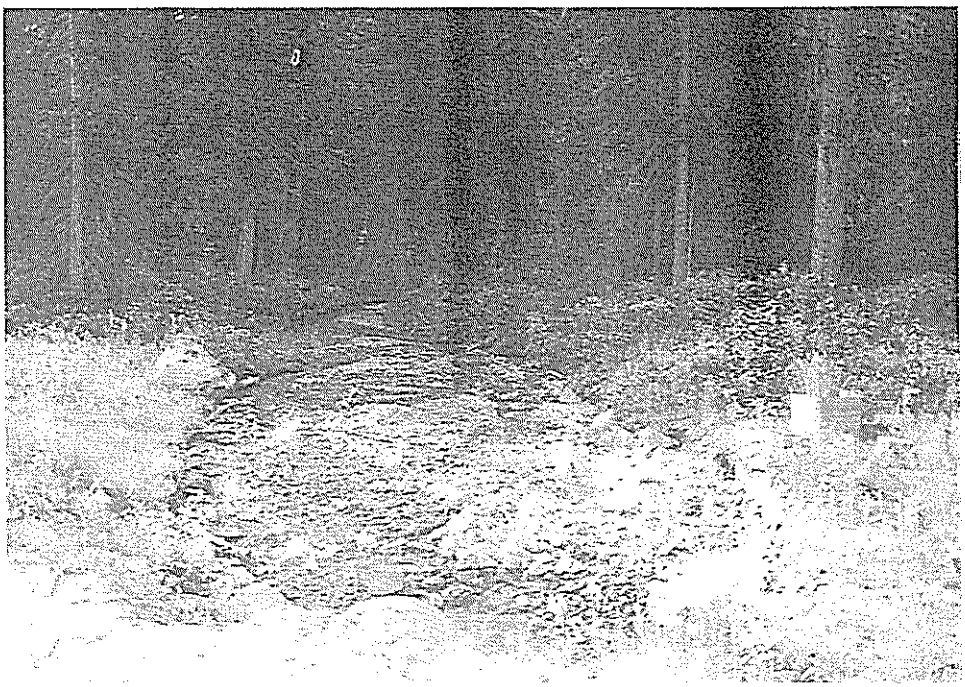


Photo 19 Despite its size and lack of cover, this small tributary entering Bigmouth Creek at km 13.5 had the highest concentrations of yearling bull trout of all sites sampled during field surveys.



Photo 20 Extensive logging has occurred on private land adjacent the lower 6 km of Bigmouth Creek, leaving little in the way of a green strip.

4.5.6 La Forme Creek

La Forme Creek is a relatively low gradient stream entering the east side Revelstoke Lake reservoir, 22 kms upstream of the dam (Fig. 18). The creek flows through a narrow constriction 400 m upstream of its mouth, but this is passable to fish (Photo 21). The stream was once blocked to fish migration due to the presence of a 5 m culvert located 1.6 km upstream of its mouth (Martin, 1976), however, this section of creek has since been flooded and the Big Eddy Highway bridge has replaced the culvert.

An old dam 5 kms upstream from the mouth, approximately 4 to 5 m high, forms a partial barrier to fish migration but the structure is passable since a small side channel south of the mainstem circumvents this obstruction (Photo 22). The structure is part of a water works associated with an abandoned ghost town and mine.

Reach 1 is a short section of stream which flows through a small gorge at the mouth of La Forme Creek. This constriction has resulted in the formation of a small logjam near the creek outlet, but it is not a barrier to fish migration.

Reach 2 follows a steep sided canyon for most of its length and has little pool habitat. This probably limits the rearing potential in reach 2, and possibly makes gravel more prone to shifting during high flow. A fire through reach 2, which occurred approximately 50 years ago (pers. comm., R. Mohr, Professional Forester BCFS, Revelstoke Office), has reduced riparian cover, and, unstable banks marked by erosion and small slides are common in this area. Numerous talus slopes and two small landslides were observed in the first 1 km of reach 2.

Reach 2 and 3 both have similar gradients and wetted areas, although reach 3 appears to have less gravel than reach 2 (Table 20). This observation is misleading however, since ice conditions at the time of the reach 3 survey hampered viewing substrate at the sample site 3, and the presented values for this reach likely underestimate actual totals. Furthermore, cobble and gravel in the lower reach is quite angular. opposed to rounder smoother substrate observed in reach 3. Numerous small pools also provide cover, and act as traps to stabilize gravel. Well

developed riparian vegetation and a large percentage of boulder/cobble substrate provides ideal cover and rearing habitat in reach 3 (photo 24).

Fish

Bull trout were the only species observed in La Forme Creek, and were captured at every site sampled, although the highest concentrations of fish were recorded in reach 3 (Table 21). Martin (1975) reports that local fisherman believe a resident Dolly Varden, presumed to be bull trout, population exists in La Forme Creek but this cannot be confirmed, however, the creek presently has no migrational barriers to lake resident fish.

A CPUE of 0.07 fish/sec and a fish density of 0.37 fish/m^2 in reach 3 were amongst the highest of all tributary sites sampled. Neither ground surveys nor helicopter overflights revealed any kokanee in La Forme Creek, although, over 800 kokanee were enumerated in this stream prior to the creation of the reservoir (Martin, 1975). Martin also indicates limited utilization by rainbow in this system.

Logging and Mining

There is presently no logging in the La Forme drainage, although the 5 year small business plan does anticipate logging to begin in 1995, when 87 ha of land are to be clear cut.

A road following the south ridge of La Forme Creek which once serviced the abandoned mine and community, is now accessible by vehicle for 2 km before slides block the route. The road does not drop to creek level until the site of the waterworks dam where a bridge used to exist. Five km of new main line logging road is planned for the La Forme Creek watershed, and this road will likely follow the existing old road. The mouth of La Forme Creek is accessible by boat or foot only.

Enhancement Opportunities

Enhancement of La Forme Creek should include removing the old waterworks dam at km 5. Although access to this site is restricted, a small crew using chain saws and

dynamite should be able to remove this partial barrier. Removing the dam prior to spring freshet will facilitate distributing gravel, retained behind this structure, to downstream locations in reach 2 when spring melt occurs. The mouth of La Forme Creek should be monitored to ensure debris does not accumulate at the constriction in this area to form a migrational impasse, after removal of the dam. The potential for blockage at the mouth of La Forme Creek may be decreased by blasting out a large rock which forms part of the constriction.

Rearing habitat in reach 2 would benefit from habitat complexing to create more pool habitat, while helping to retain gravel. Likewise, rehabilitating the riparian vegetation in this area by planting species resident to the area, such as alder, willow and red osier dogwood, would help stabilize streambanks and provide valuable overhead cover for rearing bull and/or rainbow trout.

Finally, like other unlogged or partially logged systems, efforts must be made to ensure future logging plans do not impact upon heavily utilized habitat and/or any enhancement structures. This is particularly applicable to road construction into the La Forme watershed. The old cart trail presently accessing the watershed has had numerous small slides cover as well as originate from it. A major slide within reach 2 of La Forme Creek will add undesired sediment into the stream, but may also prevent passage to fish migrating into productive reach 3 habitat, therfore, new road building activities should not follow the old road grade.

Figure 18: La Forme Creek Sampling Sites and Habitat Map .

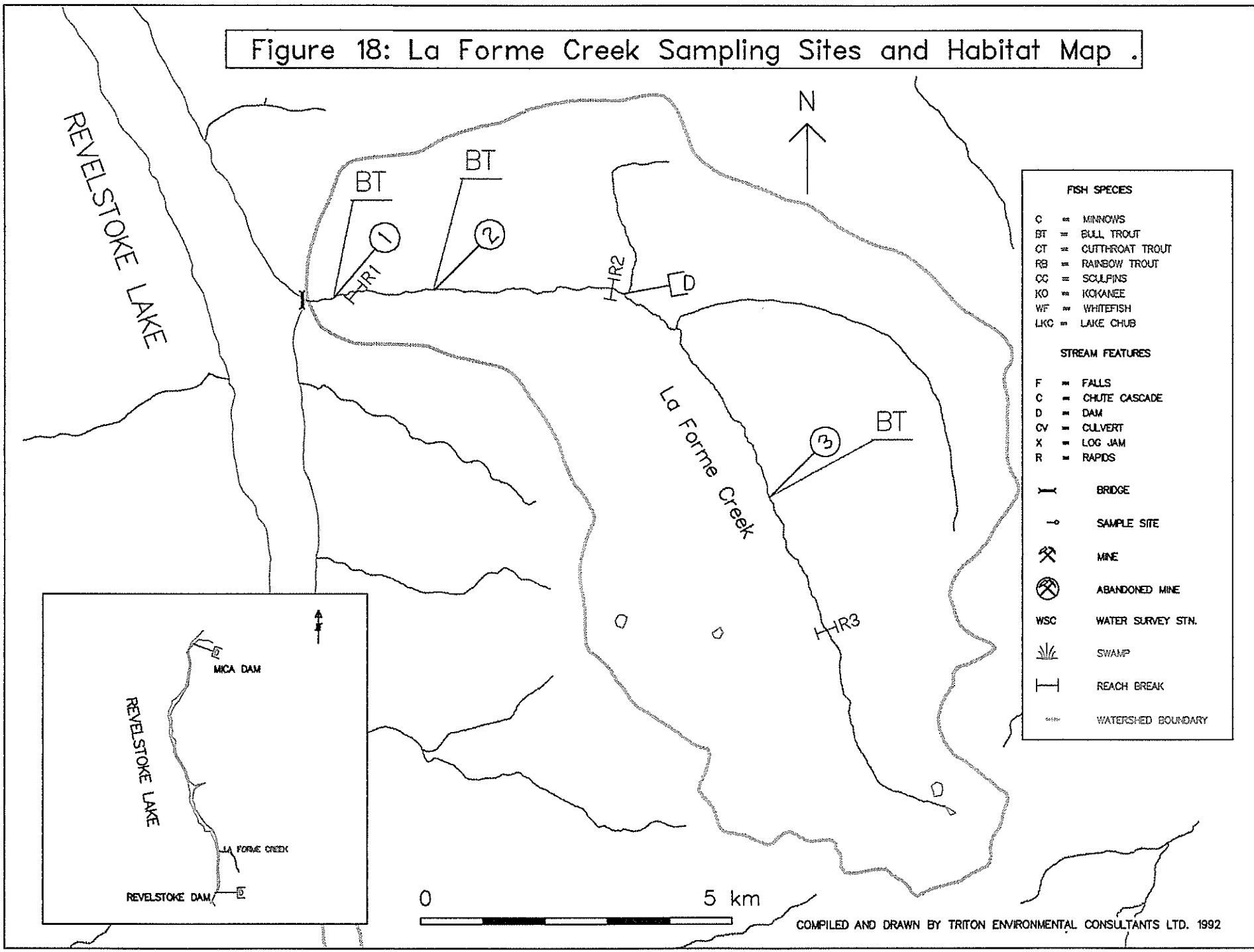


Fig 19: Stream profile for La Forme Creek (not to scale)

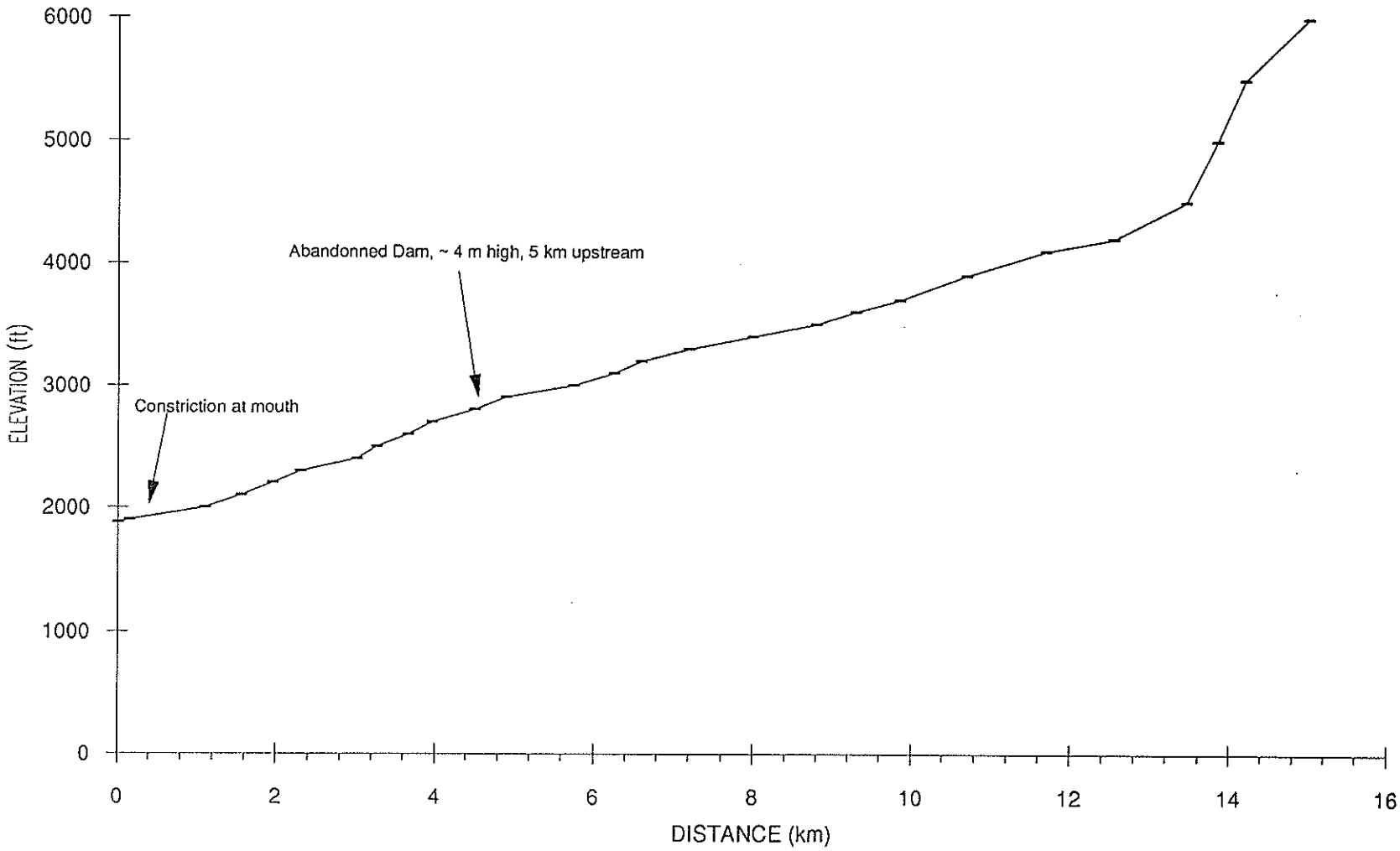


Table 20: Summary of biophysical habitat parameters for Laforme Creek.

						COVER			STREAM CHARACTER				SUBSTRATE			VALLEY CHAR.		
Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	4.0	0.8	8,240	2,472	dp/b	412	2,472	1,648	2,472	1,648	412	1,648	L	150	CO	0 - 2
mainstem	2	2	5.8	4.1	51,250	7,688	dp/b	513	10,250	23,063	15,375	2,563	2,563	12,813	L	150	EN	0 - 2
mainstem	3	3	6.0	6.1	52,460	20,984	b/ov	1,049	5,246	34,099	13,115	0	2,623	7,869	M	60	CO	0 - 2
Total				11.0	111,950	31,144		1,974	17,968	58,810	30,962	4,211	5,598	22,330		120		

Summary of geographical parameters.

Location:	Southern area of Revelstoke Lake, east side.
Length:	15 km
Barriers:	Old water works dam 5 km us forms a partial barrier.
No. of Reaches:	4
No. of Reaches Sampled:	3
Total length of stream below barriers	~ 13 km
Major Tributaries:	None
Water Source:	Numerous small lakes and ponds in the headwaters.
Resource use:	Abandoned mining town at 5 km, abandoned mine in upper reaches of tributary entering Laforme Ck. at km 5. An old fire burn exists on either side of the creek in reach 2. No logging activities at present time.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 21: **Electroshocking results (a), as well as fish size and age data (b) for Laforme Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	1	3	2	BT	p	0.013	0.009	**0.022**	n/a	n/a	**n/a**
mainstem	2	1	3	BT	p	0.004	0.013	**0.018**	n/a	n/a	**n/a**
mainstem	3	6	7	BT	p	0.032	0.038	**0.070**	0.170	0.200	**0.370**
Total:		10	12	Mean:		0.017	0.020	0.037	0.170	0.200	0.370

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range	Age Range	N
2	BT	183	124 - 228	>70.28	17.43 ->120.00	1.00	4	1 - 4	1 - 4	4
3	BT	166	125 - 218	>51.55	20.50 ->120.00	0.97	6	1 - 3	1 - 3	5*
2 + 3	BT	156	125 - 228	>46.39	17.43 ->120.00	0.98	10	1 - 4	1 - 4	9

* 1 scale sample unreadable

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available



Photo 21 A constriction at the mouth of La Forme Creek has potential to collect debris, but is passable to fish migrating from Lake Revelstoke.

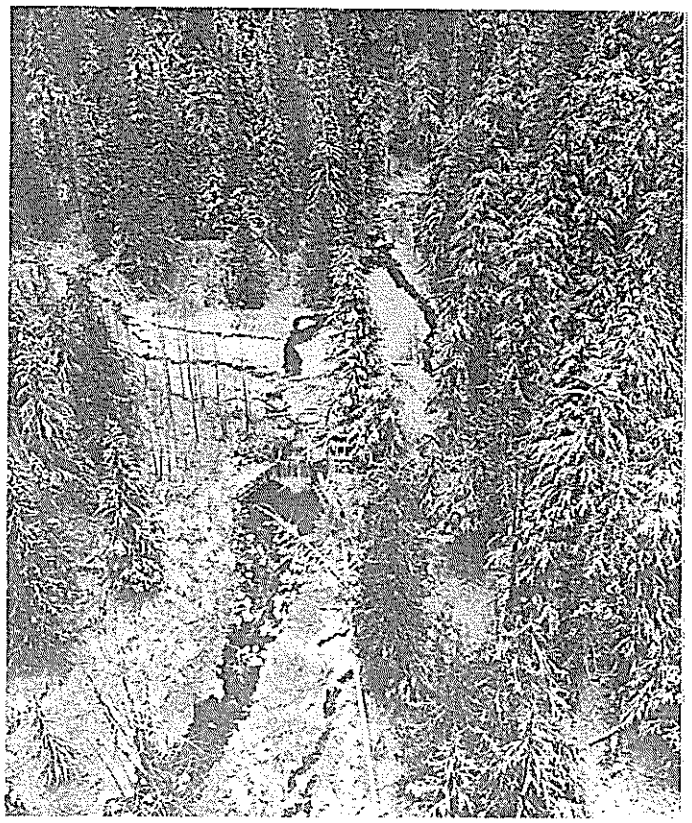


Photo 22 An old waterworks dam 5.0 km upstream on La Forme Creek may be a partial barrier to fish migration, although a small side channel (right of the structure) probably allows fish passage upstream.

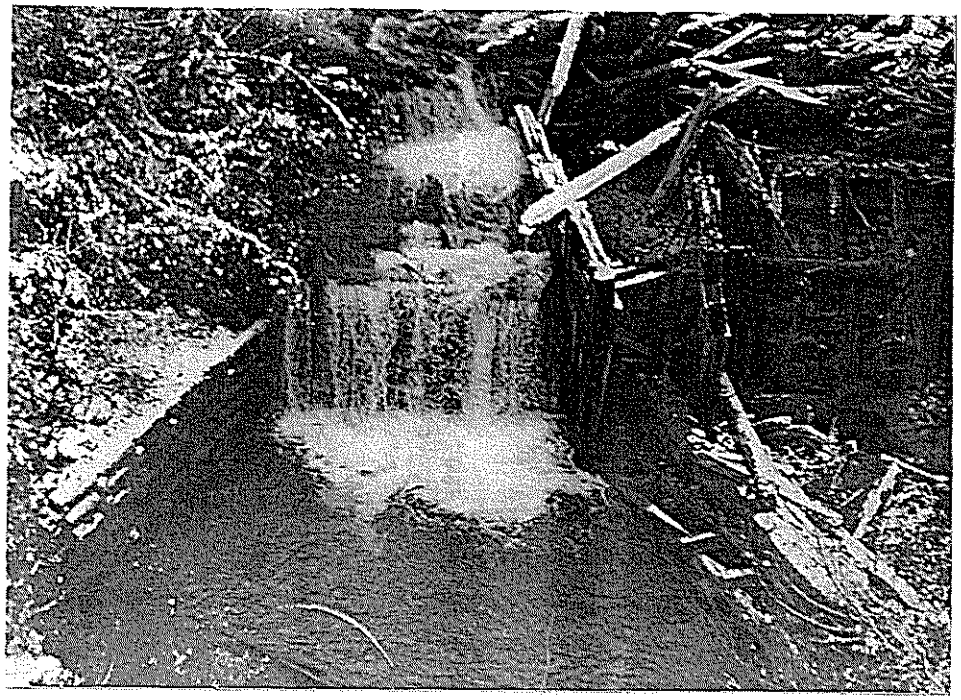


Photo 23 A closer view of the dam shown in photo 39.

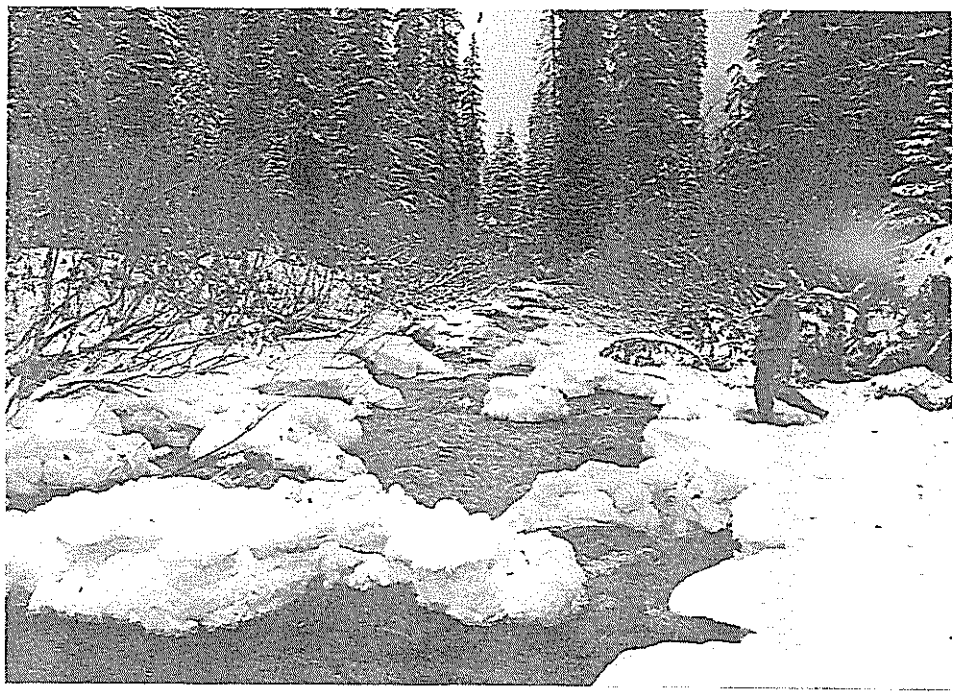


Photo 24 Healthy riparian vegetation and extensive surface ice provide good cover at site 3 (Reach 3) on La Forme Creek for rearing bull trout.

4.5.7 Downie Creek

Downie Creek is over 45 km long and has a watershed area of 60,500 ha, making it the second largest tributary entering Lake Revelstoke (Table 6). Approximately 10 km of Downie Creek was submerged when Revelstoke Lake was created. A gorge located 16.5 km upstream of the mouth, near the confluence of Downie Creek's largest tributary, Sorcerer Creek, is also the location of a series of chutes and falls (Fig. 20). These chutes\falls probably form a barrier to fish passage (Photo 25, 26). The largest single chute drops approximately 3.5 m over 30 m of stream length. During low water, some of the larger bull trout may be able to negotiate this section of Downie Creek, but it is unlikely that kokanee can do so. It is also unknown if rainbow trout can migrate past these impediments in the spring during high water.

Water clarity during the time of sampling was high, but Downie Creek, like many of its tributaries, is a glacier fed stream and runs turbid except from late fall through to early spring. Standard Creek is a notable exception, being fed by small lakes and snowmelt.

Downie Creek can be divided into 7 reaches, 2 below the barrier and 4 above, with the gorge forming its own reach. Approximately half of Downie Creek's estimated 753,000 m^2 wetted area is located below the barrier (Table 22). Reach 2 (below the barrier) and 5 (above the barrier) provide the most extensive habitat on Downie Creek, accounting for over 80% of the wetted area of the reaches sampled. These two reaches also have the lowest gradients and offer the best rearing and spawning habitat within the Downie mainstem (Fig. 21). Reach 2 and 5 are very similar, each meanders through broad marshy valley bottoms where LOD accumulates. Beaver activity is not uncommon within the marsh and side channel areas of these reaches (photo 27). The estimated area of gravel in the substrate is similar between these reaches, although sediment accumulation is more pronounced in reach 5.

Reach 1 and 4, although steeper in gradient and relatively short when compared to reaches 2 and 5, likely provide potential and rearing habitat. Gravel composition varies from 25% of the bed material in reach 1 to 35% of the bed material in reach 4.

Gravel is, for the most part, uncompacted in all these reaches, although compaction varied upon where one sampled. Gravel was generally more compacted at the downstream ends of pools and runs, whereas it was less compacted at the upstream areas of pools and runs and, in riffles.

Downie Creek has numerous small tributaries that enter it throughout it's length. Ten sites, on 7 different tributaries were surveyed. Most of these tributaries contribute a small discharge during low flow conditions, but all show evidence of flooding and bank erosion, probably incurred during spring run-off. Some of the smaller tributaries have multiple channels and extensive debris accumulations. All the tributaries sampled, aside from Sorcerer and possibly Standard Creeks, flow from steep, confined valleys or canyons, leaving only short sections near their confluence with the Downie mainstem accessible to fish.

The largest of these tributaries, Sorcerer Creek, has a set of barriers within the first 0.5 km of its confluence with Downie Creek and again at 8.3 km upstream (photo 28, 29). It is unlikely any species can migrate past these barriers, especially at high water. Reach 2 and 3 of Sorcerer Creek, both upstream of the first barrier, probably represent the best spawning and rearing habitat in this creek.

Standard Creek, Downie Creek's second largest tributary, has a logjam 0.65 km upstream of its confluence with the Downie mainstem (photo 30). Although this logjam forms a barrier at low water, multiple dry side channels in this area may allow access above this barrier during highwater. Extensive LOD combined with numerous small pools in reach one of Standard Creek provides excellent cover for rearing salmonids. It is unknown if there is a barrier in the canyon which forms reach 2, but numerous small pools are separated by small cascades, so that the ascent up Standard Creek to higher elevations upstream of the reach 2 sample site proceeds as a series of "steps" (photo 31). The stepwise nature of reach 2 of Standard Creek may facilitate fish migrating upstream of the canyon, although, the gradient profile for this stream indicates a steep ascent (Fig. 21).

Smaller tributaries such as Belcher, Pass, Long and two unnamed creeks are clear water streams with suitable salmonid rearing and spawning habitat within the first few hundred metres of their confluences with Downie Creek. The most promising of these streams is Pass Creek, which flows into the Downie mainstem upstream of

the 16.5 km barrier. It has a short braided section with a substrate comprised mainly of gravel near its mouth followed by a steeper section where diverse cover accounted for over 30% of the wetted area. A culvert separates the lower section of reach 2 from the upstream area, prior to the creek's ascent up a narrow, steep canyon (Photo 32).

Common to all the small tributaries entering Downie Creek are culverted road crossings. The drop from the outlets of these culverts to the creek water level varied between 0.2 and 0.4 m. Only Long Creek had a bridge over it. An unnamed Creek 4.9 km upstream on Downie Creek had a culvert angled approximately 20 degrees to the plane of the water. The extent to which culverts on these small creeks impede fish movements depends on water velocity through the culvert (which will vary with changes in seasonal discharge), the height of the culvert outlet above water levels, the depth of water running through the culvert and the size of the fish attempting to migrate through the culvert (Adams and Whyte 1990). High flows can even prevent adult fish from passing through such obstructions. This may have more of an impact on rainbow trout since this species typically migrates upstream to spawn prior to, and during spring freshet. Culverts probably restrict the upstream movement of rearing fry and par of both bull and rainbow trout species.

Site surveys on Downie Creek occurred during a cold spell at the end of October, providing an insight on how various sections of the Downie mainstem and its tributaries reacted to cold weather. Winter conditions varied considerably between individual tributaries and between the Downie mainstem and tributaries. Anchor ice and shore ice was common in many of the tributaries, although some were more prone to freezing than others, regardless of discharge. A small unnamed tributary at km 4.9, about 2 km downstream of Long Creek, had a water temperature of 0.5° C and had no ice formations on it in spite of very low discharge (photo 33). Freezing at Long Creek, a much larger tributary, was particularly severe. Long Creek was almost entirely covered with surface ice and anchor ice was also present (photo 34). Ice formation in Downie Creek was not as extensive as in its tributaries, and ice was generally confined to the margins of the mainstem. Ice forming on top of the water surface may provide additional cover from predators, but the formation of anchor and frazzle ice constricts open water, and reduces available area for overwintering fish.

Fish

Similar to Bigmouth Creek, sample sites on tributaries of Downie Creek typically had much higher CPUE's and fish densities than those observed at mainstem sites, suggesting tributaries form an important component of the habitat available to rearing salmonids in the Downie watershed (Table 23). Although the total rearing area in the tributaries sampled does not amount to that available in the mainstem, many of the tributaries had fish in them. Some notable exceptions were observed. No fish were captured or observed during sampling of Sorcerer Creek, although there are angler reports of adult bull trout being captured in Sorcerer Creek above the 0.4 and 0.5 km barriers (pers. com. Don Monk, owner/operator Downie R. V. Resort).

Some of the highest fish concentrations in the Downie Creek system were observed in Pass Creek and Standard Creeks. Only bull trout were observed in Pass Creek, which enters Downie Creek upstream of the 16.5 km barrier. Rainbow trout, bull trout and spawning kokanee were observed in reach 1 of Standard Creek, which enters Downie Creek downstream of the 16.5 km barrier. Bull trout and rainbow trout may have followed spawning kokanee into reach 1, but bull trout were also observed above a barrier at 0.65 km, well upstream of the observed limit of migration for kokanee.

Approximately 400 kokanee were observed in the mid to upper sections of reach 3 of Downie Creek and reach 1 of Standard Creek during a helicopter overflight on October 25. Kokanee were again noted in these two areas during ground surveys on October 28. It was apparent during ground surveys that kokanee relied heavily upon LOD as cover, hence it is expected kokanee numbers were underestimated during the aerial survey. Still, large schools of kokanee were not observed, and the overall run size is probably much reduced from that observed 2 years previous.

Not all sites sampled on the Downie Creek mainstem yielded fish. Most of the fish observed in Downie Creek were in reach 2 near the 15 km bridge. In addition to those fish captured during electroshocking, a school of approximately 50 whitefish and 25 kokanee were observed at the reach 2 sample site.

Local information from Ministry of Forest crews has also indicated the isolated observation of a single sturgeon in the shallows of Downie Arm, near the mouth of Downie Creek, during helicopter overflights (pers. comm. R. Mohr, BCFS).

Logging

The Downie Creek watershed has been extensively logged downstream of km 22. Some higher elevation logging is occurring in the Standard Creek watershed, but most of the observed logging activities are restricted to the valley floor or mid slope areas. Downie Creek is accessible by road for 29 km, and a road also parallels Sorcerer Creek for most of its length. The extent of logging in Sorcerer Creek was not observed, although it appears this drainage is just beginning to be developed. Bank erosion originating from a logging road at km 2.3 on Sorcerer Creek has input slash and other debris to create a small constriction in the creek (Photo 35). This raises the concern of side casting debris and slash during road construction when roads follow steep valleys or canyons. In many instances, such a procedure invariable leads to debris input into the stream.

In most instances, cutblocks along Downie Creek have ample green strips, but the same can not be said of tributaries. It is apparent from the lack of green strips alongside these small streams that the value of many tributaries entering Downie Creek as fish producing streams is unknown, therfore, not considered important.

Westar and the Small Business Forest Enterprise Program have plans to clear cut a further 887 ha of land within the Downie Creek watershed between 1991 and 1994. This includes approximately 145 ha. from the Sorcerer Creek valley. Over 33 km of additional roads will be constructed to accommodate this logging (Table 8).

Enhancement Opportunities

Enhancement projects on Downie Creek, like other "A" category streams, should directed at increasing juvenile production of bull and rainbow trout. Increased production could be achieved through habitat protection and rehabilitation, outplanting bull trout and rainbow trout yearlings, or increasing available rearing habitat via barrier removal or possible side channel development.

Many areas below km 22 on the mainstem in the Downie Creek valley have been logged, although there is limited logging upstream of km 22. Since tributaries appear to provide an important component of the spawning and rearing habitat available to both bull and rainbow trout utilizing Downie Creek, it is prudent to ensure further habitat degradation of these small tributaries, such as that seen at streams entering in the lower Downie watershed, is minimized. This necessitates close co-operation between MOE, BCFS and companies logging in this watershed. Implementation of a program to protect small tributaries on the Downie mainstem would require further study investigating seasonal variations in tributary utilization, as well as extensive mapping of the present level of utilization of all small tributaries within the Downie Creek Drainage.

Tributaries with fish habitat which are not presently utilized could be seeded through a hatchery outplanting program while tributaries presently utilized by fish could have their present populations augmented also via a hatchery outplanting program. Additional habitat may be made available on many of these tributaries by placement of "fish friendly culverts" or modifying previously placed culverts so they are passable to both adult and juvenile fish, such as on Belcher and Pass Creeks. Removal of the log jam on Standard Creek would facilitate the upstream migration of spawning bull and rainbow trout. The unnamed tributary at km 4.9, although not utilized by fish, is easily accessible. The small size of this tributary should not be considered as a limiting factor to fish production since similar sized tributaries within the Bigmouth watershed were found to support large numbers of yearling bull trout (Sec. 4.5.5). Revegetation of this unnamed tributary would benefit salmonid habitat. Rehabilitated riparian habitat would stabilize streambanks to reduce sedimentation into rearing and spawning grounds. Revegetetation would also increase cover for adult and juvenile fish. Many of Downie Creek's smaller tributaries entering could benefit from revegetation. Downie CreekSorcerer Creek has the potential to support a resident population of rainbow or bull trout. The option of introducing rainbow or bull trout into Sorcerer Creek to create a resident sports fishery should be explored, although such a program would have to be accompanied by the removal of the large log jam at km 8.3 as well as efforts to ensure possible impacts on fish habitat are minimized during future logging.

Bull trout captured upstream of the barrier at km 16.5 on Downie Creek could not be conclusively proven as resident fish. The presence of bull trout but absence of rainbow trout upstream of this barrier suggests either:

1) The chutes at km 16.5 on the Downie mainstem are not passable during spring flows, but may be passable during low discharges occurring during fall and winter months.

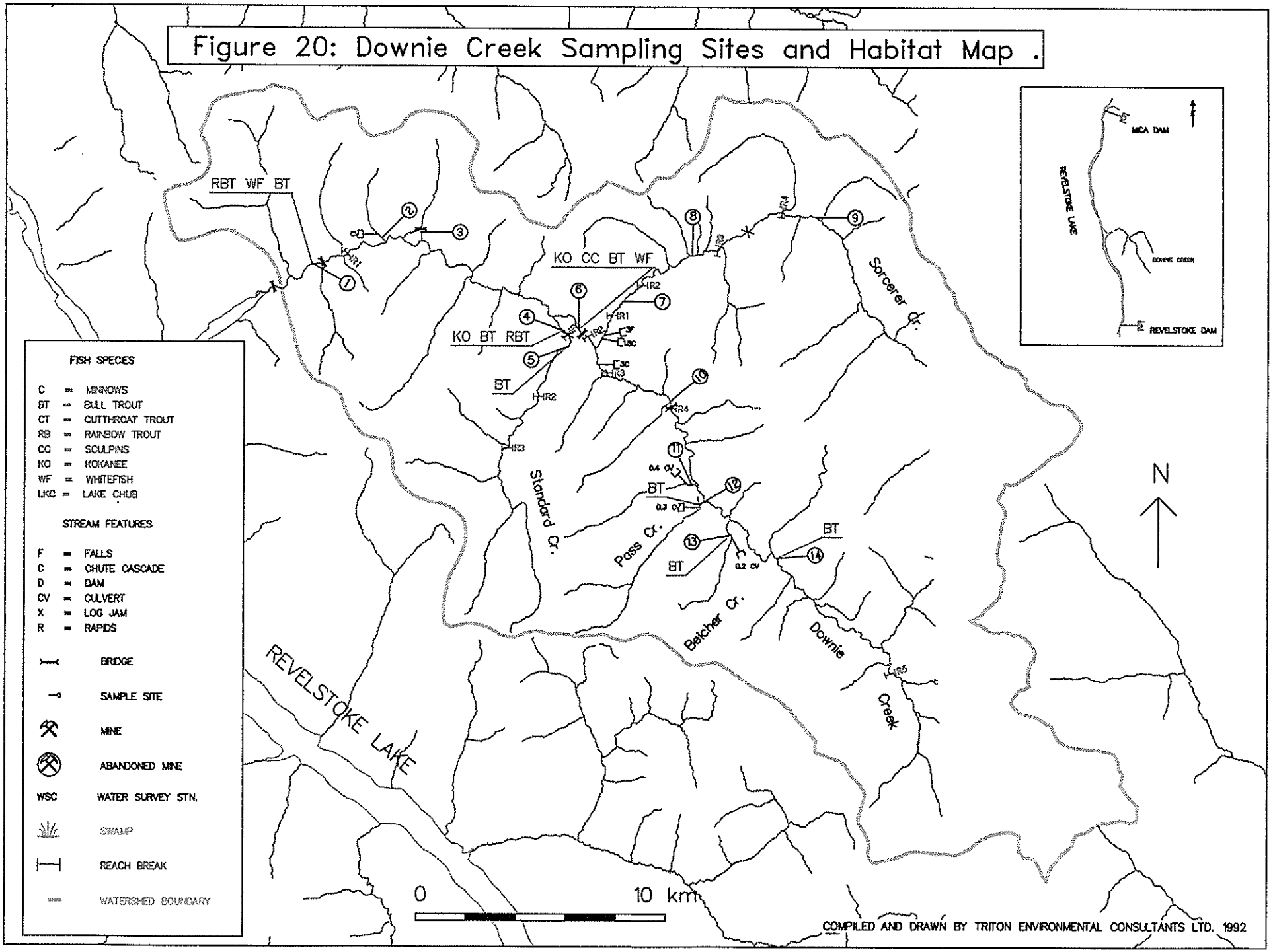
2) The bull trout captured upstream of the 16.5 km barrier represent a resident stock.

A fishway, or pool and weir system, would allow fish to easily bypass of the 16.5 km barrier and make over 330,000 m^2 of mainstem habitat as well as numerous small tributaries which enter upper Downie Creek available to lake resident fish.

Westar was open to the possibility of creating a spawning channel on Downie Creek, approximately 300 m downstream of the 15 km bridge (Lindsay, 1991, and pers. comm. Don Monk, Downie Creek R. V. Resort). This idea has some merit, and should not be discounted for a number of reasons. Excavations previously started in the proposed spawning 'channel site by Westar for road gravel were apparently halted by MOE, but an existing sub grade channel bed does exist at this site (Photo 36). With proper biological and engineering supervision, Westar could complete a costly part of spawning channel construction, specifically, the removal of material. Westar could be permitted to extract road bed material if they agree to create an excavated channel and leave sorted gravel. Additional funding to build a protective dike as well as the inflow and outflow structures could be provided by B. C. Hydro. The location for the proposed channel is situated just upstream of the mouth of Standard Creek, observed to be utilized by kokanee, bull trout and rainbow trout, and just downstream of the 15 km bridge where spawning kokanee and whitefish were observed. Utilizing Standard Creek water in this channel could reduce sedimentation when Downie Creek runs turbid, thereby providind a more suitable water source. Such a channel need not be used by kokanee only. If bull trout and rainbow trout populations utilizing Downie Creek are increased sufficiently, they too may take advantage of a controlled spawning area. It should be noted that building a spawning channel would be a long term plan, assuming other enhancement programs have successfully increased recruitment into Downie Creek.

Also, considering the financial difficulties Westar is now experiencing, the company may no longer be able to participate in this plan.

Figure 20: Downie Creek Sampling Sites and Habitat Map .



COMPILED AND DRAWN BY TRITON ENVIRONMENTAL CONSULTANTS LTD. 1992

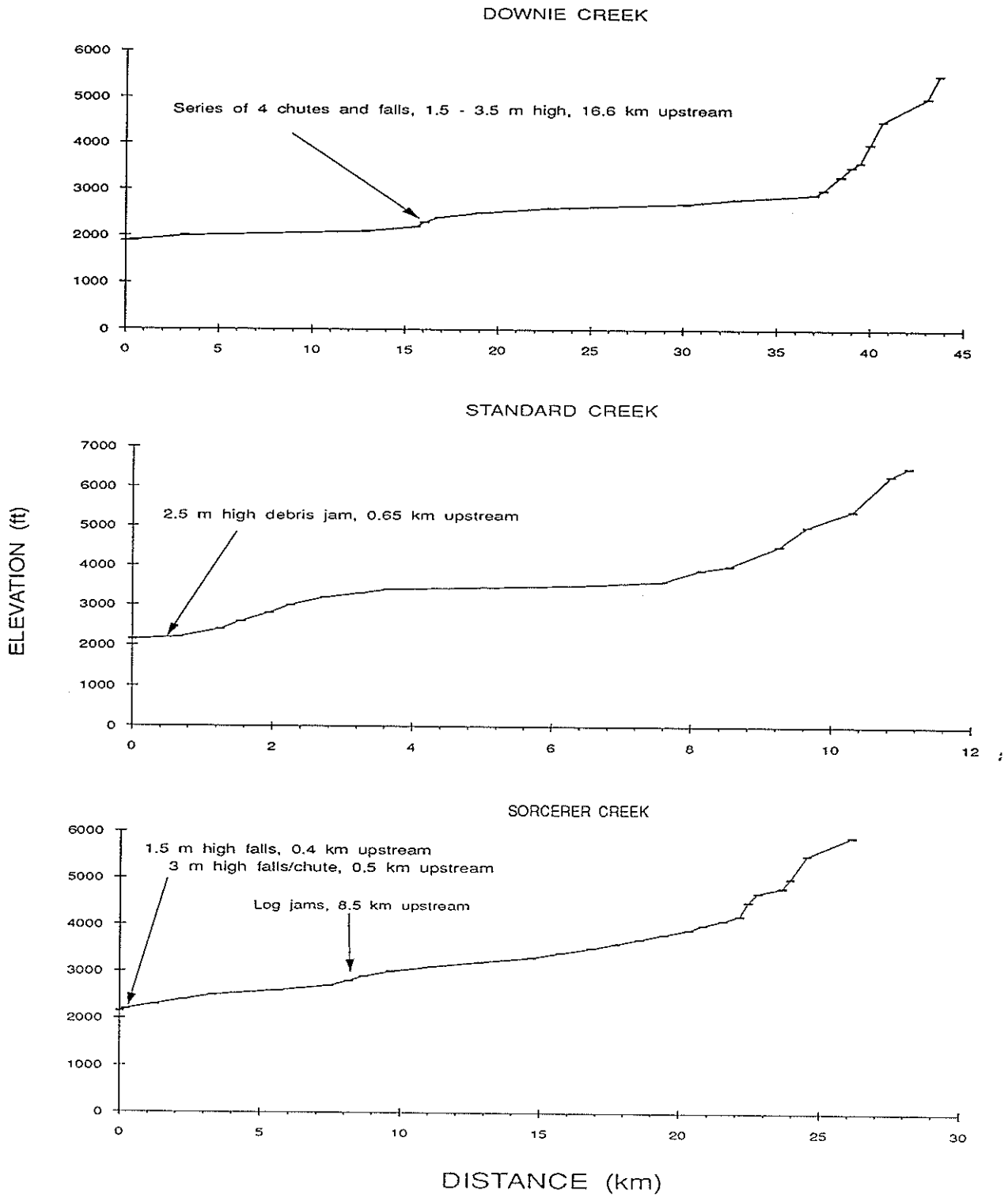


Figure 21: Stream profiles for Downie, Sorcerer and Standard Creeks (not to scale)

Table 22: Summary of biophysical habitat parameters for Downie Creek and its tributaries.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	1.1	3.2	73,600	3,680	dp/b	1,472	14,720	29,440	29,440	0	18,400	18,400	L	150	FC	2 - 5
mainstem	6	2	0.1	11.4	296,400	29,640	l/dp	14,820	44,460	74,100	177,840	0	29,640	148,200	L	100	UC	5 - 10
mainstem	10	4	1.2	7.2	48,640	4,864	dp/b	973	14,592	19,456	14,592	0	9,728	17,024	M	120	CO	2 - 5
mainstem	14	5	0.5	15.5	334,800	66,960	dp/l/b/cb	33,480	167,400	66,960	100,440	0	133,920	133,920	L	130	UC	10 +
Total mainstem 1+2+4+5:				37.3	753,440	105,144		50,745	241,172	189,956	322,312	0	191,688	317,544		125		
Total below barriers				14.6	370,000	33,320		16,292	59,180	103,540	207,280	0	48,040	166,600		125		
Downie Tributaries																		
Trib 4.9 Km	2	1	9.0	0.3	330	33	l	17	83	165	83	0	66	149	H	30	UC	10 +
Long Ck.	3	1	n/a	0.4	1,920	768	l/dp	480	480	864	480	96	192	864	M	70	NA	EN
Standard Ck.	4	1	2.3	0.8	5,040	1,512	l/dp/cb	1,008	0	0	0	0	504	1,512	L	80	UC	10 +
Standard Ck.	5	2	12.2	3.0	37,800	15,120	b/dp/l	1,890	9,450	9,450	9,450	9,450	3,780	9,450	L	110	CO	0 - 2
Total				3.8	42,840	16,632		2,898	9,450	9,450	9,450	9,450	4,284	10,962		95		
Sorcerer Ck.	7	2	3.2	1.9	19,950	2,993	b/l	998	1,995	9,975	7,980	0	1,995	6,983	L	90	CO	2 - 5
Sorcerer Ck.	8	3	2.0	3.8	88,920	13,338	b/ov/dp	1,778	17,784	17,784	53,352	0	8,892	31,122	L	130	CO	2 - 5
Sorcerer Ck.	9	5	2.0	3.0	27,000	4,050	b/dp	270	6,750	10,800	9,450	0	4,050	6,750	H	130	CO	2 - 5
Total				8.7	135,870	20,381		3,046	26,529	38,559	70,782	0	14,937	44,855		117		

Continued

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 22: Summary of biophysical habitat parameters for Downie Creek and its tributaries.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
Trib 25.2 Km	11	1		0.3	1,640	246	dp/ov	49	328	656	574	82	246	738	L	100	NA	EN
Pass Ck.	12	2		0.6	1,830	549	l/b	183	458	732	549	92	275	641	L	70	NA	EN
Belcher Ck.	13	1		0.7	3,780	945	l	3,742	945	1,701	1,134	0	945	1,890	M	85	NA	EN
Total Tributaries				14.7	188,210	39,554		10,415	38,272	52,127	83,052	9,720	20,945	60,098				
Total Tributaries below barriers				1.5	7,290	2,313		1,505	563	1,029	563	96	762	2,525				
Downie System:																		
Total					1,678,570	254,584		93,810	412,875	445,759	775,927	28,889	300,838	660,156				
Total below barriers					377,290	35,633		17,797	59,743	104,569	207,843	96	48,802	169,125				

Summary of geographic parameters for Downie Creek.

Location:	Central area of Lake Revelstoke, east side.
Length:	37 km
Barriers:	Possibly at 16.5 km
No. of Reaches:	7+
No. of Reaches Sampled:	4
Total Length of Sampled Reaches:	37.3
Major Tributaries (in order of size):	Sorcerer Ck., Standard Ck.
Water Source:	Primarily glacial
Logging:	Along valley bottom and midslope to km 29 (south side) and km 24 (north side).

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 23 **Electroshocking results (a), as well as fish size and age data (b) for Downie Creek.**

Table 23 a: Electroshocking results.

Site	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE Esc. or Obs.	CPUE Total	DENSITY (Fish/m^2) Caught	DENSITY Esc. or Obs.	DENSITY Total
mainstem	1	1	0	rbt	p	0.001	0.000	**0.001**	0.002	0.000	**0.002**
mainstem	1	2	0	wf	f	0.003	0.000	**0.003**	0.004	0.000	**0.004**
mainstem	1	1	0	bt	p	0.001	0.000	**0.001**	0.002	0.000	**0.002**
total, reach 1:		4	0	mean:		0.002	0.000	**0.002**	0.002	0.000	**0.002**
mainstem	3	1	1	bt	p/f	0.002	0.002	**0.003**	0.002	0.002	**0.004**
mainstem	3	1	0	cc	a	0.002	0.000	**0.002**	0.002	0.000	**0.002**
total, reach 3:		2	1	mean:		0.002	0.001	**0.002**	0.002	0.001	**0.003**
mainstem	4	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
mainstem	5	1	1	bt	p	0.002	0.002	**0.004**	0.001	0.001	**0.002**
Total (mainstem):		**7**	**2**	**Mean**		**0.001**	**0.001**	**0.002**	**0.001**	**0.000**	**0.002**
Downie Tributaries											
4.9 km Trib	1	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Long Ck.	1	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Standard Ck.	1	4	2	rbt	p	0.018	0.009	**0.026**	0.009	0.005	**0.014**
Standard Ck.	1	3	0	bt	p	0.013	0.000	**0.013**	0.007	0.000	**0.007**
total, reach 1:		7	2	mean:		0.015	0.004	**0.020**	0.008	0.002	**0.010**
Standard Ck.	2	5	9	bt	p	0.013	0.024	**0.037**	0.007	0.013	**0.020**
Total (Standard Ck):		**12**	**11**	**Mean:**		**0.014**	**0.014**	**0.028**	**0.008**	**0.008**	**0.015**
Sorcerer Ck.	2	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Sorcerer Ck.	3	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Sorcerer Ck.	5	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
25.2 trib	1	not shocked									
Pass Ck.	1	8	4	bt	p	0.021	0.011	**0.032**	0.022	0.011	**0.034**
Belcher Ck.	1	1	0	bt	p	0.004	0.000	**0.004**	0.004	0.000	**0.004**
Total, tributaries:		**27**	**15**	**Mean:**		**0.006**	**0.004**	**0.010**	**0.005**	**0.003**	**0.008**
				Mean (Tribs with fish):		**0.013**	**0.010**	**0.023**	**0.010**	**0.007**	**0.017**
Total system:		**34**	**17**	**Mean:**		**0.005**	**0.003**	**0.007**	**0.004**	**0.007**	**0.017**

Note: In addition to the above data, aproximatley 25 kokanee and aproximately 50 whitefish were obvserved in reach 2, sample site 7. Also, approximately 400 ko were observed during a helicopter overflight, Oct 27, 1991.

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

n/a = not available

Table 23 b: Size and Age data for fish captured from Downie Creek and its tributaries

Site/Reach	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yrs)	N
Downie mainstem									
1	RBT	161	-	49.01	-	1.17	1	3+	1
1	WF	125	61 - 168	25.90	1.98 - 49.82	0.91	2	3+	1*
2	CC	85	-	6.06	-	0.99	1	-	-
1+2+5	BT	106	85 - 108	14.50	2.21 - 29.54	0.92	3	1 - 2+	2
Downie Tributaries									
Belcher Ck	BT	196	-	78.45	-	1.04	1	3+	1
Pass Creek	BT	140	94 - 184	29.28	8.16 - 66.54	0.95	8	1 - 3+	8
Standard Ck									
1	RBT	121	105 - 131	21.55	13.31 - 29.61	1.18	4	1 - 2+	4
1	BT	136	111 - 176	27.16	13.26 - 52.09	0.95	3	1 - 2+	3
2	BT	120	103 - 159	18.44	10.15 - 42.47	0.96	5	1 - 2+	5
1+2-Standard	**BT**	**128**	**103-176**	**22.80**	**10.15-52.09**	**0.96**	**8**	**1 - 2+**	**8**
Mean: (all tributaries)	BT	136	94 - 196	28.61	8.16 - 78.45	0.96	17	1 - 3+	17
Mean:	BT	132	62 - 196	26.50	2.21 - 78.45	0.95	20	1 - 3+	19
Downie System	RBT	129	105 - 161	27.02	13.31 - 49.01	1.18	5	1 - 3+	5

* from fish = 168 mm

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb,

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available



Photo 25 A series of chutes at km 16.5 of Downie Creek probably limits upstream access for all species of fish. The pictured chute is the largest of 3 in a short section of stream.

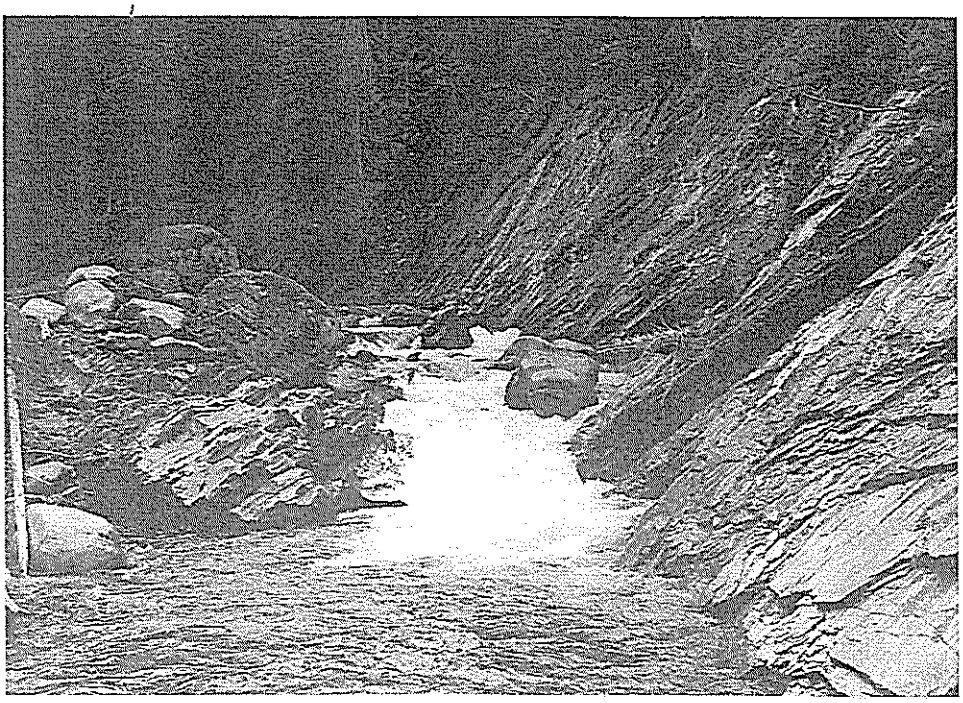


Photo 26 This chute is located approximately 100 m upstream of the chute in the preceding photo.

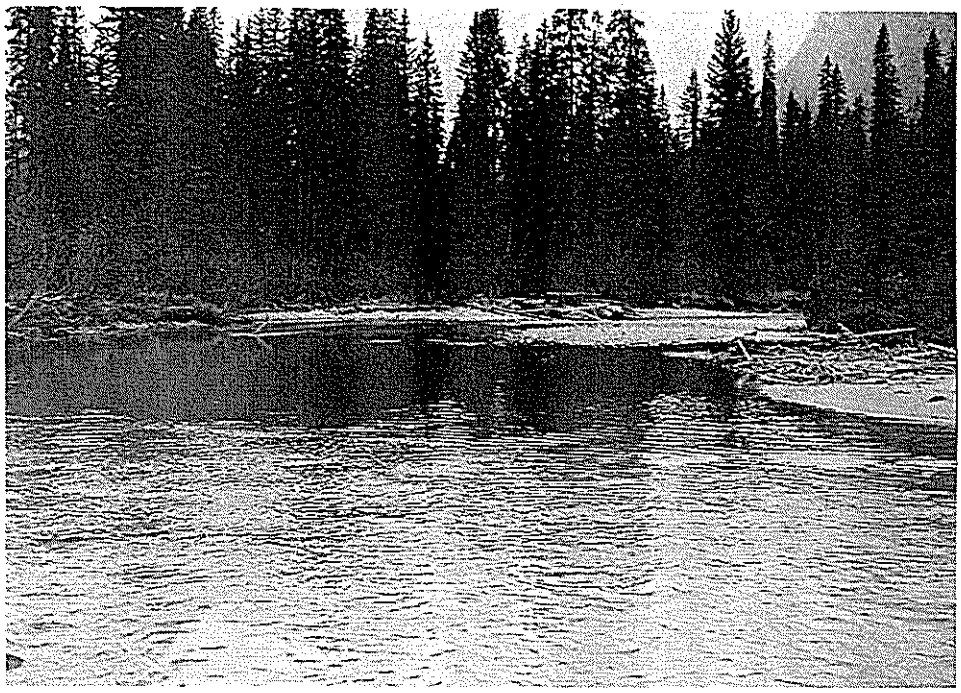


Photo 27 Reach 5 of Downie Creek flows through extensive alder marsh.



Photo 28 The narrow gorge in the first reach of Sorcerer Creek, contains 2 barriers within 100 m of each other. This 3 m falls, located 500 m upstream is the second barrier.



Photo 29 A downstream view of the massive logjam at km 8.3 of Sorcerer creek creates 2 and 2.5 high falls across the entire channel. Note the person standing in the middle of the photo.



Photo 30 This 2.5 m high logjam, located 650 m upstream of the Standard Creek mouth was the observed limit of kokanee migration, although it may be passable during high water.



Photo 31 Bull trout can easily migrate upstream through the stepwise pool and cascade sections in reach 2 of Standard Creek, although it is unknown if a barrier exists upstream of this area.



Photo 32 Culverts like the one shown here on an unnamed tributary (25.2 km upstream) are common to many Downie Creek tributaries. Such culverts may form a barrier to adult fish at high water, and likely restrict upstream movement of juvenile salmonids at low water.



Photo 33 This small unnamed tributary, which enters the Downie Creek mainstem at km 4.9, is still running despite a cold snap which has resulted in ice formations on many larger streams.



Photo 34 Unlike the small tributary in the preceding picture, Long Creek (entering Downie Creek at km 7.9) is almost completely frozen over with surface and anchor ice



Photo 35 Debris and slash was sidecast during road construction into Sorcerer Creek approximately 2.3 km upstream of the mouth.

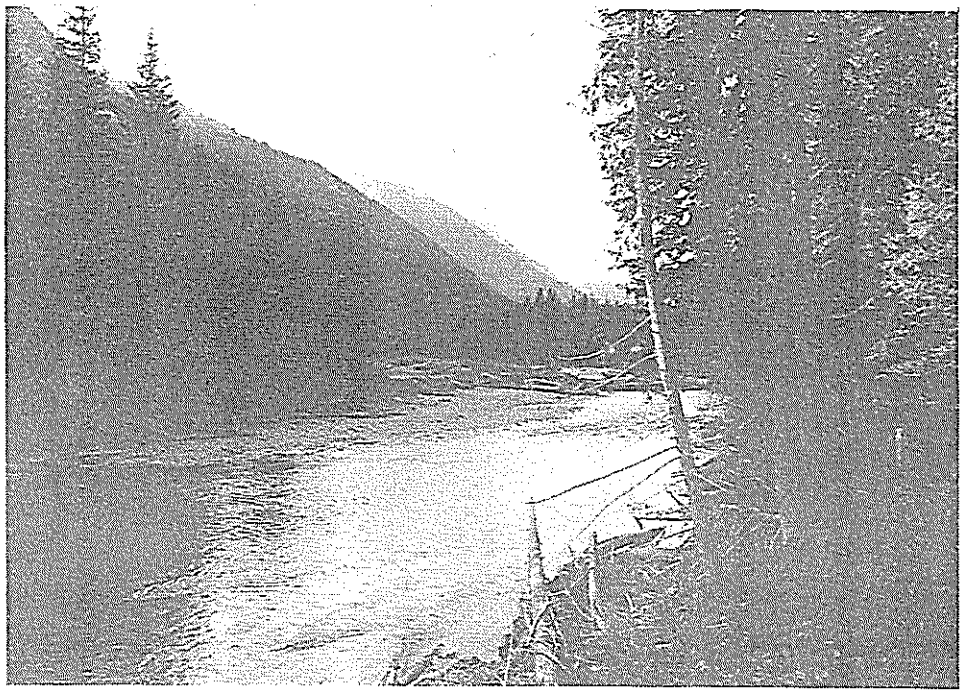


Photo 36 The area beyond the gravel bar on the far side of Downie Creek has been proposed as a potential site for a spawning channel.

4.5.8 Goldstream River

The Goldstream River, which is almost 70 km long and has a drainage area of over 93,000 ha is the largest tributary entering Revelstoke Lake. A 4 to 5 m falls at the mouth of the Goldstream River isolates this system from Revelstoke Lake (Photo 37). Stitt, Norman Wood and French Creeks are the largest tributaries of the Goldstream River. Old Camp, Brewster and McCulloch Creeks are intermediate sized tributaries flowing into the Goldstream (Fig. 22).

The Goldstream River is a glacier fed stream which did not become completely clear even after 10 days of freezing weather. McCulloch Creek, Old Camp Creek, Brewster Creek and numerous smaller creeks are clear running tributaries. Some of these unnamed tributaries have small lakes as their headwaters.

Reach 1 of the Goldstream River was not sampled. Reach 2, meanders through a wide valley bottom of predominantly marsh and alder scrub. Extensive side channel habitat exists in these marshes. Gradient is less than 0.25 % in this reach and the substrate is almost 100% fines. The River is deep and relatively slow moving with considerable amounts of LOD accumulating along the stream margins as well as in midstream areas.

Gradient increases to about 1.5% in reach 3, and cobble comprises over 50% of the substrate. Another 30% of the bed material consists of large and small gravel, although it is moderately compacted.

The gradient in reach 4 and 6 varies between 0.25% and 0.5% with gravel and cobble comprising the major fraction of the substrate. Gravel is less compacted in reach 6, but reach 4 has a higher percentage of LOD. Whitefish were the only species caught or observed in either of these reaches.

Reach 5 includes the confluences of Norman Woods and Stitt Creeks. A gradient of about 0.25% has resulted in a substrate composed of 70% fines and 30% gravel, however, most of the gravel is moderately compacted. There is little accumulation of debris and cover is composed primarily of deep pools and LOD (photo 38). Like reach 2, reach 5 meanders through marsh which provide considerable side channel

habitat. Beaver activity is in evidence in side channels and ponds within marsh areas, where the vegetation is dominated by spruce trees and alder thickets.

Gradient increases to 3.5% as the Goldstream enters a steep sided canyon in reach 5 (Fig 23). A helicopter overflight did not reveal any obvious barriers through this canyon. Substrate consists primarily of large cobble, boulders and bedrock.

The Goldstream re-enters a marsh upstream of reach 5, and the stream becomes convoluted with no main channel in evidence. This reach was overflown only, and not sampled.

Ten tributaries were sampled on the Goldstream River. Fish migration up most of these tributaries is limited by some sort of barrier.

Stitt Creek is a glacier fed creek which does not appear to have any barriers on it. Reach 1 of Stitt Creek is an extension of reach 6 of the Goldstream. Diverse cover and turbid water provides protection for rearing fish in reach 2 and 4, but the higher gradient in reach 2 results in a greater proportion of pool habitat than observed in reach 4. An estimated 38,000 m^2 of gravel exists in these 2 reaches, although substrate is dominated by cobble. Furthermore, gravel at sample site 20 in reach 4 was compacted (Table 24).

Two other large tributaries, Norman Woods and French Creeks, are also glacially fed streams, although water clarity was higher in these streams than the Goldstream River. Both Norman Woods Creek and French Creek have good spawning and rearing habitat in reaches upstream of their canyons. Each stream flows into the Goldstream River through marshy lowlands. The outlet of French Creek has changed course from one which ran parallel to the Goldstream prior to joining the it, to one which runs directly into the river.

A series of chutes and falls in a narrow gorge 1.75 km upstream of the confluence of Norman Woods Creek with the Goldstream River probably forms a barrier to fish migration (Photo 39). The longest flattest areas of Norman Woods Creek, which also appears to be the best spawning and rearing habitat in Norman Woods

Creek, is unaccessible to fish (Fig. 24, Photo 40). It is unknown if other barriers also exist within the canyon of Norman Woods Creek.

A helicopter overflight of French Creek did not reveal any obvious barriers in its canyon, although the gradient profile for this stream suggests a barrier may exist approximately 4 km upstream of its confluence with the Goldstream River (Fig 25). Reach 5, upstream of the French Creek canyon, is estimated to contain over 40,000 m^2 of uncompacted gravel (Table 24). Cover is limited in this area, but of high quality, consisting primarily of deep pools, undercut banks and overhead vegetation (Photo 41).

Three smaller tributaries, McCulloch, Old Camp, and Brewster Creek are clear running tributaries with relatively large amounts of uncompacted gravel within their substrate. Habitat available to fish is restricted by barriers existing on each of these streams. Brewster Creek has a 4 to 6 m high falls approximately 2.3 km upstream, Old Camp Creek has a 5 m falls located 2.0 km upstream, and a canyon about 700 m upstream of the mouth of McCulloch Creek probably marks the upstream limit of access for fish (Fig. 25).

Fish

Unlike Downie and Bigmouth Creeks, small tributaries did not account for most of the fish captured in the Goldstream River, however, whitefish and coarse fish were captured in the mainstem whereas cutthroat were the dominant species captured in tributaries to the mainstem (Table 25).

There are no bull trout in the Goldstream system. Fish found in the mainstem Goldstream River include whitefish, lake chub, cottids and suckers. Whitefish were most numerous in Reach 2 and 5 of the Goldstream River, and most of the specimens captured were rearing juveniles.

Cutthroat trout were found in tributaries of the Goldstream only. Of 10 tributaries sampled, cutthroat trout were found in French, Brewster, McCulloch and Old Camp Creeks. One whitefish was observed in Stitt Creek, but no fish were captured or observed in the 5 other tributaries sampled, including Norman Woods Creek. The CPUE and density for cutthroat trout in McCulloch Creek were highest of all the

Goldstream tributaries sampled and were in fact, amongst the highest observed of any of the streams sampled in the Revelstoke Lake drainage.

Logging

Considerable logging has already taken place within the Goldstream watershed. The mouth of the Goldstream River to approximately 4 km upstream is part of a private tree farm operated by Beaumont Timber Co. Ltd. Other logging concerns within the Goldstream system include Westar and the Small Business Forest Enterprise program (SPFEP). The extent of present logging includes the valley bottom and midslope areas of the Goldstream valley to approximately km 32. Five year plans submitted by Westar and the SBFEP indicate a further 2,320 ha of land, approximately 2% of the watershed, is to be clearcut by 1995. This includes 1097 ha which will be taken from the drainages of Norman Woods, French, Stitt and Old Camp Creeks (Table 8). Since most of the cutting permits have been allocated to Westar, which is in financial difficulties, the time table for future logging in the Goldstream system can change from that indicated in Table 8, should the ownership of Westar change.

Mining

In addition to logging activities, the Goldstream watershed has had considerable past and present mining activity. Past sites of mining include upper McCulloch Creek as well as on French Creek where a small mining community was located. Present mining activity is on the south side of the Goldstream River near km 10, where Bethelham Mines is operating a combined underground and open pit mine. A tailings pond for this mine is located at km 8, adjacent Brewster Creek. A small placer mine operation is also located on McCulloch Creek, at the base of its canyon (Fig. 22).

Enhancement Opportunities

The Goldstream watershed is heavily utilized for recreational and outdoor activities. These activities include fishing, hunting, heli-skiing, and trapping. A canoe route with

launches and pullouts in the lower 15 km of the Goldstream River as well as an extensive logging road system facilitate access to the river for sports fisherman.

Enhancement strategies on the Goldstream River should focus on the resident cutthroat trout population for a number of reasons:

1) Removing the major barrier at the mouth of the Goldstream River would be a large and costly undertaking.

2) Introducing bull trout into this system through removal of the barrier could be detrimental to the existing resident cutthroat trout population.

3) Despite the glacial nature of the Goldstream River, its large drainage area has proven capable of supporting resident fish species, and has considerable potential for increasing available habitat.

4) Finally, the Goldstream Valley has a history of recreational use.

Considerably more cataloging of both the mainstem and tributary streams should be completed, particularly to identify seasonal utilization of habitat by resident species, and the type of habitat available. Examples are:

1) Determining the importance of marsh and beaver ponds which dominate large sections of reach 2 and 5 of the mainstem as well as the first reaches of French, McCulloch and Norman Woods Creek. These areas were not sampled, although it is speculated that they provide important rearing habitat for juvenile cutthroat trout.

2) Preliminary surveys conducted this year have not positively identified which streams are utilized by spawning cutthroat, but it is likely clear water tributaries such as Brewster, McCulloch, and Old Camp Creek provide important spawning habitat. Initial indications are that spawning habitat in these areas has been detrimentally effected by logging and mining activities.

3) Conduct further studies of the Goldstream River to determine all tributaries utilized by cutthroat trout, and identify enhancement potential. Numerous

tributaries were not sampled. Some of these tributaries , such as Hill Creek (indicated by local anglers to have a cutthroat trout population) are utilized by cutthroat trout.

Enhancement of the resident cutthroat population may be achieved through outplanting of hatchery raised yearlings to exploit unused habitat and rehabilitated habitat. Streams which could probably benefit from stream rehabilitation are Brewster and McCulloch Creek, each of which have broad unconfined flood channels which may be the result of mining activities. The construction of a tailings pond for the Goldstream mine required a small creek be diverted into Brewster Creek, to prevent the small unnamed stream from contributing water to the tailings pond. This has increased Brewster Creek's discharge, more so during spring freshet, and may contribute to the state of the channel observed in reach one. An attempt to contain the lower section of Brewster Creek could result in a more stable spawning habitat for cutthroat trout and prevent the dewatering of wetted areas during late spring and early summer where cutthroat eggs may be incubating.

It is difficult to determine what effect placer operations has had on McCulloch Creek, but combined with extensive logging and the annual spring freshet, McCulloch Creek has become heavily braided with little riparian habitat within reach 2 (Photo 43). The high densities of cutthroat trout observed in this area may be representative of foraging activities by young fish, however, the area may also represent natal rearing grounds. More data concerning seasonal habitat utilization is required, however, if cutthroat trout are utilizing reach 2 of McCulloch Creek for spawning, containing the channel and stabilizing flows could improve spawning habitat for adult fish and increase egg and alevin survival.

Old Camp Creek was also found to support rearing cutthroat trout and likely provides spawning habitat for cutthroat trout. Subject to further investigation, reach 2 of Old Camp Creek could benefit from instream complexing designed to retain gravel and develop pool habitat. In addition, spawning platforms may be considered in reach 2. The entrenched nature of Old Camp Creek near the bridge crossing is also an excellent site for an enumeration fence.

French Creek was found to have excellent spawning gravel in reach 5, although the area is approximately 3000 ft above sea level (Fig 24). Since no fish were found in

this area, it is possible a barrier prevents migration upstream of the canyon. A barrier was not observed on French Creek during a helicopter overflight, but a more thorough examination may reveal an impediment to fish migration. If such is the case, removal of this obstruction, combined with outplanting hatchery raised cutthroat into reach 5 would aid increasing the production of cutthroat trout in Goldstream system.

Numerous smaller tributaries were examined which were devoid of any fish. Outplanting into these streams, combined with a program to ensure culverts at road crossings are made passable by fish could further increase habitat for juvenile cutthroat trout production.

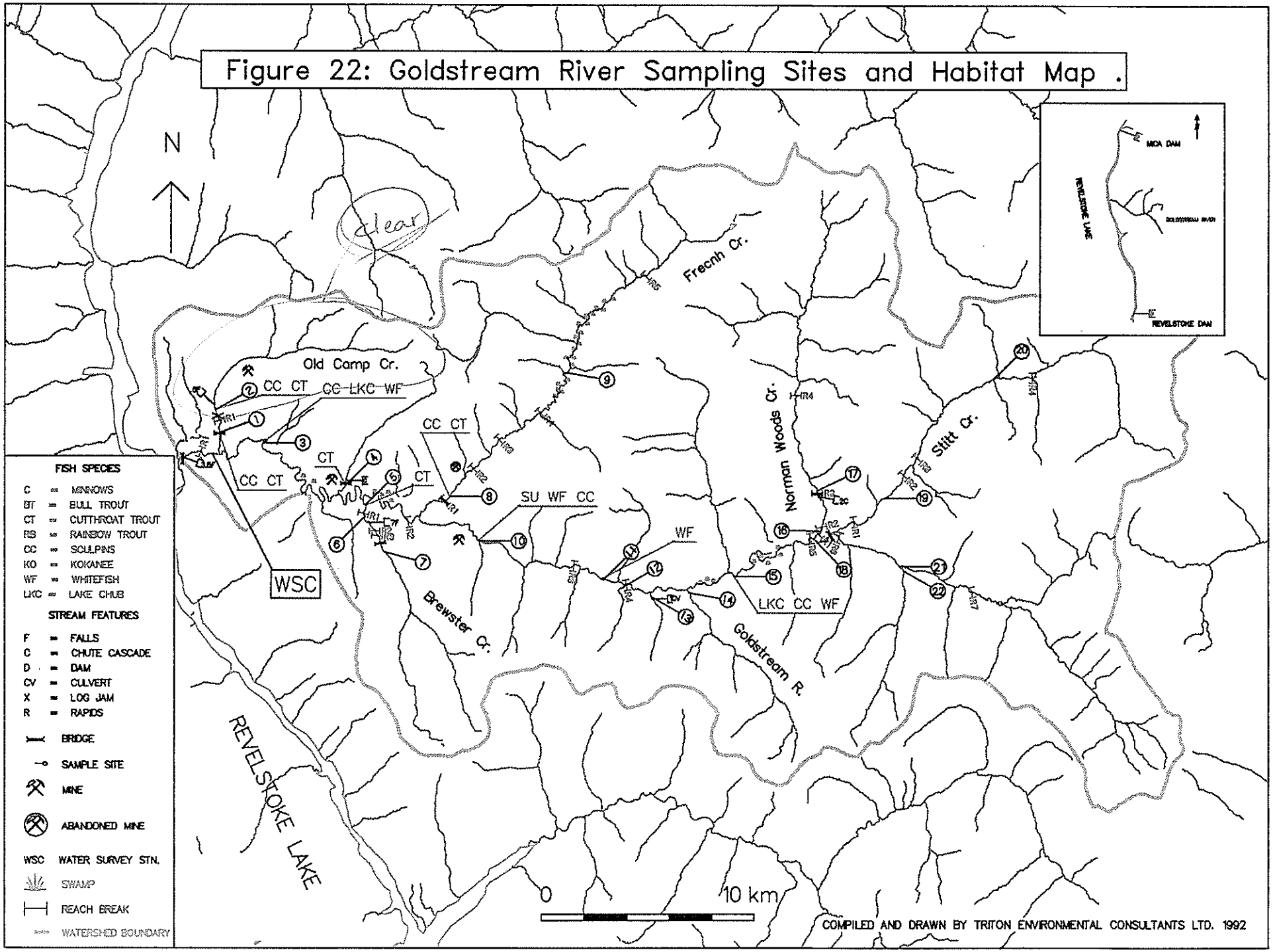
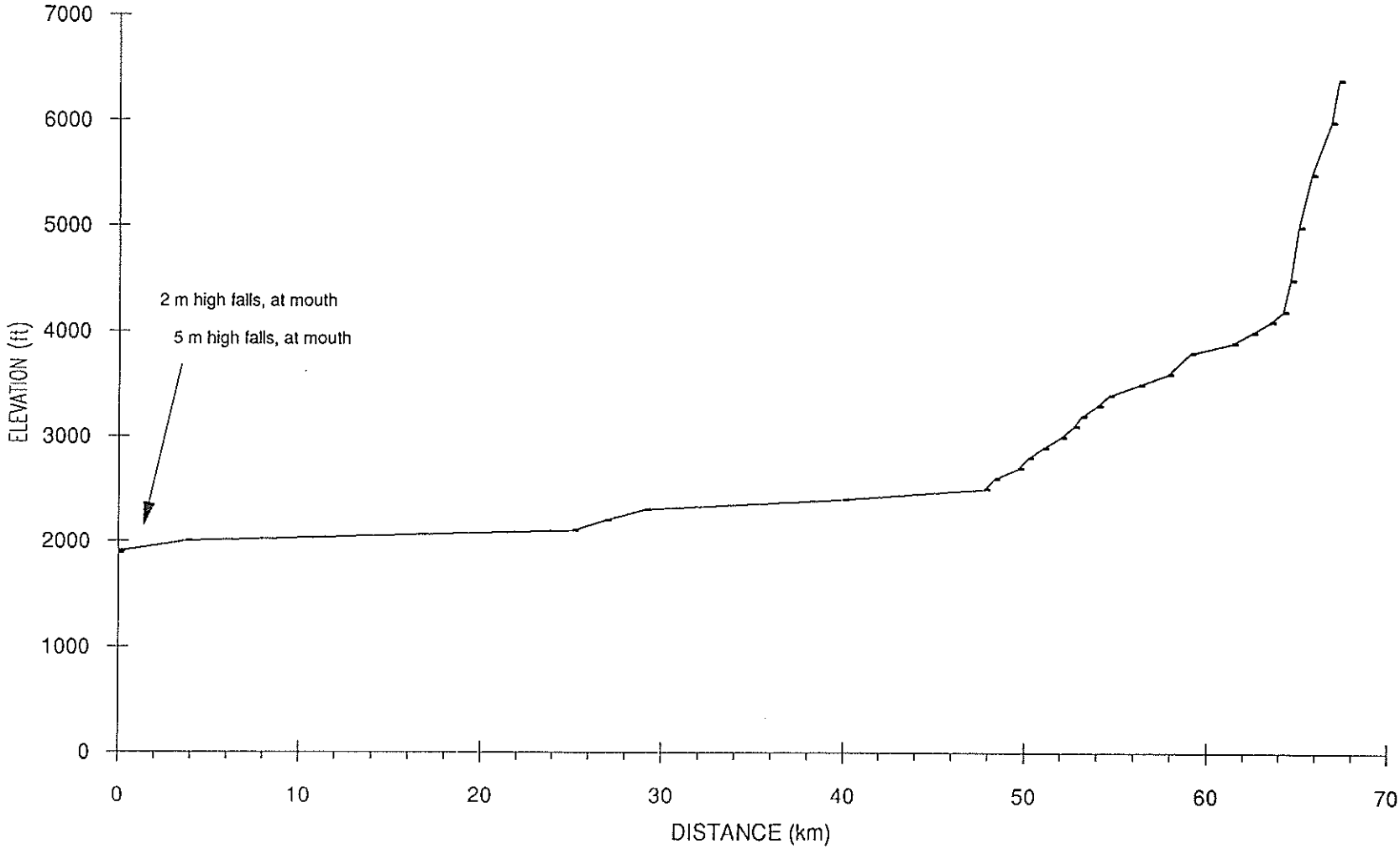

Figure 22: Goldstream River Sampling Sites and Habitat Map .
N
Clear
French Cr.
Old Camp Cr.
CC CT
CC LKC WF
CC CT
CT
CT
CC CT
SU WF CC
WF
LKC CC WF
WSC
Brewster Cr.
Goldstream R.
Norman Woods Cr.
Stitt Cr.
REVELSTOKE LAKE
MICA DAM
REVELSTOKE DAM
0
10 km
FISH SPECIES
C = MINNOWS
BT = BULL TROUT
CT = CUTTHROAT TROUT
RB = RAINBOW TROUT
CC = SCULPINS
KO = KOKANEE
WF = WHITEFISH
LKC = LAKE CHUB
STREAM FEATURES
F = FALLS
C = CHUTE CASCADE
D = DAM
CV = CULVERT
X = LOG JAM
R = RAPIDS
BRIDGE
SAMPLE SITE
MINE
ABANDONED MINE
WSC WATER SURVEY STN.
SWAMP
REACH BREAK
WATERSHED BOUNDARY
COMPILED AND DRAWN BY TRITON ENVIRONMENTAL CONSULTANTS LTD. 1992

Figure 23: The gradient profile for the Goldstream (not to scale)



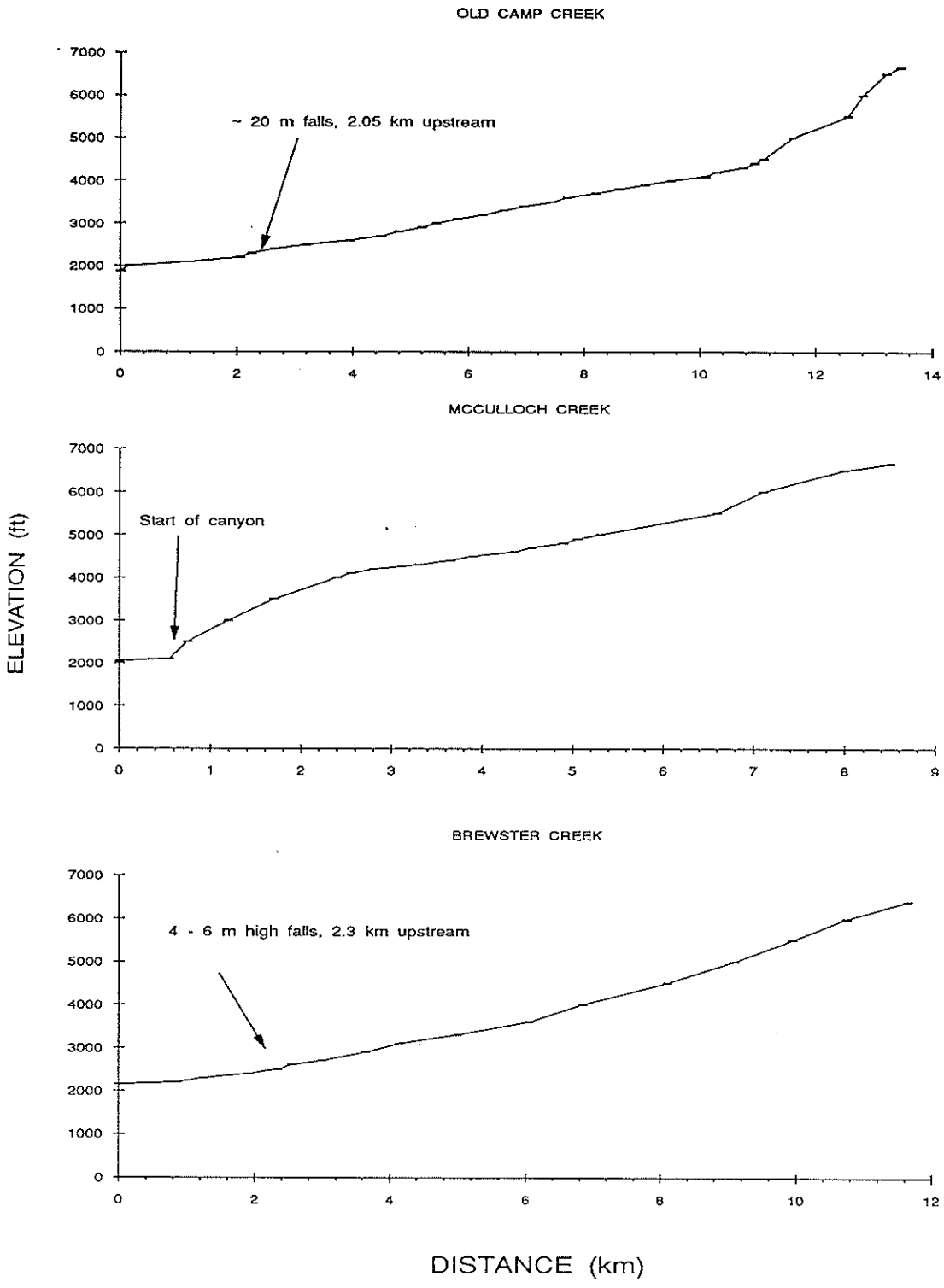


Figure 24: Stream profiles for Oldcamp, McCulloch and Brewster Creeks.

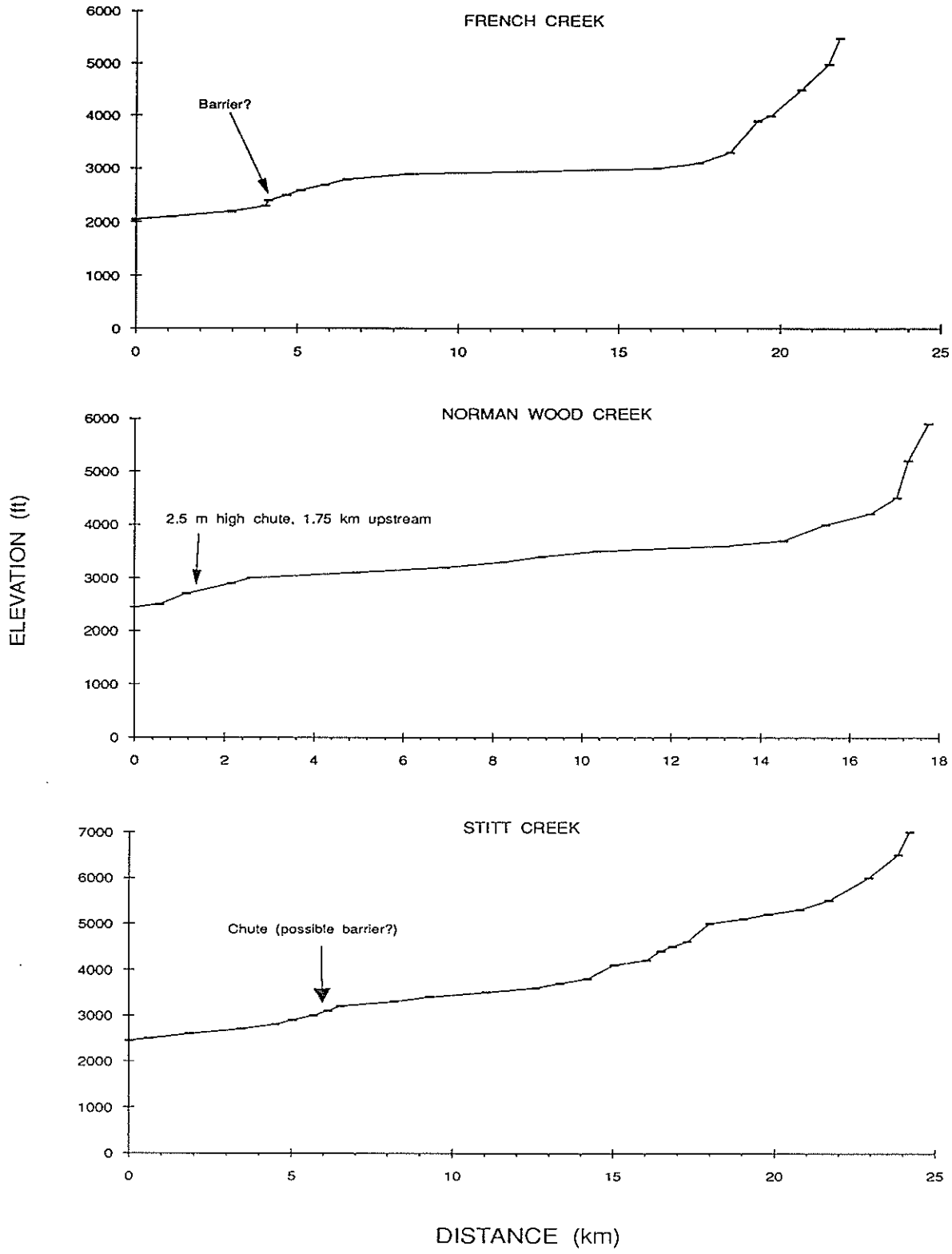


Figure 25: Stream profiles for French, Norman Woods and Stitt Creeks (not to scale)

Table 24: Summary of biophysical habitat parameters for the Goldstream River and its tributaries.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	3	2	0.1	12.0	390,000	195,000	p/l	39,000	195,000	0	195,000	0	386,100	0	L	10	OC	10 +
mainstem	10	3	1.5	4.5	198,000	39,600	dp/b	1,980	39,600	79,200	59,400	19,800	19,800	59,400	M	50	OC	5 - 10
mainstem	11	4	0.8	2.5	93,750	18,750	dp/l	2,813	28,125	32,813	32,813	0	18,750	42,188	M	60	FC	5 - 10
mainstem	15	5	0.5	9.5	237,500	47,500	dp/cb	11,875	59,375	11,875	166,250	0	166,250	71,250	L	20	UC	10 +
mainstem	18	6	0.5	2.3	41,400	10,350	b/dp/l	2,070	8,280	8,280	24,840	0	8,280	18,630	L	60	UC	10 +
mainstem	21	7	3.5	7.1	142,000	35,500	b	7,100	21,300	49,700	42,600	28,400	14,200	21,300	M	40	CO	0 - 2
Total mainstem:				37.9	1,102,650	346,700		64,838	351680	181868	520,903	48,200	613,380	212,768		40		
Goldstream Tributaries																		
Old Camp Ck.	1	1	2.0	1.7	7,990	799	b/ov	80	799	2,797	4,395	0	1,199	3,196	L	80	UC	10 +
Old Camp Ck.	2	2	2.5	0.7	4,200	840	b/dp	210	840	1,050	2,100	210	630	1,050	L	160	EN	0 - 2
Total				**2.3**	**12,190**	**1,639**		**290**	**1,639**	**3,847**	**6,495**	**210**	**1,829**	**4,246**		**120**		
Mcculloch Ck.	4	2	3.0	0.4	2,160	432	l/b	108	432	864	864	0	216	972	L	>30	NA	E
Brewster Ck.	5	1	2.0	1.0	20,000	5,000	dp/l	3,000	6,000	7,000	7,000	0	6,000	12,000	L	130	UC	10 +
Brewster Ck.	6	2	5.0	0.8	5,600	1,960	l/b/dp	1,120	840	2,800	1,400	560	840	1,680	L	130	FC	5 - 10
Brewster Ck.	7	4	8.5	0.8	9,280	3,712	b/l	464	2,320	2,320	2,320	2,320	928	2,320	M	70	CO	0 - 2
Total				**2.5**	**34,880**	**10,672**		**4,584**	**9,160**	**12,120**	**10,720**	**2,880**	**7,768**	**16,000**		**110**		
French Ck.	8	2	2.0	1.9	24,890	3,734	b/dp	249	2,489	14,934	7,467	0	2,489	3,734	M	100	FC	2 - 5
French Ck.	9	5	1.0	4.7	64,390	9,659	dp/cb/ov	1,932	19,317	25,756	19,317	0	22,537	41,854	L	110	UC	10 +
Total				**6.6**	**89,280**	**13,392**		**2,181**	**21,806**	**40,690**	**26,784**	**0**	**25,026**	**45,587**		**105**		
Trib 22 Km	12	1	1.5	0.3	2,420	847	l	2,396	242	1,573	484	121	363	1,089	L	50	UC	10 +
Trib 23.8 Km	13	1	4.0	0.8	2,080	416	l/ov	312	312	1,248	520	0	416	1,040	M	100	UC	10 +
Trib 26.2 Km	14	1	1.5	1.0	6,100	610	dp/l	305	915	3,660	1,525	0	610	2,745	M	75	UC	10 +

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.

Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

...continued

Table 24: Summary of biophysical habitat parameters for the Goldstream River and its tributaries.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
Norman Wood C	16	2	4.5	0.5	9,000	0	b/dp/ov	450	1,350	4,500	2,250	900	900	900	M	50	FC	2 - 5
Norman Wood C	17	3	1.5	4.5	65,250	13,050	b	3,263	9,788	39,150	16,313	0	13,050	29,363	M	60	CO	0 - 2
Total				**5.0**	**74,250**	**13,050**		**3,713**	**11,138**	**43,650**	**18,563**	**900**	**13,950**	**30,263**		**55**	**0**	**0**
Stitt Ck.	19	2	3.5	3.4	58,820	17,646	l/b/dp/ov	5,882	8,823	29,410	14,705	5,882	5,882	11,764	L	50	FC	2 - 5
Stitt Ck.	20	4	n/a	7.3	108,040	21,608	l/dp/b/ov	5,402	10,804	64,824	32,412	0	10,804	27,010	H	110	FC	2 - 5
Total				**11.1**	**166,860**	**39,254**		**11,284**	**19,627**	**94,234**	**47,117**	**5,882**	**16,686**	**38,774**		**80**		
Trib 36.9 Km	22	1	15.0	0.7	3,500	1,050	dp/l/b	350	1,050	1,050	1,050	350	350	525	n/a	100	UC	5 - 10
Total Tributaries:				27.8	393,720	81,362		25,522	66,321	202,936	114,121	10,343	67,213	141,241				
Total below Barriers				20.7	249,200	52,992		18,744	34,056	132,910	74,772	7,463	29,859	66,025				
Total Goldstream System				65.7	1,496,370	428,062		90,359	418,001	384,803	635,024	58,543	680,593	354,008				
Total Goldstream below Barriers:				0.0	1,351,850	399,682		83,581	385,736	314,777	595,674	55,663	643,239	278,792				

Summary of geographical parameters for the Goldstream River.

Location:	Central area of Revelstoke Lake, east sied.
Length:	67 km
Barriers:	3 sets of falls, 2 to 5 m high at mouth of river.
No. of Reaches:	9+
No. of Reaches Sampled:	6
Length of stream below barriers	0 km
Major Tributaries (in order of size):	Stitt Ck., Norman Woods Ck., French Ck., Old Camp Ck., Brewster Ck., McCulloch Ck.
Water Source:	Primarily glacier fed.
Resource use:	Logging throughout lower watershed, just entering areas upstream of km 34. Underground and open pit minning at km 15 on mainstem and placer operations at McCulloch Ck.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.

Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 25: **Electroshocking results (a), as well as fish size and age data (b) for the Goldstream River.**

Table 25 a: Electroshocking Results

Site	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE Esc. or Obs.	CPUE Total	DENSITY (Fish/m^2) Caught	DENSITY Esc. or Obs.	DENSITY Total
mainstem	2*	8	0	lkc	a/f	n/a - minnow trapped			n/a	n/a	n/a
mainstem	3	1	0	su	j	0.002	0.000	**0.002**	0.000	0.000	**0.000**
mainstem	3	1	0	wf	f	0.002	0.000	**0.002**	0.000	0.000	**0.000**
mainstem	3	3	0	cc	a	0.007	0.000	**0.007**	0.001	0.000	**0.001**
total. reach 3		5	0	mean, reach 3:		0.004	0.000	**0.004**	0.001	0.000	**0.001**
mainstem	4	1	0	wf	f	0.009	0.000	**0.009**	0.002	0.000	**0.002**
mainstem	5	24	6	wf	f/p	0.061	0.015	**0.076**	0.040	0.010	**0.050**
mainstem	6	0	1	wf	a	0.000	0.004	**0.004**	0.000	0.001	**0.001**
mainstem	7	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Total (mainstem):		38	7	Mean		0.015	0.004	0.018	0.008	0.002	0.011
Goldstream tributaries											
Old Camp Ck	1	1	0	ct	a	0.002	0.000	**0.002**	0.002	0.000	**0.002**
Old Camp Ck	1	4	1	cc	a	0.009	0.002	**0.011**	0.007	0.002	**0.009**
Subtotal, reach 1:		5	1	mean, reach 1:		0.006	0.001	**0.007**	0.005	0.001	**0.006**
Old Camp Ck	2	2	0	ct	p	0.007	0.000	**0.007**	0.006	0.000	**0.006**
Old Camp Ck	2	1	0	cc	a	0.004	0.000	**0.004**	0.003	0.000	**0.003**
Subtotal, reach 2:		3	0	mean, reach 1:		0.005	0.000	**0.005**	0.004	0.000	**0.004**
Total (Old Camp Ck.):		8	1	Mean:		0.006	0.001	0.006	0.004	0.000	0.005
McCulloch Ck.	2	6	1	ct	p	0.030	0.005	**0.035**	0.033	0.006	**0.039**
Brewster Ck.	1	1	0	ct	p	0.004	0.000	**0.004**	n/a	n/a	
Brewster Ck.	4	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Total (Brewster):		1	0	Mean:		0.002	0.000	0.002	n/a	n/a	n/a

Table continued on next page

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb,
n/a = not available

Table 25: **Electroshocking results (a), as well as fish size and age data (b) for the Goldstream River.**

Table 25 a: Electroshocking Results

Site	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE Esc. or Obs.	CPUE Total	DENSITY (Fish/m^2) Caught	DENSITY Esc. or Obs.	DENSITY Total
Table continued from previous page											
French Ck.	2	1	0	ct	p	0.004	0.000	**0.004**	0.003	0.000	**0.003**
French Ck.	2	1	0	cc	a	0.004	0.000	**0.004**	0.003	0.000	**0.003**
subtotal, reach 1:		2	0	mean, reach 1:		0.004	0.000	**0.004**	0.003	0.000	**0.003**
French Ck.	5	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Total (French Ck):		2	0	**Mean:**		0.002	0.000	0.002	0.001	0.000	0.001
22 k trib. Ck.	1	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
26.2 k. trib. Ck.	1	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Norman Wood Ck	2	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Norman Wood Ck	3	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Stitt Ck.	2	0	1	wf	a	0.000	0.003	**0.003**	0.000	0.001	**0.001**
Stitt Ck.	4	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Total (Stitt Ck.):		0	1	**Mean:**		0.000	0.001	0.001	0.000	0.001	0.001
37 k. Trib.	1	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
Total (Tributaries):		17	3	Mean:		0.004	0.001	0.005	0.004	0.001	0.005
Total (tribs. with fish):		17	3	Mean:		0.010	0.001	0.011	0.013	0.002	0.015

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb,
n/a = not available

Table 25: **Electroshocking results (a), as well as fish size and age data (b) for the Goldstream River.**

Table 25 a: Electroshocking Results

Site	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total

Table 25 b: **Size and age data for fish captured in the Goldstream River and its tributaries.**

Site/Reach	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yrs)	N
2	CC	54	25 - 70	1.51	0.68 - 0.77	0.71	3	-	-
2	LKC	49	38 -74	1.46	0.12 - 4.52	1.04	11	-	-
3	CC	96	91 - 104	11.11	7.55 - 15.50	1.21	3	-	-
3	WF	69	-	2.42	-	0.74	1	-	-
3	SKR	131	-	28.51	-	1.27	1	-	-
5	LKC	66	54 - 77	3.52	1.80 - 6.49	1.18	8	-	-
5	CC	82	-	6.26	-	1.14	1	-	-
5	WF	90	44 - 200	12.39	1.05 - 43.56	0.87	21	n/a	5*
Mean (mainstem)	LKC	56	38 - 77	2.33	0.12 - 6.49	1.10	19	-	-
	CC	76	25 - 82	6.30	0.68 - 15.50	0.98	7	-	-
	WF	84	44 - 200	10.06	1.05 - 43.56	0.84	22	n/a	5*
Goldstream Tributaries									
French Ck.	CC	101	-	13.35	-	1.30	1	-	-
	CT	122	-	17.39	-	0.96	1	1+	1
McCulloch Ck.	CT	118	98 - 132	17.88	-	1.06	6	1+	4**
Old Camp Ck. 1+2	CC	97	88 - 110	9.65	7.61 - 13.61	1.04	5	-	-
Old Camp Ck. 1+2	CT	182	139 - 229	>26.63	26.63 ->120.00	1.01	3	2+	2
Brewster Ck	CT	132	-	24.21	-	1.05	1	n/a	1***
Mean: (All Tributaries)	CC	98	88 - 101	10.27	7.61 - 13.61	1.03	7	-	-
	CT	137	98 - 229	>24.21	7.61 ->120.00	1.05	11	1 - 2	7
Mean: (Goldstream System)	CC	86	25 - 110	8.13	0.68 -15.50	1.03		-	-

* all scale samples were unreadable.

** does not include 2 unreadable scale samples

*** Scales regenerated.

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb,

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available



Photo 37 The falls at the mouth of the Goldstream River has a series of 3 drops, ranging from approximately 1.5 m to 4 m high. The pictured falls is about 3.0 m high.

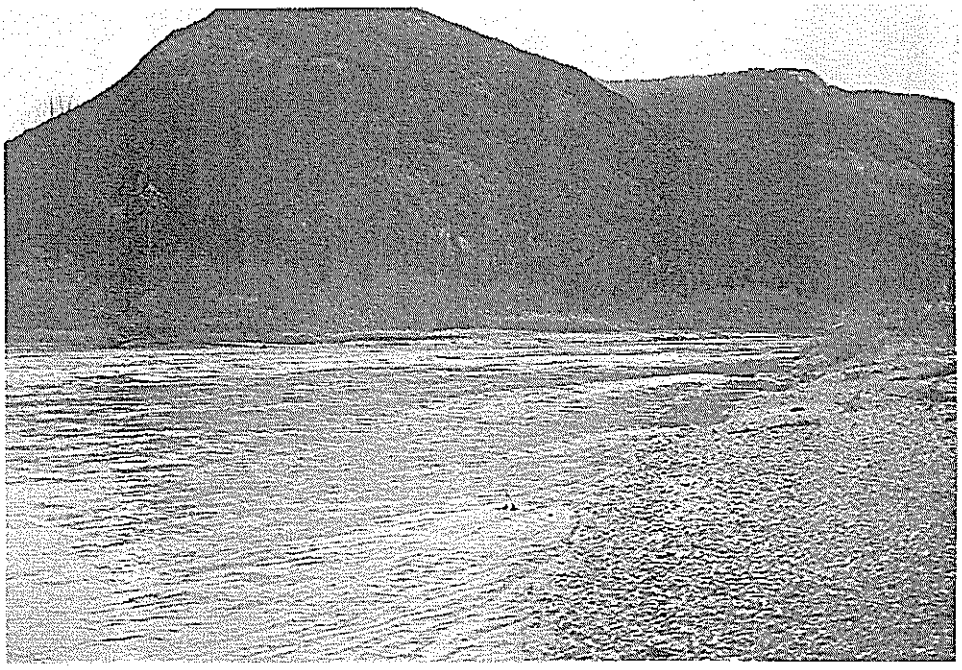


Photo 38 Reach 5, like reach 2, of the Goldstream River meanders through alder marsh.



Photo 39 This chute and falls on Norman Woods Creek is located at km 2, the upstream end of this creek's canyon. It is unknown if other barriers exist downstream of this chute in the canyon.



Photo 40 The valley above the Norman Woods canyon broadens and stream gradient is reduced as the creek meanders through alder marsh.

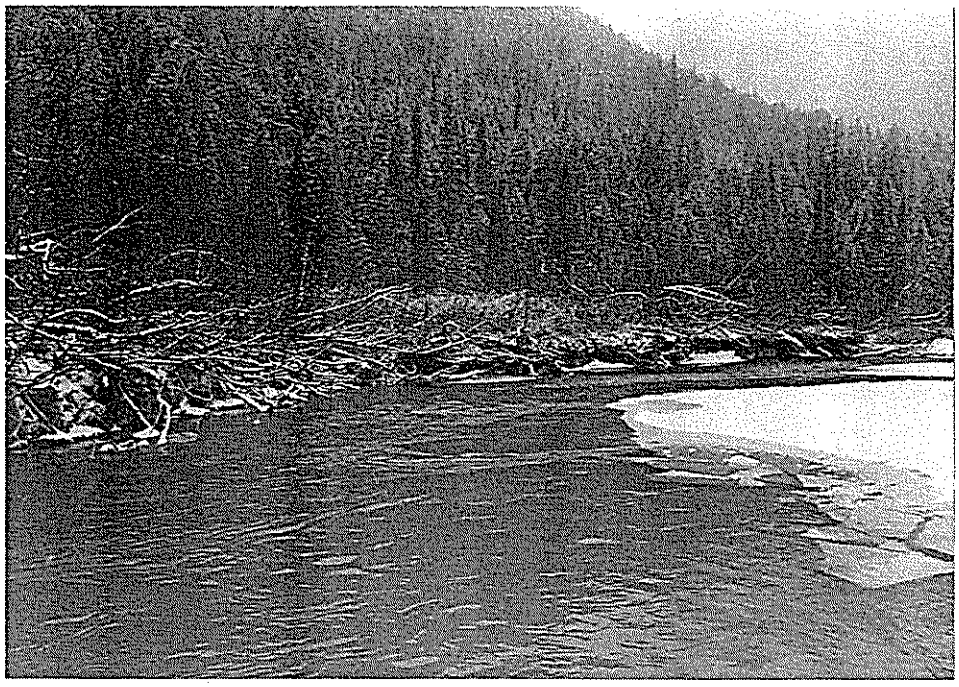


Photo 41 Reach 5 of French Creek, like the upper reaches of Norman Wood Creek meanders through swamp. Extensive uncompacted gravel and undercut banks provide good salmonid habitat.



Photo 42 Camp Creek near the bridge crossing, 1 km upstream from its confluence with the Goldstream River. Underlying bedrock prevents scouring, so few deep pools have formed and little gravel is retained.

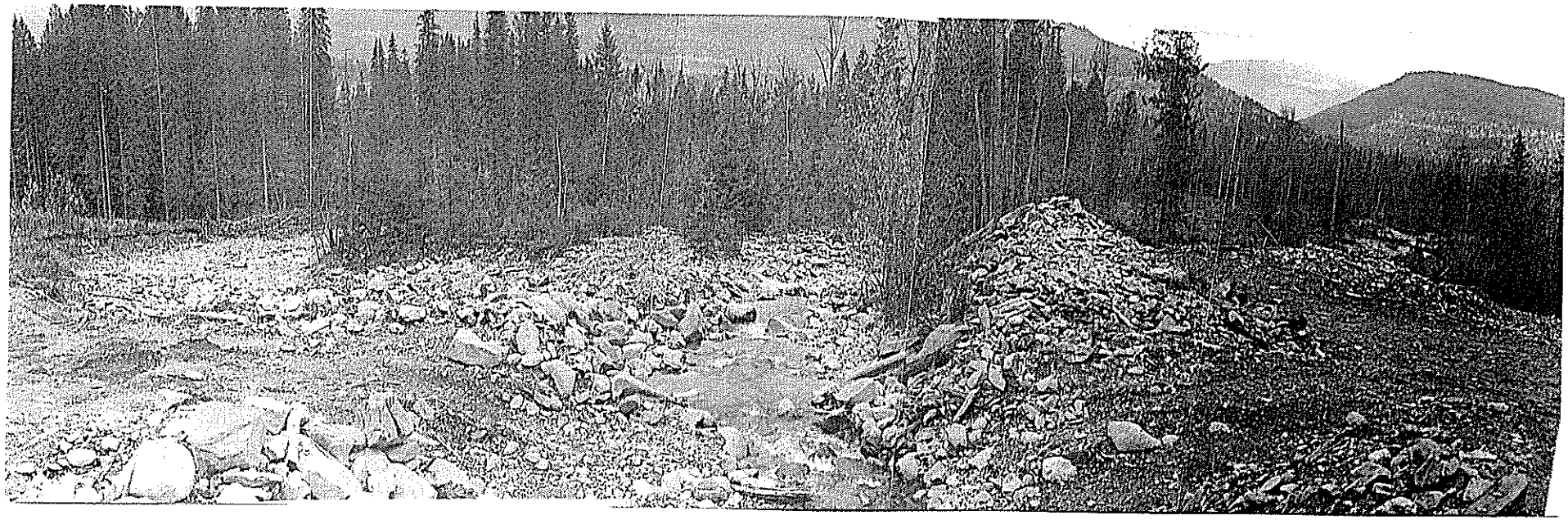


Photo 43 Placer mining and logging have probably contributed to the condition of McCulloch Creek in Reach 2, although a steep gorge upstream of this section of stream, combined with spring freshet probably also effects channel morphology.



Photo 44 Despite the condition of McCulloch Creek, the unconfined channel pictured here produced numerous yearling cutthroat trout.

4.5.9 Nagel Creek

Nagel creek was visited twice through the course of the project, once in July during high water and again in October during lower water. It is a glacier fed river, although water clarity increases as discharge drops in the fall. The lower 4 km of Nagel Creek is bordered by logging roads, although only 2 km of this road is accessible to vehicle.

Like most of the streams flowing into Revelstoke Lake, Nagel Creek has an impassable barrier located 400 m upstream of its mouth where the creek flows through a gorge (Fig. 26). The barrier consists of a 3 m high falls and a 2 m high chute 65 m upstream of the falls (Photo 45). Reaches 3, 4 and 5 of an estimated 8 reaches in Nagel Creek were sampled.

Reach 1 is the low gradient section of stream prior the to falls. It is approximately 0.4 km long and the water is a slow moving and deep. Reach two is the short gorge in which the falls and chute are located.

Reach 3 has some potential for rearing, but the relatively steep gradient (3.5%) and large portion of boulder and cobble substrate (75%) restricts the amount of available spawning habitat. Cover consists mainly of large substrate, but some LOD and vegetative cover is also present (Table 25).

Reach 4 and 5 have the most potential for spawning and rearing. Reach 4 contains large sections of riffle, with 80% of the substrate composed of either fines or cobble. There is little spawning habitat available and the substrate in this section is moderately compacted and sometimes armored. Considerable loose organic debris (LOD) combined with a healthy riparian zone, large substrate and cutbanks provides a diverse cover for 20% of the wetted channel (Photo 46). No fish were captured in this site but one unidentified fish may have been observed while the crew walked through the sample site.

Reach 5, accessed by helicopter, represents the section of Nagel Creek with the most potential for spawning. This reach meanders through approximately 9 km of alder marsh, where gradient averages 0.25% (photo 47). The estimated total cover is less than that for reach 4, but deep pools and extensive cutbank provides excellent

concealment for adult and juvenile salmonids. Fifty percent of the substrate in reach 5 consists of moderately compacted gravel. Erosion along the outside curves of meanders appears to be common in this reach, where large clumps of clay/loam have collapsed into the stream from the bank (Photo 48).

Fish

Although 3 sites were sampled on Nagel Creek, two of which were shocked on each trip, no fish were captured above the falls. This includes 536 seconds expended shocking at site 3, in reach 5. One fish was observed in reach 5 during sampling but could not identified (Table 26). This fish may have been a rainbow trout, based on observations at Soards Creek and the fact that rainbow trout were the most frequently encountered species upstream of barriers on Lake Revelstoke tributaries.

The almost complete lack of fish captured or observed above the falls on Nagel Creek may indicate some factor which detrimental effects fish productivity, otherwise, the inconclusive results of electroshocking may be misleading.

Logging

Cutblocks have been logged on either side of Nagel Creek along most of the length of reach 3. A logging road follows the south side of Nagel Creek for 2 km before it crosses the stream to access upper elevations on the northern side of reach 3. This road also accesses the Encampment Creek watershed. The road was being utilized to access Encampement Creek during the July field trip, but no active logging was occurring in the Nagel watershed. The SBFEP's (administered by the BCFS) 5 year plan indicates a planned harvest of 25 ha. from the Nagel Creek watershed.

Enhancement Opportunities.

A fishway circumventing the falls at the mouth of Nagel Creek would make at least 13.6 km of stream available to spawning fish. Although there is a road near the north side of the falls, access to the falls for machinery would have to be made. The height of the Nagel Creek barrier will change as the lake water levels fluctuate, but 2 culverts near the mouth of the creek act as a weir, limiting changes in barrier height, even if large fluctuations in the reservoir water level were to occur.

The geographic location of Nagel Creek, the presence of suitable spawning habitat and the low numbers of fish observed upstream of the falls, may facilitate pioneering by kokanee during years spawners accumulate below Mica Dam, if the falls were removed or bypassed. Nagel Creek is a glacial stream but low and moderately compacted gravel is still available for spawning in reach 3, 4 and 5. Incubating kokanee and bull trout eggs would not be as severely impacted by Nagel Creek's glacial nature since water clarity normally increases and sediment load decreases during the fall and winter in most glacial streams. Also, freshet does not occur until after kokanee and bull trout eggs have hatched.

Rainbow trout may also take advantage of the spawning and rearing habitat in Nagel Creek should the falls be removed, however, incubating eggs of this species may be more severely impacted by scour and siltation associated with glacial run-off in the spring and summer.

A large plain near the mouth of Nagel Creek provides adequate space to construct a spawning channel. The glacial nature of Nagel Creek would require settling basins to reduce sedimentation in such a channel. The option of constructing a spawning channel, while viable, would be considerably more expensive than removing or bypassing the barrier.

Figure 27: Nagle Creek Sampling Sites and Habitat Map .

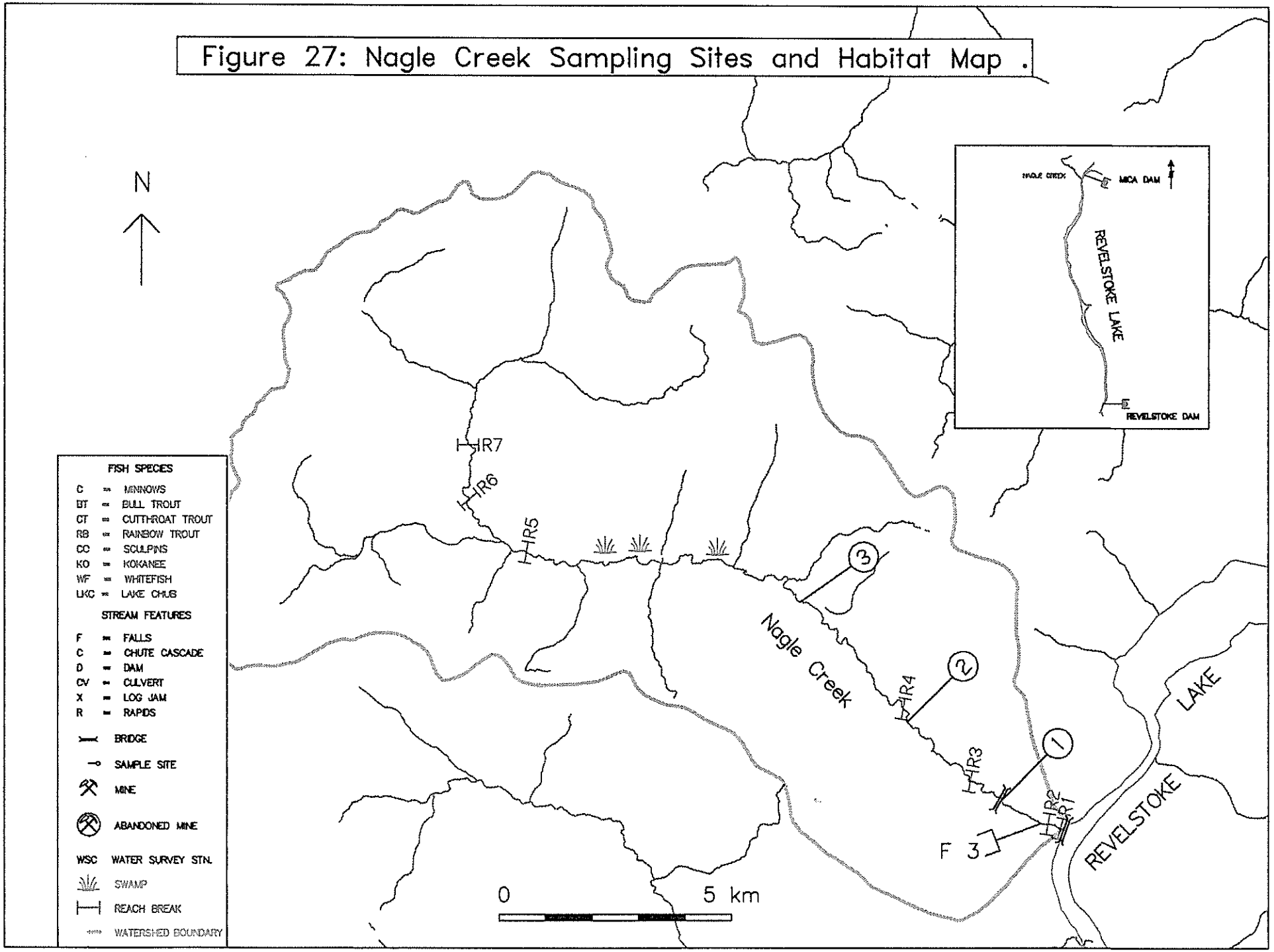


Figure 27: The stream profile for Nagel Creek. (not to scale)

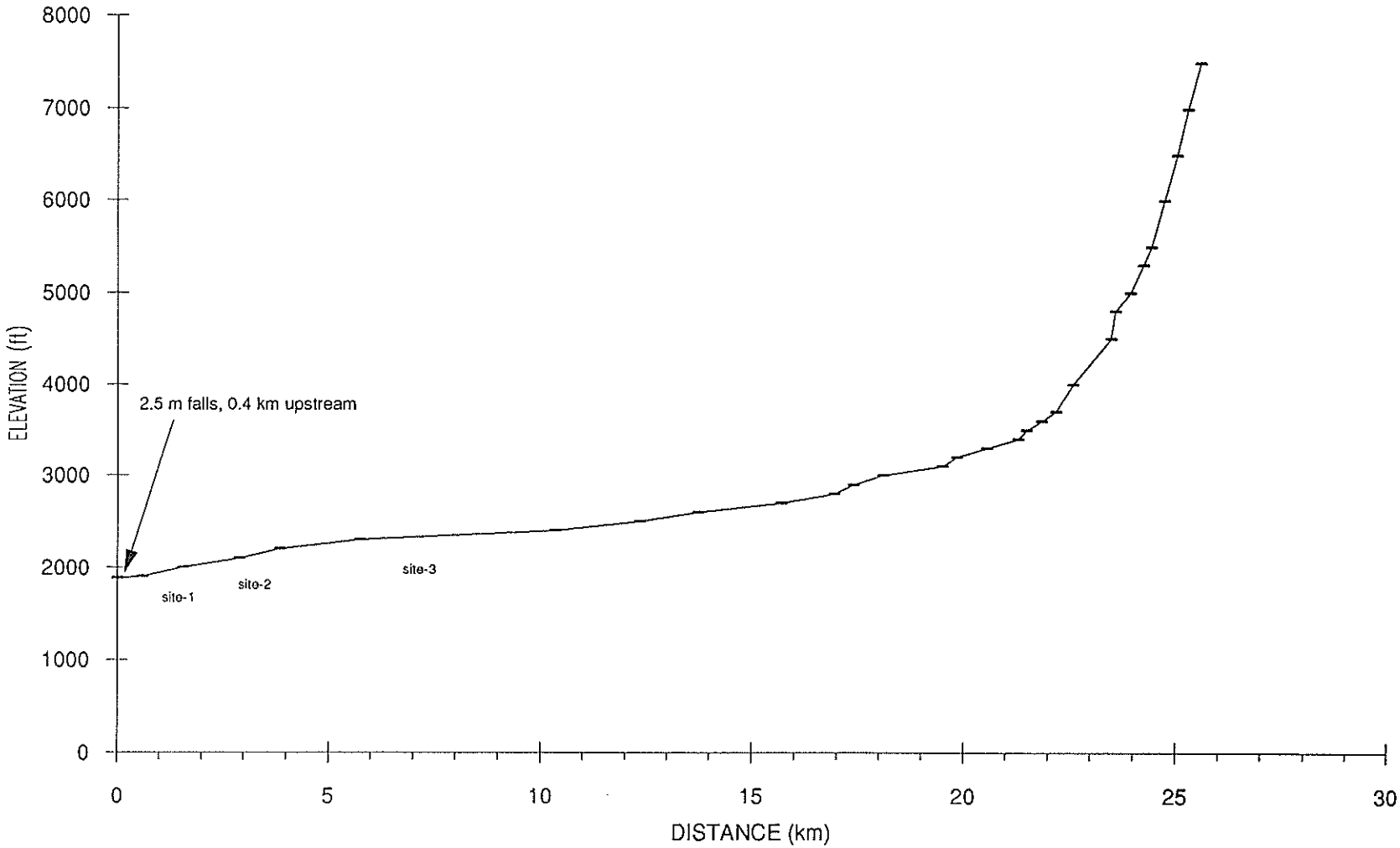


Table 26: Summary of biophysical habitat parameters for Nagle Creek.

						COVER			STREAM CHARACTER				SUBSTRATE			VALLEY CHAR.		
Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	Turb. (cm)	Confine	Valley to Ch. Ratio
Mainstem	1	3	4.0	1.5	22,500	5,625	b/l/ov	2,250	2,250	13,500	2,250	4,500	1,125	4,500	M	70	OC	2 - 5
Mainstem	2	4	2.1	3.4	66,000	13,200	l/b/ov/cb	9,900	13,200	33,000	19,800	0	19,800	13,200	M	70	OC	2 - 5
Mainstem	3	5	0.2	8.7	186,010	27,902	dp/cb	3,720	55,803	65,104	65,104	0	46,503	93,005	M	120	UC	5 - 10
Total				13.6	274,510	46,727		15,870	71,253	111,604	87,154	4,500	67,428	110,705		87		

Location: Northernmost tributary entering the Revelstoke lake, west side.
Length: 26
Barriers: 2.5 m chute and falls 400 m us of mouth.
No. of Reaches: 8+
No. of Reaches Sampled: 3
Total Length of Sampled Reaches: 14
Major Tributaries: None
Water Source: Glacier, some small lakes.
Resource use: In valley bottom and midslopes to 4 km.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 27: Electroshocking results for Nagel Creek

Site	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	3	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
mainstem	4	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
mainstem	5	0	1	u/s	p	0.000	0.002	**0.002**	0.000	0.002	**0.002**
Total:		0	0		Mean	0.007	0.000	0.007	n/a	n/a	n/a

Note: 1 cottid was caught by gee trapping at the mouth of Nagel Creek.

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available



Photo 45 The falls at the mouth of Nagel Creek.

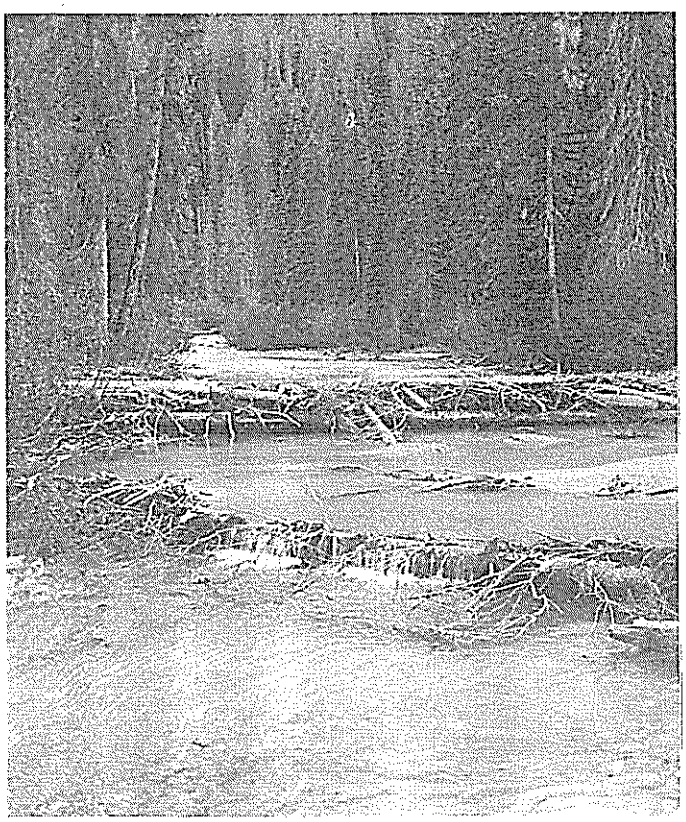


Photo 46 Diverse cover is present in reach 4 of Nagel Creek, although substrate consists mainly of fines.



Photo 47 Reach 5 of Nagel Creek seen from the air, looking upstream.

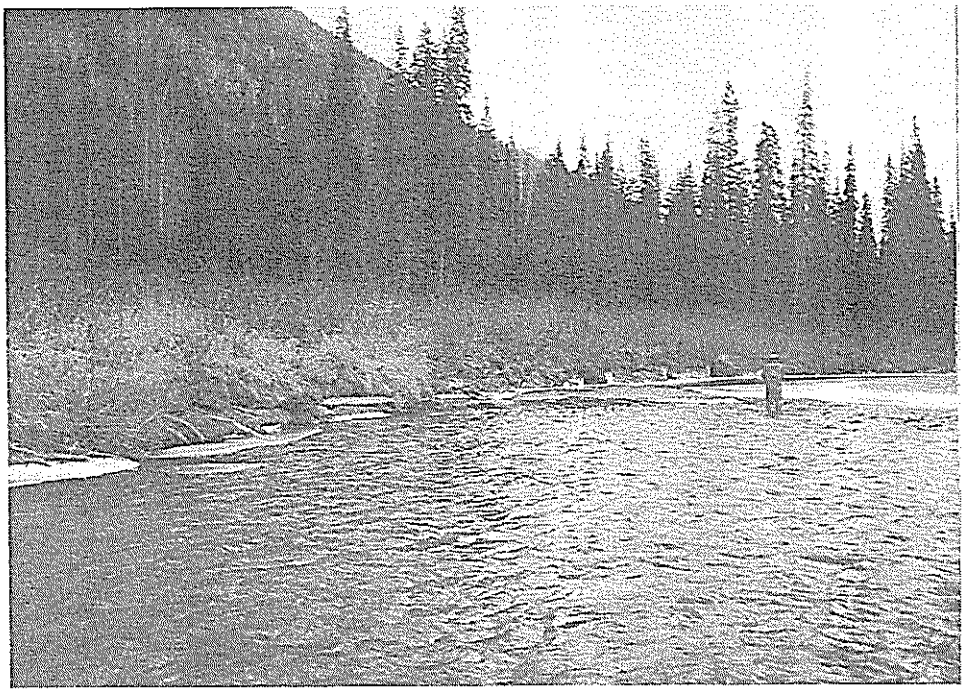


Photo 48 The sample site at reach 5. Extensive gravel and low gradient provides good spawning habitat for salmonids.

B CATEGORY STREAMS

4.5.10 Soards Creek

A 6 to 8 m falls located 370 m upstream from the mouth of Soards Creek leaves only a short section of habitat below this falls accessible to lake resident fish (Photo 49). A canyon extends 2.85 km upstream of the falls and forms Reach 2. Soards Creek becomes less confined, and the valley bottom bottoms broadens beyond the canyon. It is unknown if more barriers are present in reach 2 since the entire length of the canyon was not walked.

Both reach 3 and 4 offer good rearing habitat but a large fraction of gravel in the substrate (40%) and a high percentage of riffle (35%) and run (60%), provides reach 3 with better spawning habitat (Photo 50). Reach 3 is also relatively shallow and has a low gradient (Fig. 28). Shallow margins with slow current and extensive riparian cover as well as some boulder cover also provides excellent rearing habitat for fry and juvenile fish (Table 28). This was verified by the relatively large number of fry captured in this section of stream compared to upstream areas.

Large substrate and a larger percentage of deep pools suggest reach 4 is more suitable for rearing area of large fish rather than spawning although some side channel habitat is also present (Photo 51). A second falls, 5 m in height is located in reach 4, 9.5 kms upstream of the mouth. Survey sites were on Soards Creek were limited to the area below the second falls (Photo 52).

Fish

Both stream resident and lake stocks of fish were found in Soards Creek. Reach 1, although short in length, is the only section of the stream available to lake species of fish. Bull trout fry were captured and one large (~400 mm) bull trout adult escaped capture during electroshocking in reach 1. The adult bull trout likely migrated from the lake to spawn.

Resident rainbow trout were captured above the falls only, in both reach 3 and 4. Rainbow trout were more numerous in reach 3 but the single fish captured and those observed escaping during sampling in reach 4 were larger (Table 29).

Logging

Soards Creek is accessible via an extensive network of logging roads. These roads, unlike many roads bordering tributaries entering the west side of Revelstoke Lake, are accessible to vehicles without the need for a ferry, via the Nagel Creek road. Bridges cross Soards Creek twice, 7.3 and 9.5 km upstream of the mouth. Numerous old cutblocks exist on either side of the stream in both upper and lower elevations of the valley (excluding the canyon) to the end of reach 4, approximately 9.5 kms upstream. Recently constructed road was observed at mid-slopes on the north side of Soards Creek beyond reach 4 during the time of the survey. Downie Street Sawmills Ltd. is planning to log 277.5 ha. within the Soards watershed between 1991 and 1995.

Enhancement Opportunities

Enhancement opportunities for Soards Creek should be directed towards the resident stock of rainbow trout which might provide recreational fishing opportunities. The first falls is difficult to access and, because of its height, would require a constructed fishway to bypass it. Also, it is unknown if this is the only barrier in the canyon that must be removed. Furthermore, introducing lake stocks of fish into the upper watershed could create competition between resident and non resident species, detrimentally impacting each stock.

The ability for Soards Creek to provide a viable recreational fishery is unknown, but the recreational fishery potential may be enhanced by increasing the amount of habitat presently available to resident rainbow trout. Removal of the falls located at km 9.5 would make approximately 5 km of low gradient stream accessible to resident rainbow trout (Fig. 28). This area was not surveyed, so it is unknown if fish presently utilize it, or if other barriers exist upstream of the 9.5 km falls. The low gradient stream and marsh above the second falls through which Soards Creek meanders would likely provide excellent rearing and, potentially spawning, habitat for rainbow trout.

Figure 28: The stream profile for Soards Creek (not to scale)

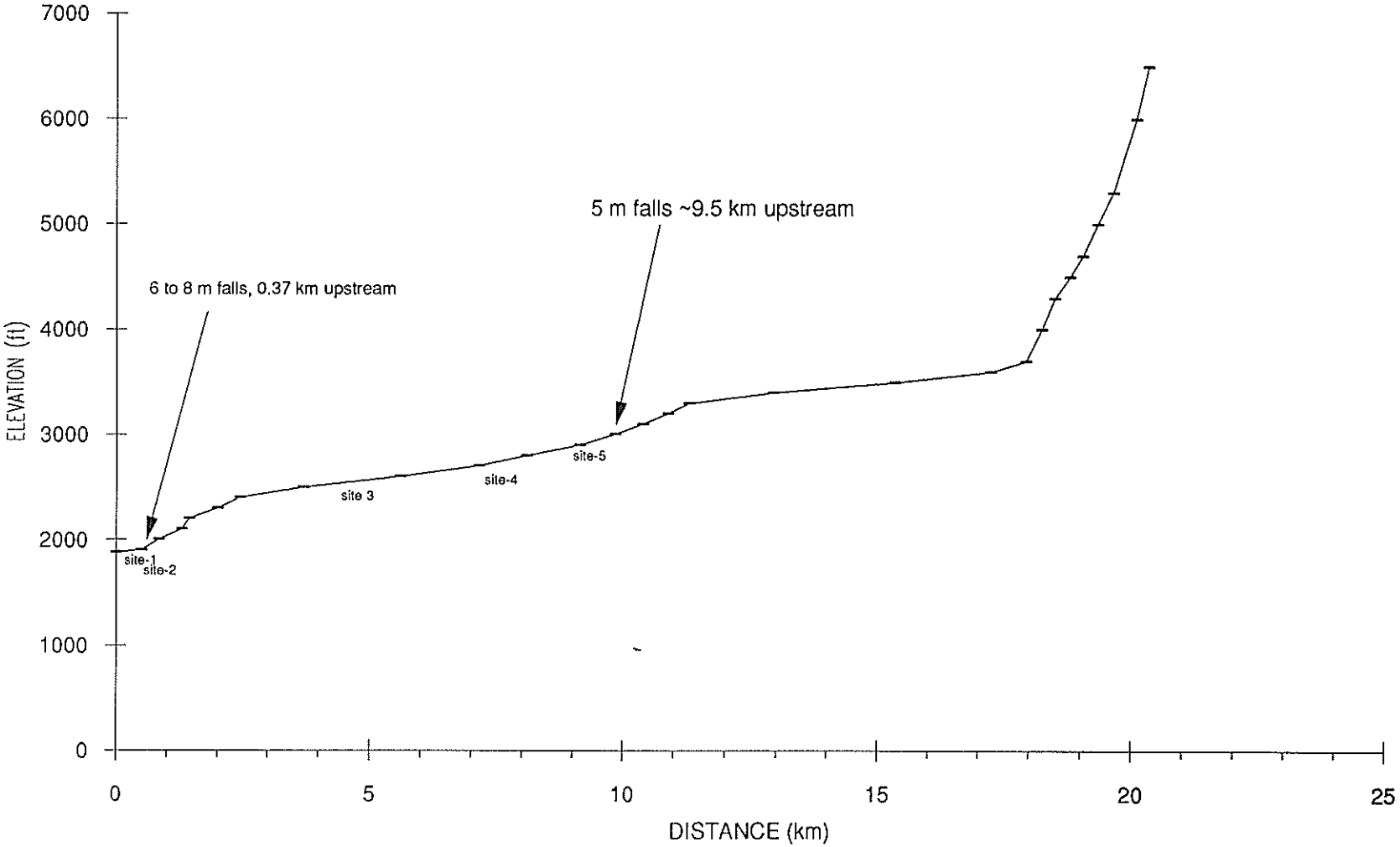


Table 28: Summary of biophysical habitat parameters for Soards Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	1.2	0.4	6,680	1,670	b/dp	200	1,670	1,670	2,338	1,002	1,336	1,670	M	70	CO	0 - 2
mainstem	2	2	8.0	2.9	36,540	10,962	b/dp	1,827	7,308	3,654	18,270	7,308	7,308	9,135	M	70	EN	0 - 2
mainstem	3	3	1.5	2.9	30,450	9,135	ov/b	305	1,523	10,658	18,270	0	6,090	12,180	M	50	OC	5 - 10
mainstem	4,5	4	4.0	3.4	56,925	15,139	dp/b/l	23,785	12,293	15,386	12,293	16,954	9,446	5,816	M	60	FC	0 - 2
Total 1+2+3+4:					130,595	36,906		26,117	22,793	31,368	51,171	25,264	24,180	28,801		63		

Summary of geographical parameters.

Location:	Northern end of resevoir, west side.
Length:	20 km
Barriers:	6 to 8 m falls 0.37 km upstream and 5 m falls 9.4 kms upstream. Canyon in reach 1 not explored
No. of Reaches:	7
No. of Reaches Sampled:	4
Length of stream belwo barriers:	0.37 km
Major Tributaries:	One unamed trib. entering at km 7.5.
Water Source:	Mainly glacial
Resource use:	Logging throughout watershed.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 29: **Electroshocking results (a), as well as fish size and age data (b) for Soards Creek.**

(a) Electroshocking results,

Site	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	1	4	3	bt	f	0.017	0.013	0.03	n/a	n/a	n/a
mainstem	2	0	0	-	-	0.000	0.000	n/a	n/a	n/a	n/a
mainstem	3	5	3	rbt	p	n/a	n/a	n/a	n/a	n/a	n/a
mainstem	4	1	2	rbt	a	0.002	0.004	0.006	n/a	n/a	n/a
Total		10	8	Mean:		0.006	0.011	0.004	n/a	n/a	n/a

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yr)	N
1	BT*	~40	n/a	n/a	n/a	n/a	4	n/a	0
3	RBT	134	29 - 111	9.27	0.23 - >120.00	1.09	1	1+	1
4	RBT	380	-	> 120	-	1.270	0	n/a	
3 + 4	RBT	134	79-180	27.72	0.23->120.0	1.09	1	1+	1

* = Data lost

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available

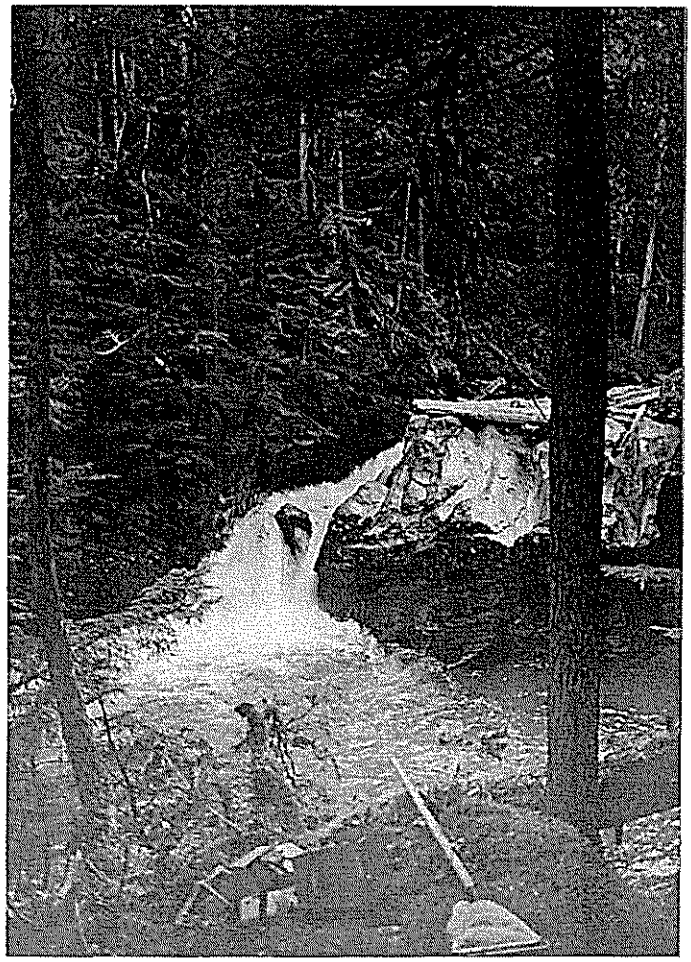


Photo 49 This 6 to 8 m falls is located 370 m upstream of the mouth of Soards Creek.

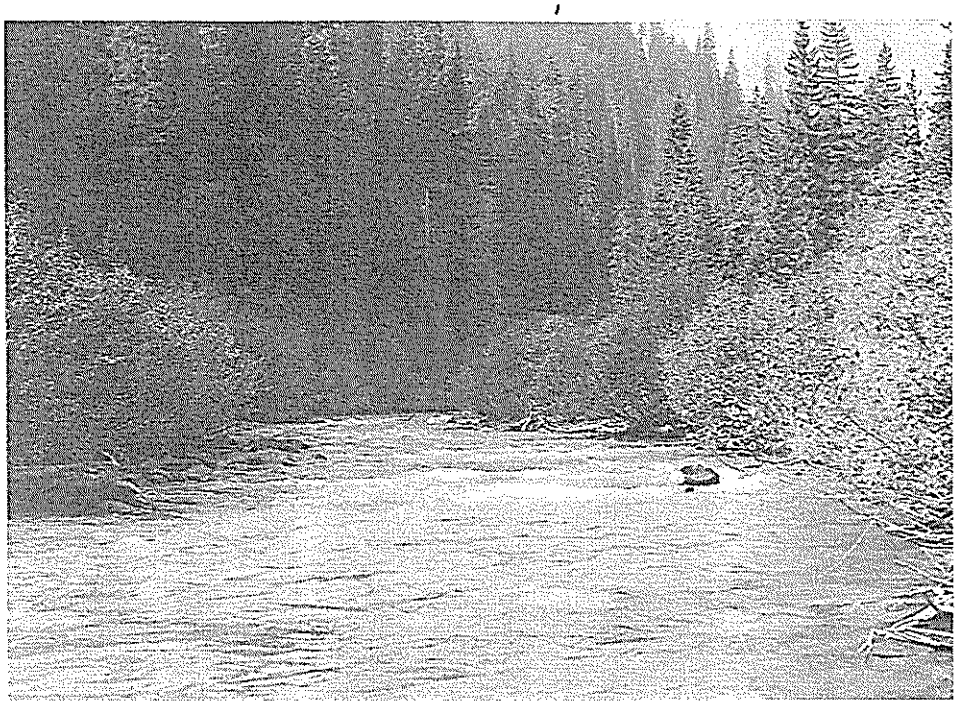


Photo 50 Slow water near stream margins and good riparian cover provides reach 3 of Soards Creek with good rearing habitat for juvenile trout.

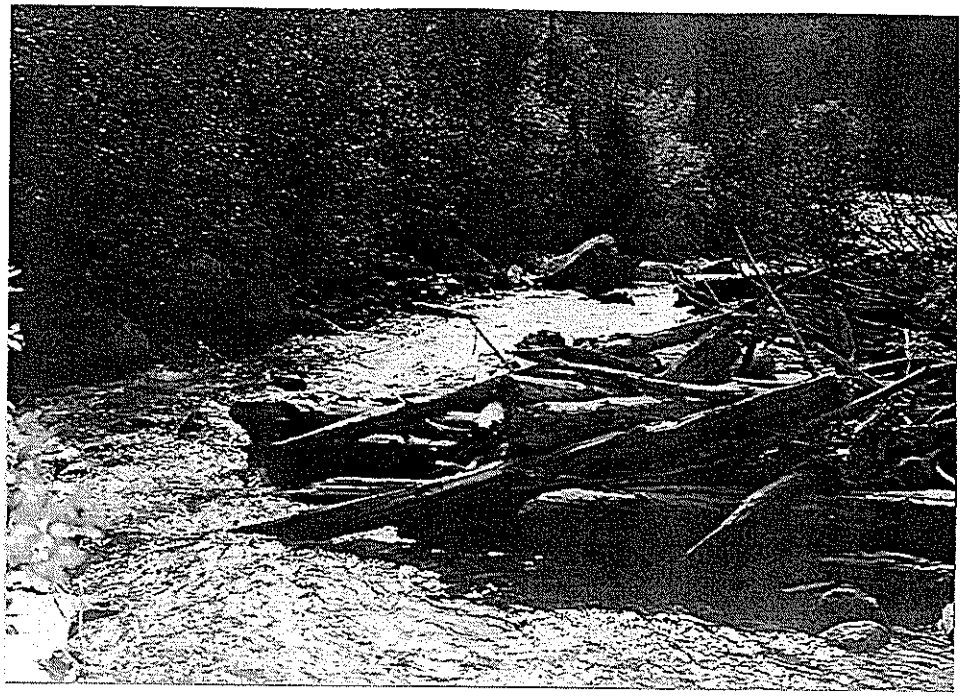


Photo 51 Side channel habitat in reach 4 of Soards Creek.

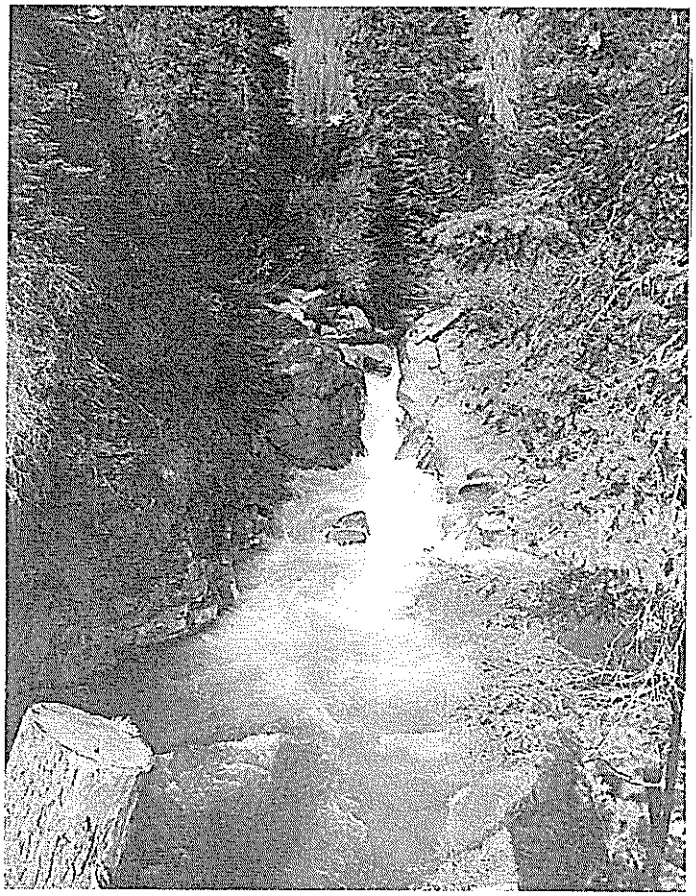


Photo 52 A 5 m falls located 9.5 km upstream divides the upper and lower halves of Soards Creek. The area above this second falls was not surveyed.

4.5.11 Mica Creek

There may be limited spawning or rearing habitat available to lake resident fish in Mica Creek. Reach 1 extends 500 m upstream and has mostly cobble and boulder in its substrate. Gravel is limited to small pockets in backeddies behind large boulders. Substantial riparian and boulder cover, complemented with some deep pool and cutbank cover, provides diverse rearing habitat for juvenile fish.

Reach 2 encompasses a steep sided canyon and a series of barriers. Two chutes 2 and 3 m in height followed by 2 falls, approximately 2 m in height each, begin at the start of this reach and extends for 100 m upstream (Photo 53). Another barrier, approximately 1.4 km upstream and estimated to be 3 m high, was observed during a helicopter overflight.

Reach 3 is characterized by evenly spaced pools and runs separated by riffle/cascade "steps". No single step amounts to more than 0.5 m rises in stream level. A large percentage of moderately compacted gravel in the substrate provides a suitable spawning medium for bull trout while extensive cover supplies the habitat necessary for rearing fish (Table 30).

Two weeks of freezing temperatures during a cold spell near the end of October, prior to sampling at site 3, created shore and frazzle ice, limiting access to open for both fish and the field crew (photo 54). This build up of both shore and anchor ice may be indicative of winter conditions for Mica Creek. If such freezing is common place during the winter months, high mortality may be expected. Bull trout fry prefer the shallow, slow moving water near stream margins which is prone to freezing (Pratt, 1985).

Fish

Only three bull trout were caught from Mica Creek, one from reach 1 and 2 from reach 3. Bull trout captured in reach 3 were considerably larger than the single bull trout caught in reach 1 (Table 31). Scale analysis indicated reach 3 specimens were 3^+ and 4^+ years old, within the age range of sexual maturity (Ford et. al 1992, Scott and Crossman 1973). Fish were not captured in reach 2 but three large bull trout (estimated >400 mm) were observed in a pool below a 2.5 m falls. One of these fish

was observed attempting to jump this falls, but was unsuccessful after three tries. Barriers within reach 2 definitely restrict the upstream movement all kokanee but possibly not large bull or rainbow trout. The only evidence that suggests bull trout found in reach 3 are resident is the fact they were captured above suspected barriers.

Historical data indicates bull trout, rainbow trout, whitefish and kokanee utilized Mica Creek prior to the creation of the 1880 reservoir level (Martin, 1976). Mica Creek still does support limited spawning habitat for kokanee, although none were seen during this years' surveys (Pers. comm. Brian Gadbois, B.C. Hydro Tech.).

Logging

Logging in the Mica Creek watershed is limited primarily to the south side of the creek within the first 2 km of the stream mouth. Cutblocks are located at midslope and higher elevations. As of yet, there is no road access into the valley bottom although a new road was being built along the north face of the valley above reach three, about 3 km upstream of the mouth. During a helicopter overflight of Mica Creek on October 25, road construction was contributing sediment into the mainstem from a small tributary crossed by the new road approximately 3 km upstream. The effect of this sediment input upon water turbidity was first observed at the mouth of Mica Creek. Also, a small land slide on the south side of Mica Creek originates from a cutblock which borders the top of the canyon within the first 300 m of reach 2, behind the Mica Creek town site. Westar has planned to remove 284.1 ha. from the Mica Creek drainage from 1991 to 1993, however, the status of this planned logging may be affected by the impending sale of Westar.

Enhancement Opportunities

Redirecting a portion of Mica Creek's discharge into a drainage ditch which runs parallel to the Big Bend Highway, adjacent to the village of Mica Creek, provides a strip approximately 500 m long which could be utilized to construct a spawning channel (photo 55). A clear water supply is conducive to positioning a spawning channel at this site. Kokanee which have been observed to accumulate at the base of the Mica Creek Dam could utilize this channel, as might spawning bull trout. The presence of the drainage ditch along the Big Bend Highway would reduce the

amount of excavation necessary to build a spawning channel and thereby reduce the costs of constructing such a structure. A flow control structure at the upstream end of the channel would be necessary to prevent damage to the spawning channel, and protect against the possibility of flooding in the village during peak flows. Also the terminus of the spawning channel would have to rejoin Lake Revelstoke downstream of Mica Creek, thereby requiring a highway crossing.

Barrier removal may facilitate upstream migration of spawning bull trout, but at least 3, possibly more, barriers would have to be modified or removed. A thorough examination of the canyon in reach 2 of Mica Creek would be required before barrier removal is considered. Furthermore, the origin of bull trout captured in reach 3 would have to be addressed if stock competition is a concern.

Figure 29: The stream profile for Mica Creek (not to scale)

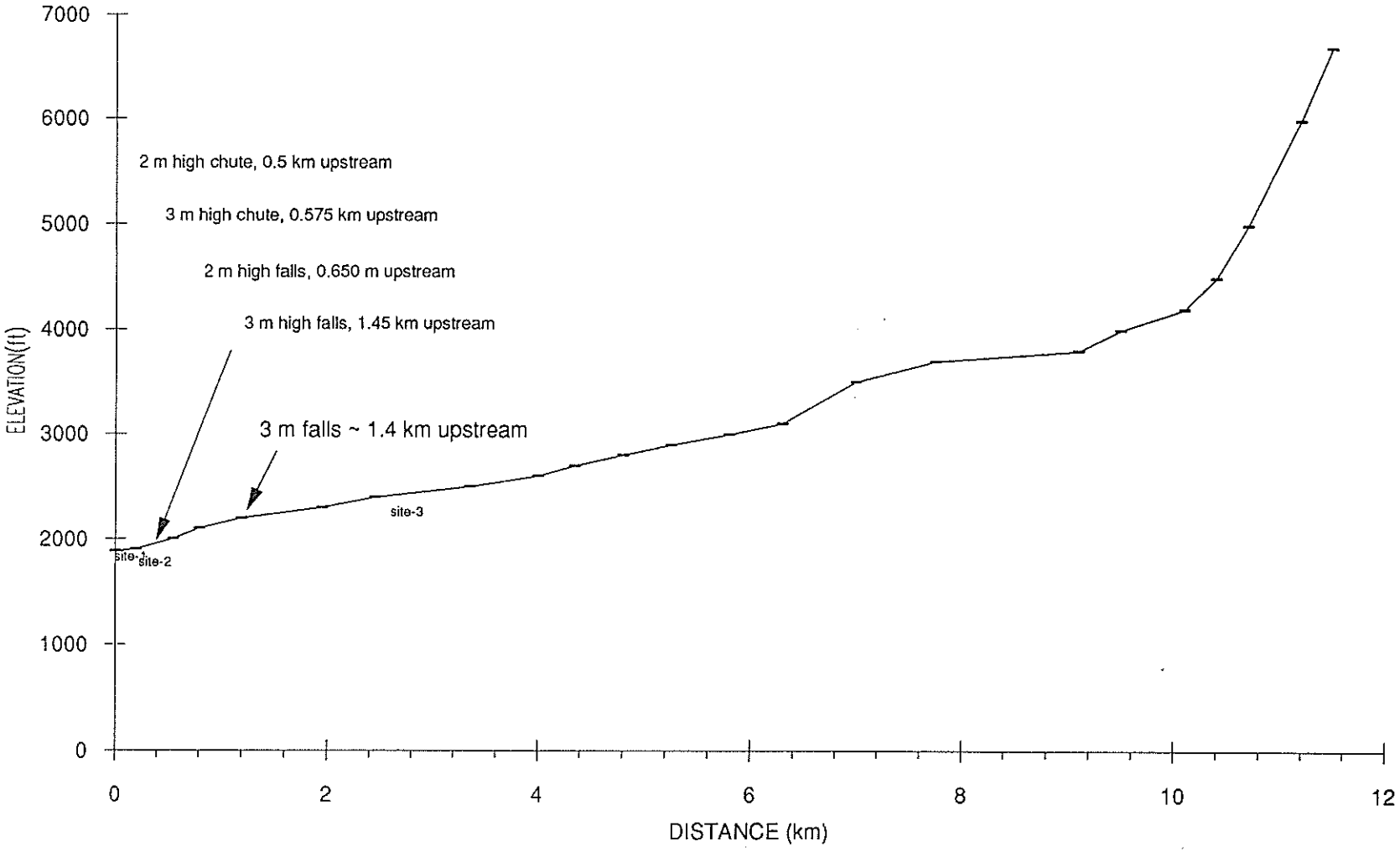


Table 30: Summary of biophysical habitat parameters for Mica Creek.

						COVER			STREAM CHARACTER				SUBSTRATE			VALLEY CHAR.		
Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	4.0	0.4	3,360	1,344	ov/b/dp	101	1,008	672	672	1,008	504	672	M	100	CO	0 - 2
mainstem	2	2	6.4	2.0	12,000	4,800	dp/b	1,200	4,800	600	4,800	1,800	1,800	0	M	100	EN	0 - 2
mainstem	3	3	6.0	2.3+	31,050	9,315	dp/lod/b	1,553	9,315	9,315	12,420	0	3,105	10,868	M	90	CO	2 - 5
Total 1+2+3:				4.7+	46,410	15,459		2,853	15,123	10,587	17,892	2,808	5,409	11,540		97		

Summary of geographical parameters.

Location:	Northern most tributary entering Revelstoke lake, east side.
Length:	12 km
Barriers:	2.0 - 3.0 m chutes & falls starting 500 m upstrteam, also a 3 m falls approx. 1.5 km upstream.
No. of Reaches:	4.7+ km
No. of Reaches Sampled:	3
Total Length below barriers:	~0.5 km
Major Tributaries:	None
Water Source:	Small lakes and small glaciers
Resource use:	Along upper slopes of reach 2 and the start of reach 3.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 31: **Electroshocking results (a), as well as fish size and age data (b) for Mica Creek.**

(a) Electroshocking results,

Site	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	1	1	0	bt	p	0.005	0.000	0.005	n/a	n/a	n/a
mainstem	3	2	0	bt	a/p	0.009	0.000	0.009	n/a	n/a	n/a
Total:		3	0		Mean:	0.007	0.000	0.007	n/a	n/a	n/a

Note: 3 adult bull trout were observed in a pool at the base of the third falls (~ 3.0 m high). One bull was unsuccessful in 3 attempts to jump the falls. These fish were likely spawners.

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yrs)	N
1	BT	86	-	6.28	-	0.99	1	n/a	0
3	BT	207	202-211	92.98	82.44-103.51	1.03	2	3 - 4+	2
1 + 3	BT	166	202-211	69.30	82.44-103.51	1.05	2	3 - 4+	2

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available



Photo 53 Bull trout were observed attempting to jump this 2.5 m falls located approximately 650 m upstream on Mica Creek.



Photo 54 Extensive frazzle, anchor and surface ice made sampling at reach 3 of Mica Creek difficult, and reduced available habitat for rearing bull trout.



Photo 55 A drainage ditch which parallels the highway near the mouth of Mica Creek could be made into a spawning channel.

4.5.12 Nicholls Creek

Two submerged culverts exist at the mouth of Nicholls Creek under the Big Bend Highway. A small pond which has formed between the highway and the mouth of the Creek, collects driftwood flushed out of Nicholls Creek. This pond, associated with the large amount of LOD, probably provides good rearing habitat for juvenile fish, but the LOD may also contribute to a blockage of the culverts. The proximity of floating LOD to the culverts may result in water logged wood settling on top of the culverts or if the pond level drops in conjunction with lowering reservoir levels.

Reach one is a short, braided section of stream with approximately 30% cover. Low to moderately compacted gravel comprises about 25% of the stream bed material, while cobble and boulders account for 60% of the bed material.

Nicholls Creek becomes entrenched in a narrow gorge within the first few hundred m of reach 2, after which elevation increases rapidly (Fig. 30). Large debris accumulations were observed in the first section of reach 2, although most of this LOD was not within the wetted channel at the time of the survey. Numerous small falls and logjams exist in reach 2 of Nicholls Creek, although many of these barriers may be negotiable at high water. The largest single barrier is a 5 m falls located 2.3 km upstream and likely presents the upstream limit of migration for lake resident fish (photo 57). Gravel retainment was observed upstream of these barriers. Stream gradient varied between 9% and 14% in this reach, although short sections of creek with gradients as low as 2.5% often occurred between 2 sets of falls. These short sections were found to provide good rearing and spawning habitat for rainbow trout. Reach 2 of Nicholls Creek has the most cover and pool area of any of the reaches surveyed although it contains less wetted area than reach 3 (Table 32).

Nicholls Creek is braided, and less confined in reach 3 than in reach 2 and relatively flat (~4% slope) for short sections of stream (Photo 58). Surface ice was forming along the margins of Nicholls Creek during the survey of the reach 3 sample area (site 5), but this ice did not impinge on fish habitat as much as it added extra cover. Anchor ice was not observed. Pools associated with LOD provide excellent rearing

habitat for juvenile rainbow trout, while extensive riffle area between pools provides ample spawning habitat.

Fish

Similar to Pitt Creek, Nicholls Creek also appears to contain a resident stock of rainbow trout, although lake resident fish likely utilize the lower sections of the creek also. Bull trout and cottids were captured in reach 1 only, whereas rainbow trout were captured in every reach sampled in Nicholls Creek (Table 33a). CPUE for rainbow trout was highest in reach 1, and the overall CPUE for Nicholls Creek was amongst the highest observed of all tributaries sampled.

The presence of a 5 m falls in reach 2 suggests rainbow trout fish captured upstream of this barrier are resident fish, however, none of the rainbow trout captured in Nicholls Creek exceeded 200 mm in length or 50 g in weight (Table 33b). Small, slow growing fish may be expected in the colder, higher elevations of Nicholls Creek, but scale analysis indicated none of the rainbow trout aged were over 3 years old. Furthermore, although there is no water quality data to suggest otherwise, the comparatively high CPUE observed for this stream suggests good food resources exist to support a population of rearing trout. The absence of adult fish may be indicative of the inefficiency of an electroshocker to sample the larger deeper pools where adult fish are more likely to reside, however, there was no indication that large fish were escaping the effects of the electroshocker, which might be expected in the confined areas of a stream as small as Nicholls Creek.

Logging

The five year plan submitted by Westar indicates 186.1 ha will be clear-cut from the Nicholls watershed in 1995 but the extent of present logging activities within this drainage was not determined. Scott Logging Contractors once had a small water supply dam adjacent the mouth of Nicholls Creek to service its crew camp (still present) although this was removed some time ago (Pers. com. Camp attendant for Scott Logging). It is unknown if this dam was a migration barrier.

There is presently no road access to Nicholls Creek other than the highway crossing at the mouth.

Enhancement Opportunities

Nicholls Creek likely provides spawning and rearing habitat for lake resident fish within reach 1 and 2. Removal of some small barriers within reach 2 may facilitate transport of gravel downstream, benefitting available spawning habitat for lake resident rainbow trout and facilitating upstream access. The culverts at the mouth of Nicholls Creek should be inspected at low lake levels to determine if LOD settling at the mouth of the pond creates a barrier. It is also prudent to ensure habitat which now exists in Nicholls Creek is not impacted by future activities which may occur within the watershed. Finally, Nicholls Creek may be a potential source of rainbow trout brood stock for hatchery operations.

Figure 30: The stream profile for Nicholls Creek (not to scale).

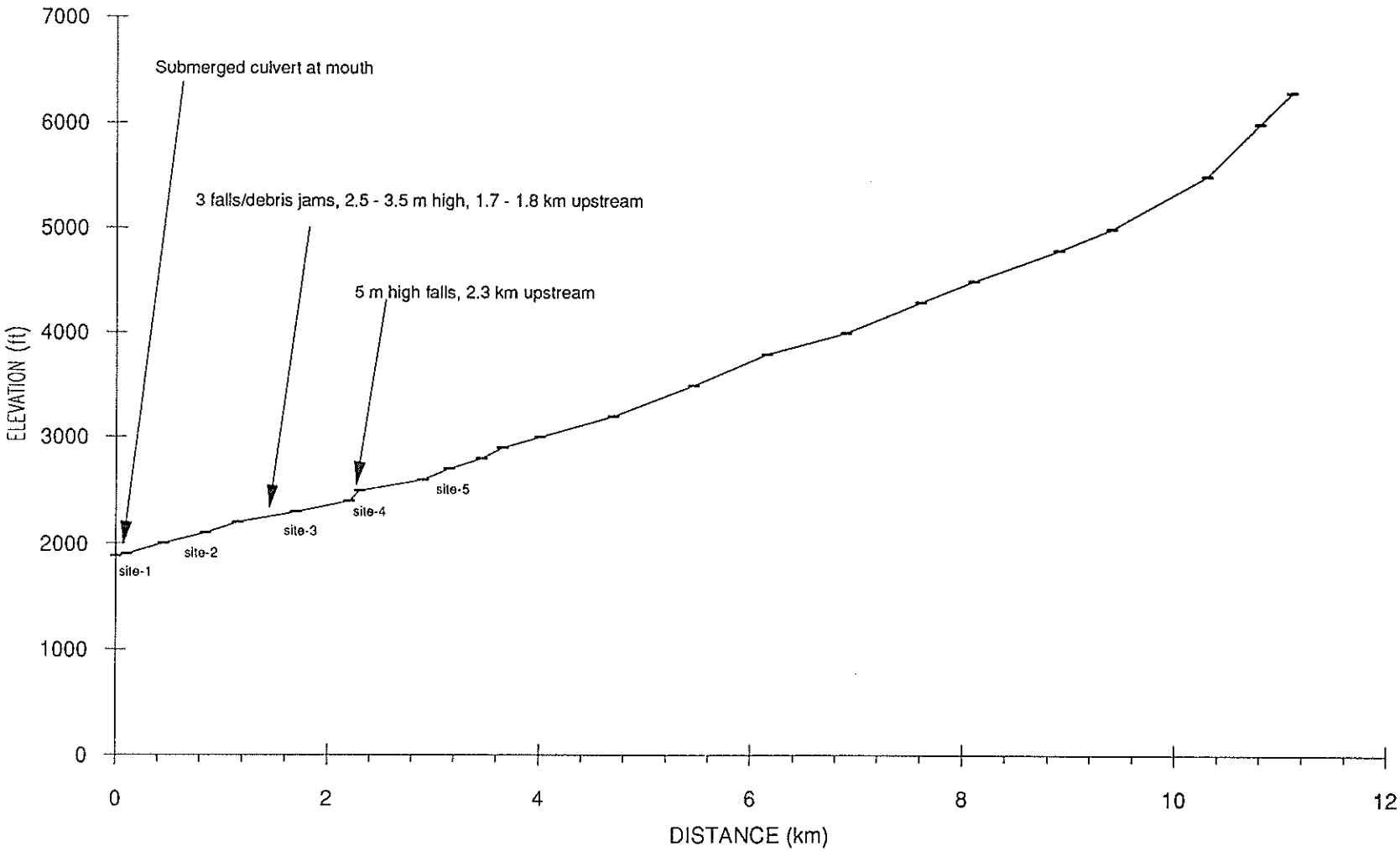


Table 32: Summary of biophysical habitat parameters for Nicholls Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	4.5	0.3	3,810	1,143	l/b	572	1,143	1,143	1,143	381	572	953	M	100	CO	0 - 2
mainstem	2,3,4	2	7.5	2.1	14,700	5,789	dp/b/l	2,244	4,837	2,776	5,191	1,463	2,212	4,501	L - M	100	EN	0 - 2
mainstem	5	3	8.0	1.5	18,430	4,608	l/b	1,843	4,608	6,451	6,451	922	1,843	6,451	M	90	CO	0 - 2
Total 1+2+3:				3.8	36,940	11,540		4,658	10,588	10,369	12,784	2,766	4,627	11,904		97		

Summary of geographical parameters.

Location:	North central area of resevoir, east side.
Length:	11 km
Barriers:	Numerous small barriers throughout reach two, including a 5 m barrier 2.3 km upstream.
No. of Reaches:	3
No. of Reaches Sampled:	3
Length of stream below barriers:	2.3 km
Major Tributaries:	None
Water Source:	Marsh and a small lake, crstal clear water.
Resource use:	No logging observed, possibly a source of well water for a small logging camp at creek mouth.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 33: **Electroshocking results (a), as well as fish size and age data (b) for Nicholls Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
	1	12	7	rbt	f/p	0.030	0.018	0.048	n/a	n/a	n/a
	1	1	0	bt	p	0.003	0.000	0.003	n/a	n/a	n/a
	1	1	0	cc	a	0.003	0.000	0.003	n/a	n/a	n/a
total reach 1:		**14**	**7**	**mean:**		**0.012**	**0.006**	**0.018**	**n/a**	**n/a**	**n/a**
	2	7	10	rbt	f/p	0.010	0.014	0.023	n/a	n/a	n/a
	3	5	1	rbt	p	0.020	0.004	0.024	0.021	0.004	0.025
Total:		26	18	Mean:		0.014	0.008	0.022	n/a	n/a	n/a

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (K)	N	Age Range (yr)	N
1	RBT	73	34 - 179	11.46	0.95 - 1.33	1.11	12	2 - 3+	3
2	RBT	111	46 - 168	19.44	1.28 - 44.87	1.15	7	2 - 3+	3
3	RBT	125	81 - 167	24.68	5.88 - 49.13	1.06	6	1+	1
1	BT	98	-	10.76	-	1.14	1	1+	1
1	CC	89	-	8.26	-	1.17	1	n/a	0
1+2+3	RBT	95	34-168	16.54	0.95-49.13	25	1.11	25	1 - 3	7

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available

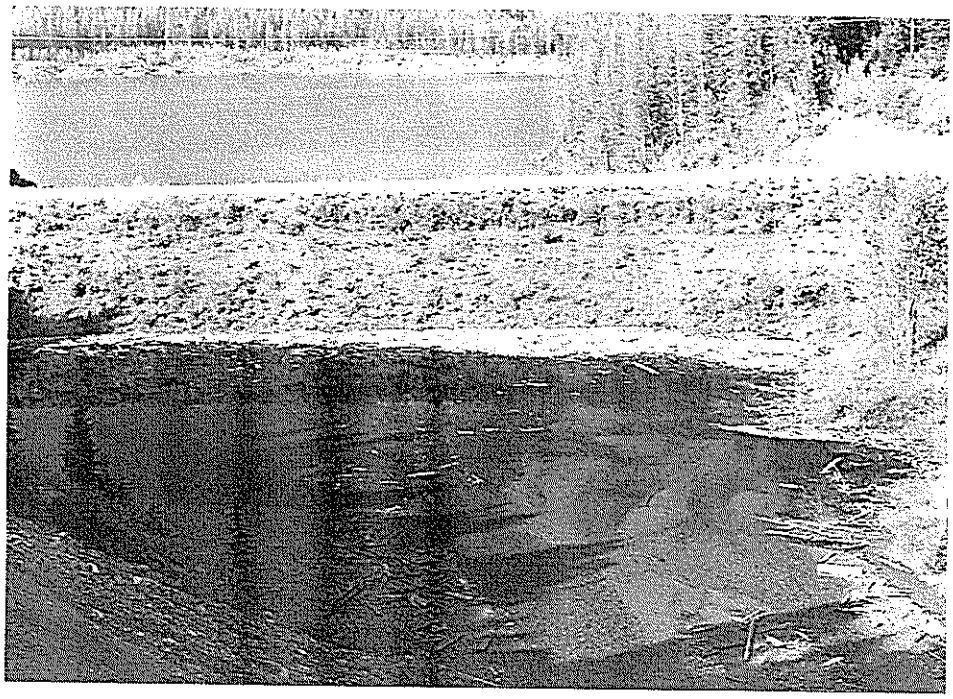


Photo 56 A large pool between the highway and the mouth of Nicholls Creek probably provides good rearing habitat for salmonids. Note the extensive floating debris in the proximity of submerged culverts.

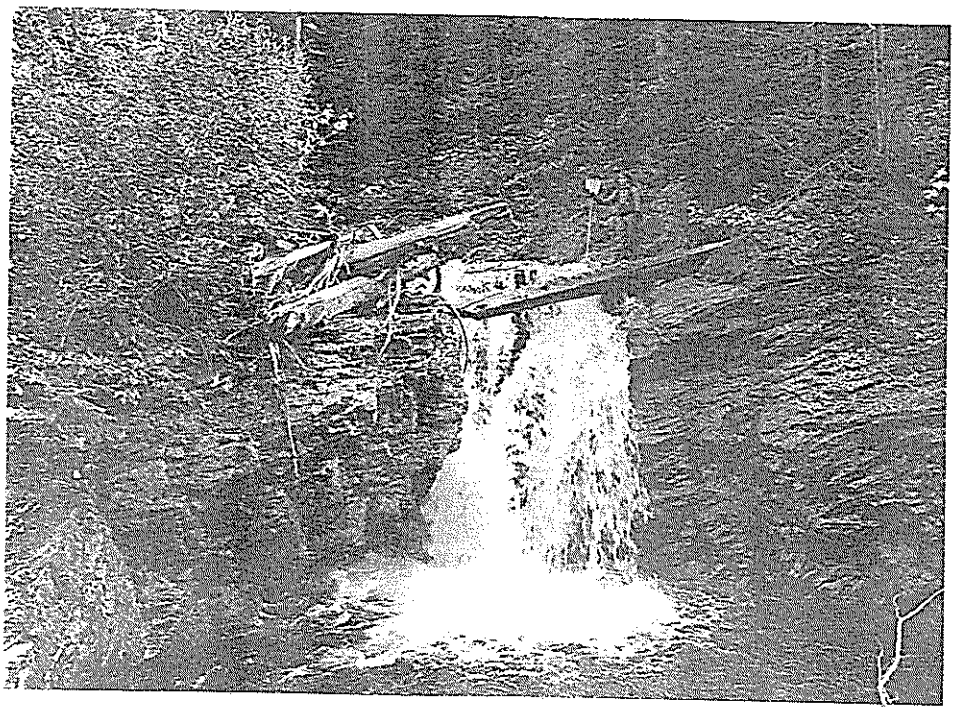


Photo 57 Numerous small barriers exist in reach 2 of Nicholls Creek, but this 5 m falls located 2 km upstream is a definite migrational impasse to lake resident fish.



Photo 58 Rearing habitat in reach 3 of Nicholls Creek is supplemented by LOD and pool cover.

4.5.13 Park Creek

Park Creek is a short glacier fed stream flowing into the west side of Revelstoke Lake. Two obstructions, a chute and a debris jam within the first 200 m of Park Creek restrict access to this stream (Fig 31). The short section of creek where the barriers occur is littered with wind fall from a green strip left on the south side of the creek. The 1.5 m high chute is negotiable to bull trout and rainbow trout, but probably not to kokanee. Accumulations of LOD in a small gorge upstream of the chute has created a 2 m high falls which is impassable to fish (Photo 59).

Unlike many of the smaller streams entering Revelstoke Lake, Park Creek valley broadens almost immediately upstream of the barriers near the creek mouth. A broad flood plain and a large fraction of boulder and large cobble in the bed material and a relatively steep gradient (4.5% to 5.5% in reach 2) suggests Park Creek is subject to extreme flow conditions during freshet. This has lead to extensive disruption of channel direction and uniformity (Photo 60). Pools, boulders, and to a lesser extent LOD, provides most of the cover in this stream (Table 34). Glacial water supplements available cover but also subjects Park Creek to seasonal variations in turbidity, and likely, sedimentation.

Fish

Martin (1976) reports kokanee, whitefish, rainbow trout and bull trout were all found in the lower quarter mile of Park Creek prior to the flooding of the Columbia River upstream of Revelstoke Dam. At present, bull trout are the only species observed in Park Creek, although they were captured both upstream and downstream of the falls. Habitat once available for kokanee spawning is no longer present.

Bull trout above the falls are likely resident stock but scale analysis indicates fish captured in this area were sub adult and there were no indications of adult bull trout above the barrier (Table 35). The highest fish densities, 0.02 fish per m^2, were recorded in reach 2. Scouring during high flow events and siltation due to the glacial nature of Park Creek probably increases egg mortality and non-volitional movement of fry downstream, limiting the productivity of this stream.

Logging

Some logging has occurred near the mouth of Park Creek, otherwise, there is planned logging to occur in the watershed. As no logging roads exist, access to Park Creek above the falls is limited to helicopter or foot, the latter is facilitated by a guide trail on the north side of the stream. The mouth of Park Creek is crossed by a logging road bridge, and the falls readily accessible. Ferry transportation across the lake is necessary for vehicles to access the logging road.

Enhancement Opportunities

Park Creek has approximately 3.5 km of stream, representing about 21,000 m^2 of wetted area, available to fish upstream of its barrier (Fig. 31). The fact that the falls on Park Creek is composed of debris accumulated at a constriction suggests this barrier is not permanent, hence, it may have been negotiable to fish in past years. Although a relatively small amount of habitat is available to fish upstream of the Park Creek barrier, compared to other streams entering Revelstoke Lake, the ease of access to the falls and its small drop facilitate removal of this obstruction. Such a project is appropriate for the local Rod and Gun Club to complete. The falls on Park Creek is not affected by fluctuating lake levels, although the chute at the entrance of the creek from the lake may be affected. This could not be determined during the fall survey when lake levels where high.

The broad valley upstream of the Park Creek barriers provides sufficient area to construct off channel rearing habitat. Suitable space and grade facilitates the construction of an access road to the upstream reaches of Park Creek if construction of side channel habitat or the like is deemed appropriate.

Figure 31: The stream profile for Park Creek (not to scale)

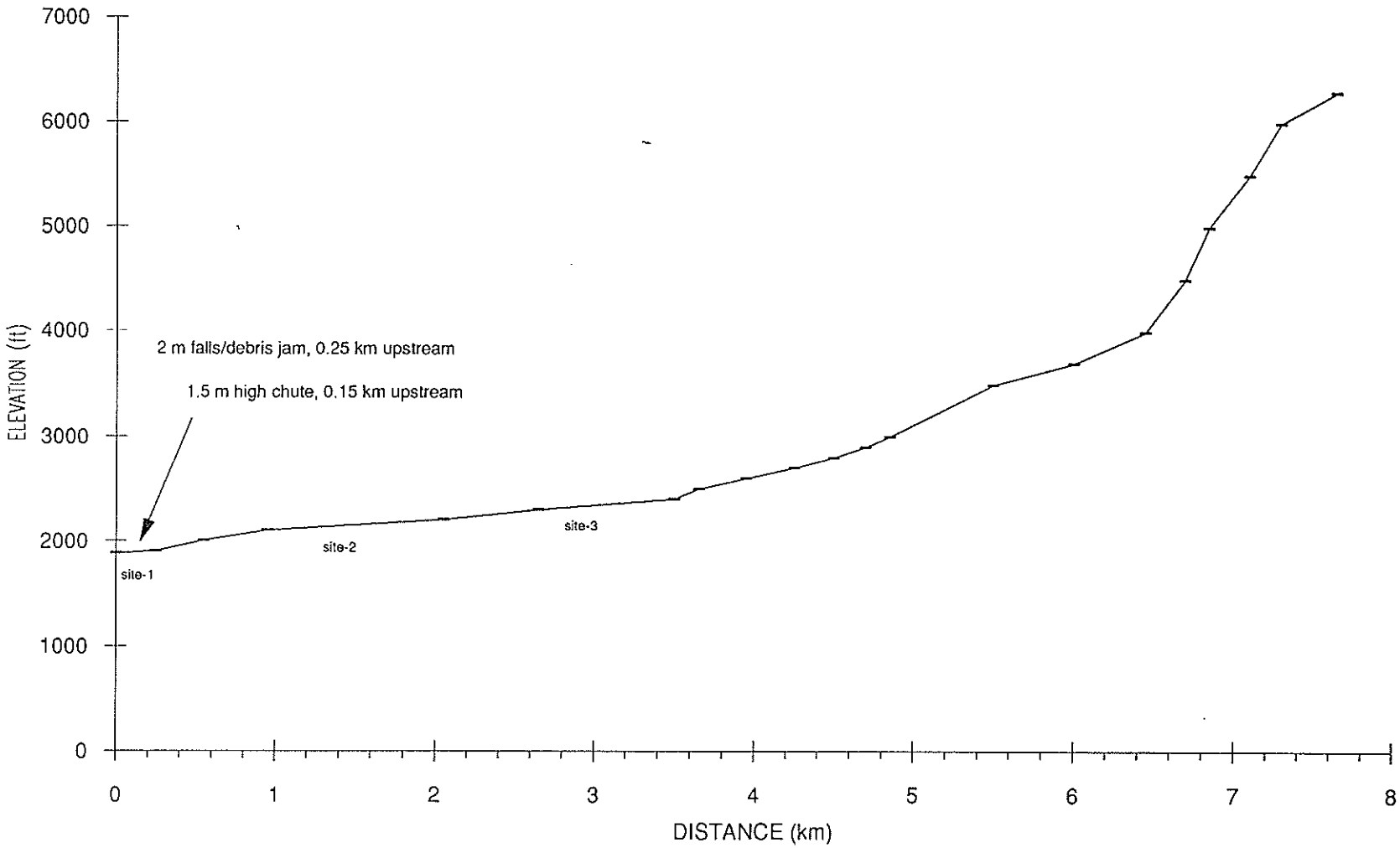


Table 34: Summary of biophysical habitat parameters for Park Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	n/a	0.2	2,680	938	l/b/dp	536	402	1,072	804	402	134	670	L	35	EN	0 - 2
mainstem	2,3	2	4.3	2.8	21,000	2,240	dp/ov	1,610	2,100	10,920	7,000	980	2,100	7,350	L - M	45	FC-OC	2 - 5
Total 1+2					23,680	3,178		2,146	2,502	11,992	7,804	1,382	2,234	8,020		40		

Summary of geographical parameters.

Location:	Southern area of Revelstoke Lake, west side.
Length:	7.65 km
Barriers:	1.5 m chute and a 2 m falls 100 and 150 m upstream.
No. of Reaches:	3+
No. of Reaches Sampled:	2
Total Length of stream below barriers:	0.2 km
Major Tributaries:	none
Water Source:	Glaciers
Resource use:	Little observed logging. Hunitng guide trail present adjacent stream for first 2 km.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

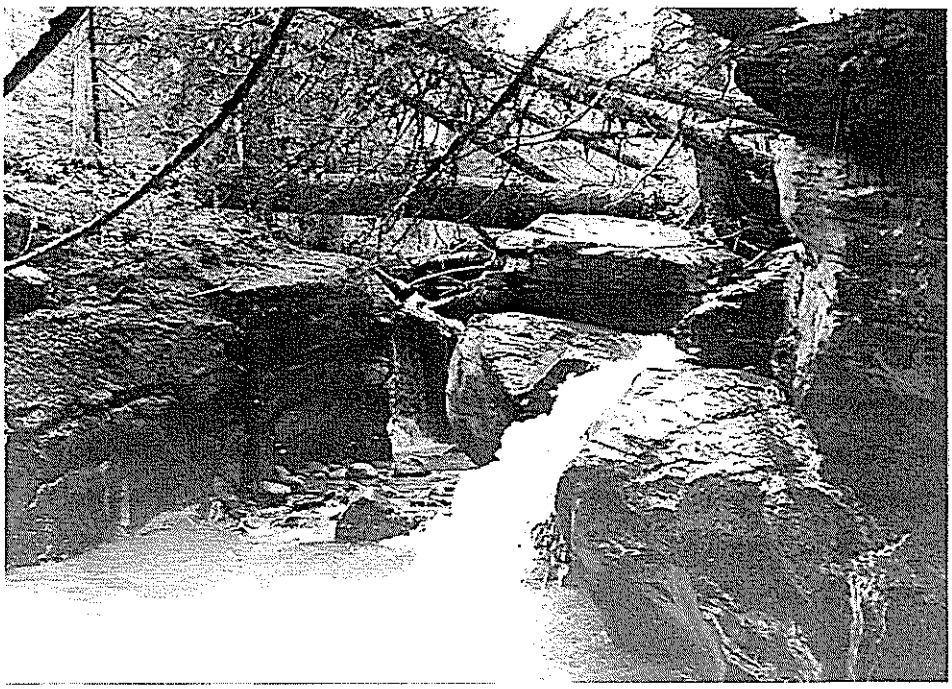


Photo 59 This 2 m high debris jam at the mouth of Park Creek is accessible, and could be easily removed.



Photo 60 A broad uncontained flood plain with extensive cobble and boulder substrate suggests Park Creek is subject to large fluctuations in discharge.

Table 35: **Electroshocking results (a), as well as fish size and age data (b) for Park Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
main	1	2	2	bt	f/p	0.014	0.014	**0.028**	0.005	0.005	**0.010**
main	2	0	3	bt	f/p	0.000	0.013	**0.013**	0.000	0.008	**0.008**
main	2	6	4	bt	p	0.013	0.008	**0.021**	0.012	0.008	**0.020**
total, reach 2:		**6**	**7**	**mean:**		**0.006**	**0.011**	**0.017**	**0.006**	**0.008**	**0.014**
Total, 1 + 2:		8	9	Mean		0.009	0.012	0.021	0.006	0.007	0.013

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	Range N	Age Age (yr)	Range	N
1	BT	98	43 - 153	18.86	1.40 - 36.31	1.39	2	n/a*		0
2	BT	163	130 - 187	43.25	21.90 - 66.90	0.96	6	2 - 3+		3**
1 + 2	BT	147	43-187	37.15	1.40-66.90	1.07	8	2 - 3+		3

* scale sample unreadable

** 3 of 6 scale samples unreadable, only fish > 130 mm.

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available

4.5.14 Pat Creek

Pat Creek is one of 5 streams entering Revelstoke Lake which has a resident rainbow trout population. These resident fish are isolated from the lake by a 5 to 10 m high barrier approximately 4 km upstream of the mouth (photo 61). A number of smaller chutes and falls also exist in a steep sided canyon/gorge which originates at the mouth of Pat Creek and extends about 4 kms upstream. Included with these small barriers are a 1.5 m high chute and 1 m high falls at the creek mouth. The height of these barriers will change with fluctuations in water levels as water levels of Lake Revelstoke, hence they may be impassable to lake resident fish at low reservoir levels. This may be most relevant for rainbow trout which spawn during the spring, when reservoir levels may be low. Mason (1985) does not indicate a barrier on Pat Creek whereas Martin (1976) reports a 2.5 m barrier 2.3 km upstream of the mouth, presumably the barrier which is now located at the mouth of the creek. The field crew was not able to assess the entire canyon for the presence of migrational barriers since it was not negotiable by foot. A number of small lakes, combined with little glacial input provides Pat Creek with a clear steady water source.

Reach 1 is located within a canyon. Access into this area is restricted by steep banks and numerous rock bluffs. Numerous small chutes and falls in this area would restrict upstream movement of kokanee and possibly rainbow and bull trout.

Reach 2 is situated in a short gorge which contains the major falls observed at km 4. Water flows fast through this area, although numerous small, relatively deep pools exist behind the large boulders which dominate the substrate.

Reach 3 and 4 have the lowest gradients observed in Pat Creek (Fig. 32). These reaches also have the best spawning and rearing habitat. Reach 3 meanders for about 7 km through a broad valley bottom with considerable off channel habitat, provided by alder marsh and beaver ponds. Large, deep pools, punctuated with short stretches of riffle and/or run, are common to this section of stream (Photo 62). Similar to reach 3, beaver ponds and alder marsh also provide good off channel habitat in reach 4, but the valley narrows in this section of stream and the channel becomes straighter (photo 63). Reach 3 has more pool but less riffle area than

reach 4 (Table 36). Both reaches have high proportions of gravel in their substrate (50% to 60%), although the gravel in reach 3 is less compacted.

Fish

Only rainbow trout were observed in Pat Creek, all of which were captured upstream of the major barrier. For this reason, these rainbow trout are considered a resident stock. The mean size of these fish decreased as sampling progressed upstream (Table 37). No rainbow trout captured in Pat Creek were over 2 years old, but 2 large, and presumably older, fish escaped during sampling at the reach 2 site.

Dolly Varden, presumably bull trout, once utilized the section of stream flooded below the falls which now exists at the mouth of Pat Creek (Martin, 1976). High flows prevented electroshocking immediately upstream of the small falls at the mouth, so it is unknown if bull trout still utilize reach 1 of Pat Creek. Habitat available to lake resident bull and/or rainbow trout is restricted to reach 1 below the 10 m high falls at km 4, assuming the smaller barriers downstream of this falls are negotiable by large bull and rainbow trout.

Logging

The Pat Creek Valley has been logged throughout its drainage at both high and low elevations. Future logging plans include clearcutting approximately 322 ha of land in 1992, 94 and 95.

The creek is easily accessed from a number of points along the logging road servicing the north side of the creek valley, although this road can only be reached by ferry. In some instances, the road follows steep banks adjacent the stream, which are prone to erosion. Site 2 on Pat Creek represents one such area. The road has been built over an unstable bank and erosion caused by runoff is presently threatening a total collapse of this road into the stream. The relatively large amount of cut blocks may impact upon water quality in Pat Creek. A single night of rain resulted in crystal clear water becoming so turbid, visibility was reduced to only 20 cm.

Enhancement Opportunities

Pat Creek may be able to support a recreational fishery, but, sports fishing activities would have to be closely monitored to ensure the stock remains self sustaining. An extensive network of logging roads makes Pat Creek very accessible to sports fisherman, although ferry transportation is required to transport vehicles to these roads. Any enhancement activities for Pat Creek should involve resident fish only. More information is required, prior to recommending potential enhancement projects.

Figure 32: The stream profile for Pat Creek (not to scale).

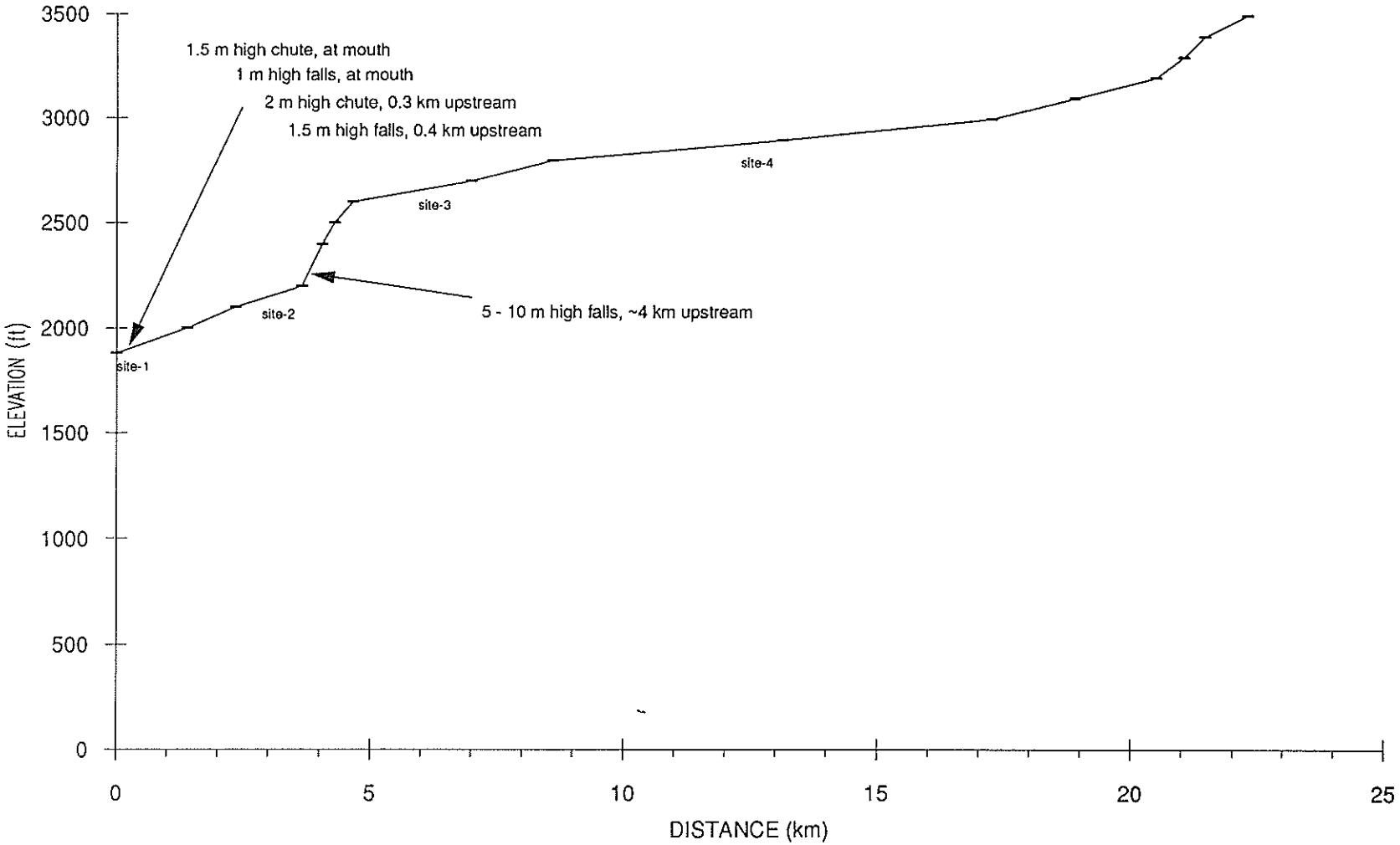


Table 36: Summary of biophysical habitat parameters for Pat Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	4.7	2.5	32,500	3,250	b/dp	325	3,250	16,250	9,750	3,250	n/a	n/a	n/a	20	EN	0 - 2
mainstem	2	2	2.5	2.4	30,960	7,740	b/dp	929	4,644	13,932	10,836	1,548	3,096	3,096	L	110	CO	2 - 5
mainstem	3	3	0.5	6.7	130,650	52,260	dp/l	26,130	65,325	32,663	32,663	0	45,728	78,390	L	200	OC	5 - 10
mainstem	4	4	0.7	7.8	156,000	31,200	dp/l	7,800	39,000	62,400	54,600	0	23,400	78,000	M	150	FC	2 - 5
Total 1+2+3+4:				19.3	350,110	94,450		35,184	112,219	125,245	107,849	4,798	72,224	159,486		120		

Summary of geographical parameters.

Location:	Northern area of Revelstoke Lake, west side.
Length:	29 km
Barriers:	A series of falls and chutes ranging from 1 to 2 m high exist in canyon, at start right at the mouth. A 4 m falls is located approx. 1.8 km upstream.
No. of Reaches:	8
No. of Reaches Sampled:	4
Total length of stream below barriers:	Potentially none at low lake levels, but possibly up to 1.8 km.
Major Tributaries:	2 small unamed creeks entering the mainstem at km 12.5 and km 15.5 (approx.).
Water Source:	Numerous small lakes and ponds in the headwaters. Water crstal clear, except after a brief rain storm.
Resource use:	Extensive logging throughout the valley bottom and mid and upper slopes of the watershed. This includes an extensive road network, some of which are being actively constructed upstream of km 14.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

habitat for juvenile rainbow trout, while extensive riffle area between pools provides ample spawning habitat.

Fish

Similar to Pitt Creek, Nicholls Creek also appears to contain a resident stock of rainbow trout, although lake resident fish likely utilize the lower sections of the creek also. Bull trout and cottids were captured in reach 1 only, whereas rainbow trout were captured in every reach sampled in Nicholls Creek (Table 33a). CPUE for rainbow trout was highest in reach 1, and the overall CPUE for Nicholls Creek was amongst the highest observed of all tributaries sampled.

The presence of a 5 m falls in reach 2 suggests rainbow trout fish captured upstream of this barrier are resident fish, however, none of the rainbow trout captured in Nicholls Creek exceeded 200 mm in length or 50 g in weight (Table 33b). Small, slow growing fish may be expected in the colder, higher elevations of Nicholls Creek, but scale analysis indicated none of the rainbow trout aged were over 3 years old. Furthermore, although there is no water quality data to suggest otherwise, the comparatively high CPUE observed for this stream suggests good food resources exist to support a population of rearing trout. The absence of adult fish may be indicative of the inefficiency of an electroshocker to sample the larger deeper pools where adult fish are more likely to reside, however, there was no indication that large fish were escaping the effects of the electroshocker, which might be expected in the confined areas of a stream as small as Nicholls Creek.

Logging

The five year plan submitted by Westar indicates 186.1 ha will be clear-cut from the Nicholls watershed in 1995 but the extent of present logging activities within this drainage was not determined. Scott Logging Contractors once had a small water supply dam adjacent the mouth of Nicholls Creek to service its crew camp (still present) although this was removed some time ago (Pers. com. Camp attendant for Scott Logging). It is unknown if this dam was a migration barrier.

There is presently no road access to Nicholls Creek other than the highway crossing at the mouth.

Enhancement Opportunities

Nicholls Creek likely provides spawning and rearing habitat for lake resident fish within reach 1 and 2. Removal of some small barriers within reach 2 may facilitate transport of gravel downstream, benefitting available spawning habitat for lake resident rainbow trout and facilitating upstream access. The culverts at the mouth of Nicholls Creek should be inspected at low lake levels to determine if LOD settling at the mouth of the pond creates a barrier. It is also prudent to ensure habitat which now exists in Nicholls Creek is not impacted by future activities which may occur within the watershed. Finally, Nicholls Creek may be a potential source of rainbow trout brood stock for hatchery operations.

Figure 30: The stream profile for Nicholls Creek (not to scale).

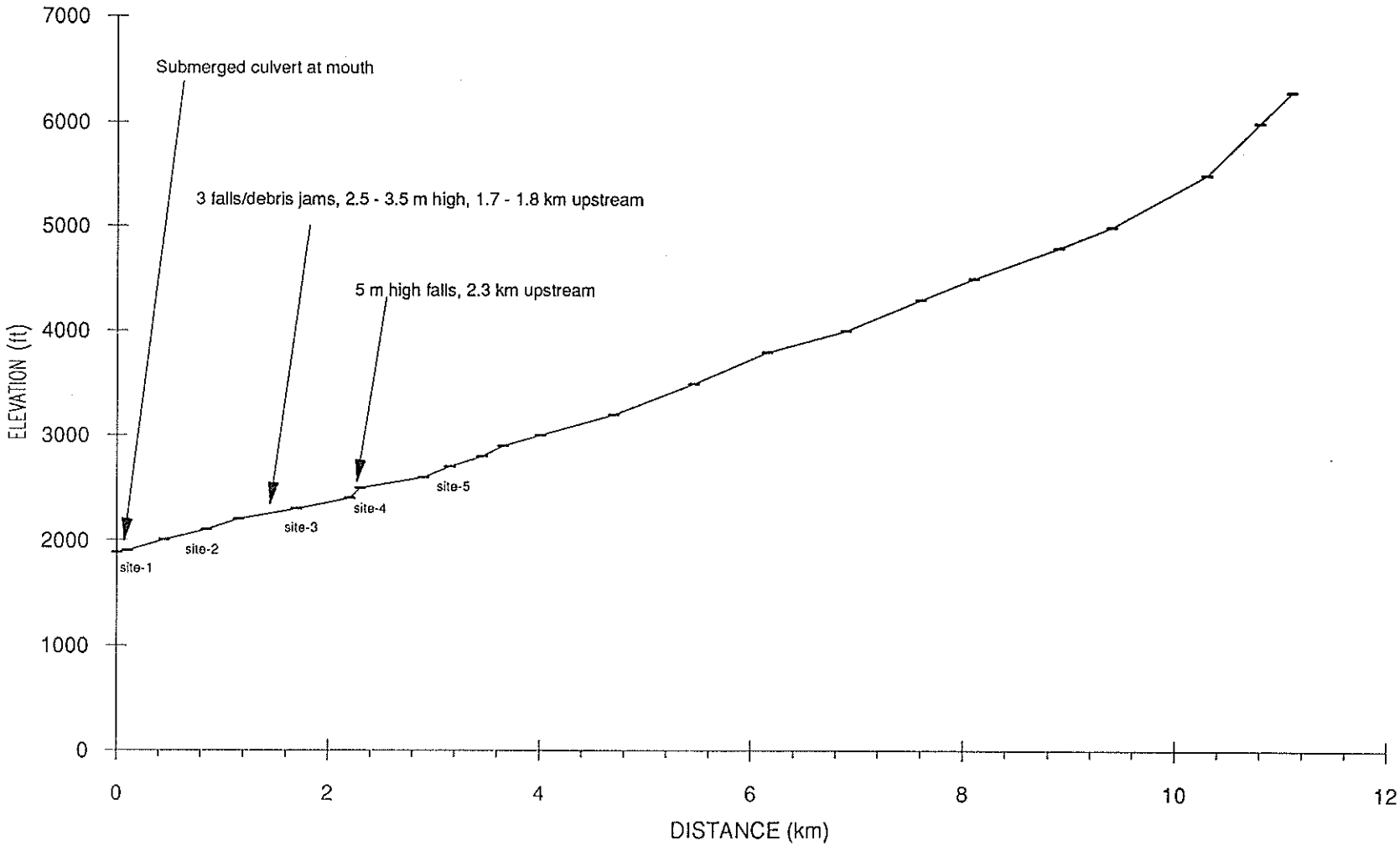


Table 32: Summary of biophysical habitat parameters for Nicholls Creek.

						COVER			STREAM CHARACTER				SUBSTRATE			VALLEY CHAR.		
Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	4.5	0.3	3,810	1,143	l/b	572	1,143	1,143	1,143	381	572	953	M	100	CO	0 - 2
mainstem	2,3,4	2	7.5	2.1	14,700	5,789	dp/b/l	2,244	4,837	2,776	5,191	1,463	2,212	4,501	L - M	100	EN	0 - 2
mainstem	5	3	8.0	1.5	18,430	4,608	l/b	1,843	4,608	6,451	6,451	922	1,843	6,451	M	90	CO	0 - 2
Total 1+2+3:				3.8	36,940	11,540		4,658	10,588	10,369	12,784	2,766	4,627	11,904		97		

Summary of geographical parameters.

Location:	North central area of resevoir, east side.
Length:	11 km
Barriers:	Numerous small barriers throughout reach two, including a 5 m barrier 2.3 km upstream.
No. of Reaches:	3
No. of Reaches Sampled:	3
Length of stream below barriers:	2.3 km
Major Tributaries:	None
Water Source:	Marsh and a small lake, crstal clear water.
Resource use:	No logging observed, possibly a source of well water for a small logging camp at creek mouth.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 33: **Electroshocking results (a), as well as fish size and age data (b) for Nicholls Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
	1	12	7	rbt	f/p	0.030	0.018	0.048	n/a	n/a	n/a
	1	1	0	bt	p	0.003	0.000	0.003	n/a	n/a	n/a
	1	1	0	cc	a	0.003	0.000	0.003	n/a	n/a	n/a
total reach 1:		**14**	**7**	**mean:**		**0.012**	**0.006**	**0.018**	**n/a**	**n/a**	**n/a**
	2	7	10	rbt	f/p	0.010	0.014	0.023	n/a	n/a	n/a
	3	5	1	rbt	p	0.020	0.004	0.024	0.021	0.004	0.025
Total:		26	18	Mean:		0.014	0.008	0.022	n/a	n/a	n/a

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yr)	N
1	RBT	73	34 -179	11.46	0.95 - 1.33	1.11	12	2 - 3+	3
2	RBT	111	46 -168	19.44	1.28 - 44.87	1.15	7	2 - 3+	3
3	RBT	125	81 - 167	24.68	5.88 - 49.13	1.06	6	1+	1
1	BT	98	-	10.76	-	1.14	1	1+	1
1	CC	89	-	8.26	-	1.17	1	n/a	0
1+2+3	RBT	95	34-168	16.54	0.95-49.13	25	1.11	25	1 - 3	7

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available

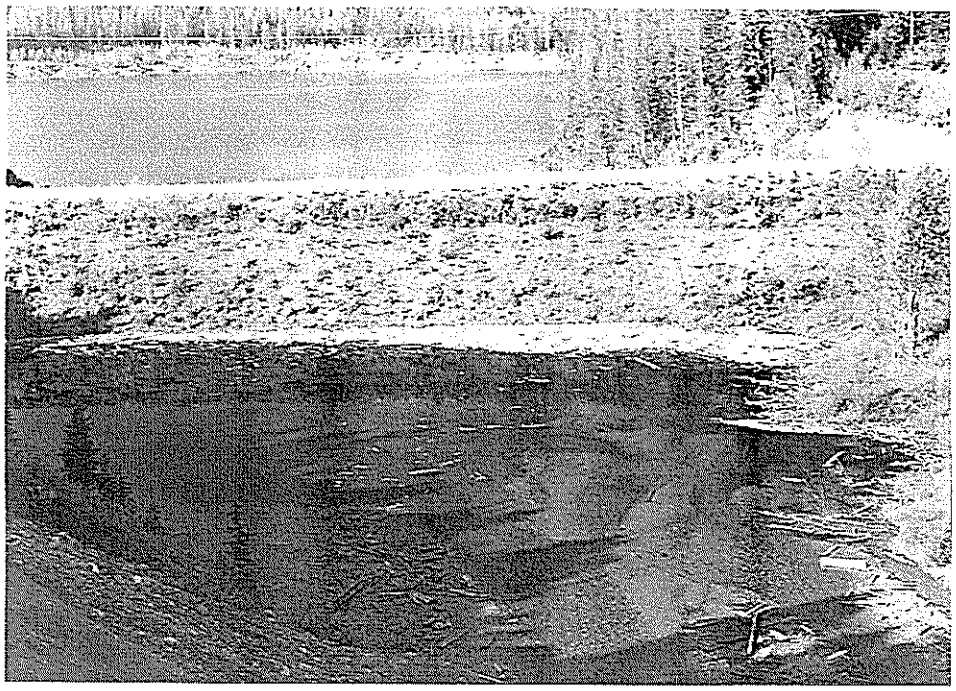


Photo 56 A large pool between the highway and the mouth of Nicholls Creek probably provides good rearing habitat for salmonids. Note the extensive floating debris in the proximity of submerged culverts.

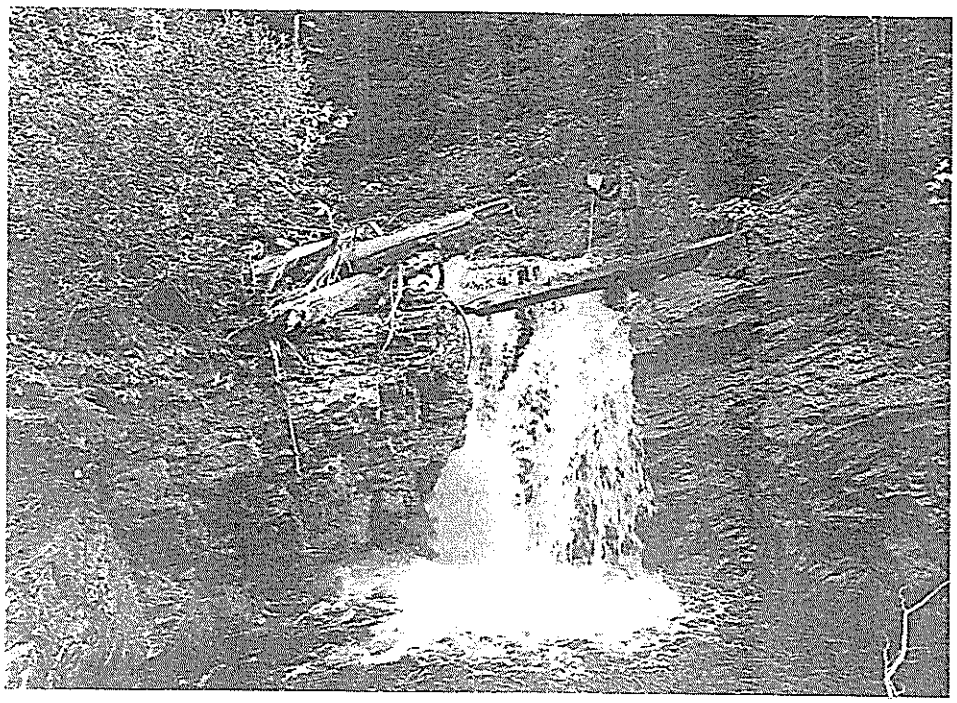


Photo 57 Numerous small barriers exist in reach 2 of Nicholls Creek, but this 5 m falls located 2 km upstream is a definite migrational impasse to lake resident fish.



Photo 58 Rearing habitat in reach 3 of Nicholls Creek is supplemented by LOD and pool cover.

4.5.13 Park Creek

Park Creek is a short glacier fed stream flowing into the west side of Revelstoke Lake. Two obstructions, a chute and a debris jam within the first 200 m of Park Creek restrict access to this stream (Fig 31). The short section of creek where the barriers occur is littered with wind fall from a green strip left on the south side of the creek. The 1.5 m high chute is negotiable to bull trout and rainbow trout, but probably not to kokanee. Accumulations of LOD in a small gorge upstream of the chute has created a 2 m high falls which is impassable to fish (Photo 59).

Unlike many of the smaller streams entering Revelstoke Lake, Park Creek valley broadens almost immediately upstream of the barriers near the creek mouth. A broad flood plain and a large fraction of boulder and large cobble in the bed material and a relatively steep gradient (4.5% to 5.5% in reach 2) suggests Park Creek is subject to extreme flow conditions during freshet. This has lead to extensive disruption of channel direction and uniformity (Photo 60). Pools, boulders, and to a lesser extent LOD, provides most of the cover in this stream (Table 34). Glacial water supplements available cover but also subjects Park Creek to seasonal variations in turbidity, and likely, sedimentation.

Fish

Martin (1976) reports kokanee, whitefish, rainbow trout and bull trout were all found in the lower quarter mile of Park Creek prior to the flooding of the Columbia River upstream of Revelstoke Dam. At present, bull trout are the only species observed in Park Creek, although they were captured both upstream and downstream of the falls. Habitat once available for kokanee spawning is no longer present.

Bull trout above the falls are likely resident stock but scale analysis indicates fish captured in this area were sub adult and there were no indications of adult bull trout above the barrier (Table 35). The highest fish densities, 0.02 fish per m^2, were recorded in reach 2. Scouring during high flow events and siltation due to the glacial nature of Park Creek probably increases egg mortality and non-volitional movement of fry downstream, limiting the productivity of this stream.

Logging

Some logging has occurred near the mouth of Park Creek, otherwise, there is planned logging to occur in the watershed. As no logging roads exist, access to Park Creek above the falls is limited to helicopter or foot, the latter is facilitated by a guide trail on the north side of the stream. The mouth of Park Creek is crossed by a logging road bridge, and the falls readily accessible. Ferry transportation across the lake is necessary for vehicles to access the logging road.

Enhancement Opportunities

Park Creek has approximately 3.5 km of stream, representing about 21,000 m^2 of wetted area, available to fish upstream of its barrier (Fig. 31). The fact that the falls on Park Creek is composed of debris accumulated at a constriction suggests this barrier is not permanent, hence, it may have been negotiable to fish in past years. Although a relatively small amount of habitat is available to fish upstream of the Park Creek barrier, compared to other streams entering Revelstoke Lake, the ease of access to the falls and its small drop facilitate removal of this obstruction. Such a project is appropriate for the local Rod and Gun Club to complete. The falls on Park Creek is not affected by fluctuating lake levels, although the chute at the entrance of the creek from the lake may be affected. This could not be determined during the fall survey when lake levels where high.

The broad valley upstream of the Park Creek barriers provides sufficient area to construct off channel rearing habitat. Suitable space and grade facilitates the construction of an access road to the upstream reaches of Park Creek if construction of side channel habitat or the like is deemed appropriate.

Figure 31: The stream profile for Park Creek (not to scale)

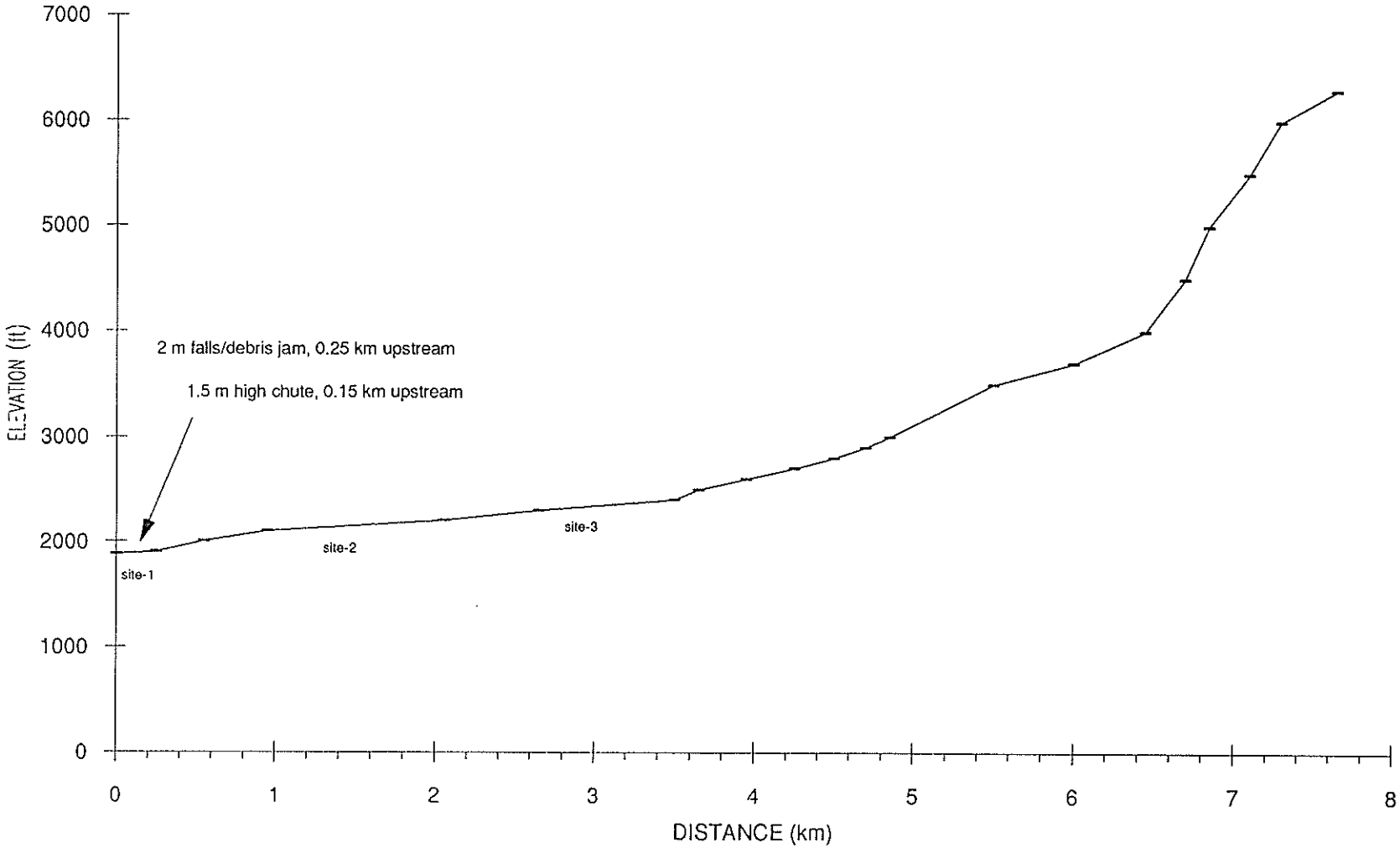


Table 34: Summary of biophysical habitat parameters for Park Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	n/a	0.2	2,680	938	l/b/dp	536	402	1,072	804	402	134	670	L	35	EN	0 - 2
mainstem	2,3	2	4.3	2.8	21,000	2,240	dp/ov	1,610	2,100	10,920	7,000	980	2,100	7,350	L - M	45	FC-OC	2 - 5
Total 1+2					23,680	3,178		2,146	2,502	11,992	7,804	1,382	2,234	8,020		40		

Summary of geographical parameters.

Location:	Southern area of Revelstoke Lake, west side.
Length:	7.65 km
Barriers:	1.5 m chute and a 2 m falls 100 and 150 m upstream.
No. of Reaches:	3+
No. of Reaches Sampled:	2
Total Length of stream below barriers:	0.2 km
Major Tributaries:	none
Water Source:	Glaciers
Resource use:	Little observed logging. Hunitng guide trail present adjacent stream for first 2 km.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 35: **Electroshocking results (a), as well as fish size and age data (b) for Park Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
main	1	2	2	bt	f/p	0.014	0.014	**0.028**	0.005	0.005	**0.010**
main	2	0	3	bt	f/p	0.000	0.013	**0.013**	0.000	0.008	**0.008**
main	2	6	4	bt	p	0.013	0.008	**0.021**	0.012	0.008	**0.020**
total, reach 2:		**6**	**7**	**mean:**		**0.006**	**0.011**	**0.017**	**0.006**	**0.008**	**0.014**
Total, 1 + 2:		8	9	Mean		0.009	0.012	0.021	0.006	0.007	0.013

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	Range N	Age Age (yr)	Range	N
1	BT	98	43 - 153	18.86	1.40 - 36.31	1.39	2	n/a*		0
2	BT	163	130 - 187	43.25	21.90 - 66.90	0.96	6	2 - 3+		3**
1 + 2	BT	147	43-187	37.15	1.40-66.90	1.07	8	2 - 3+		3

* scale sample unreadable

** 3 of 6 scale samples unreadable, only fish > 130 mm.

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available



Photo 59 This 2 m high debris jam at the mouth of Park Creek is accessible, and could be easily removed.



Photo 60 A broad uncontained flood plain with extensive cobble and boulder substrate suggests Park Creek is subject to large fluctuations in discharge.

4.5.14 Pat Creek

Pat Creek is one of 5 streams entering Revelstoke Lake which has a resident rainbow trout population. These resident fish are isolated from the lake by a 5 to 10 m high barrier approximately 4 km upstream of the mouth (photo 61). A number of smaller chutes and falls also exist in a steep sided canyon/gorge which originates at the mouth of Pat Creek and extends about 4 kms upstream. Included with these small barriers are a 1.5 m high chute and 1 m high falls at the creek mouth. The height of these barriers will change with fluctuations in water levels as water levels of Lake Revelstoke, hence they may be impassable to lake resident fish at low reservoir levels. This may be most relevant for rainbow trout which spawn during the spring, when reservoir levels may be low. Mason (1985) does not indicate a barrier on Pat Creek whereas Martin (1976) reports a 2.5 m barrier 2.3 km upstream of the mouth, presumably the barrier which is now located at the mouth of the creek. The field crew was not able to assess the entire canyon for the presence of migrational barriers since it was not negotiable by foot. A number of small lakes, combined with little glacial input provides Pat Creek with a clear steady water source.

Reach 1 is located within a canyon. Access into this area is restricted by steep banks and numerous rock bluffs. Numerous small chutes and falls in this area would restrict upstream movement of kokanee and possibly rainbow and bull trout.

Reach 2 is situated in a short gorge which contains the major falls observed at km 4. Water flows fast through this area, although numerous small, relatively deep pools exist behind the large boulders which dominate the substrate.

Reach 3 and 4 have the lowest gradients observed in Pat Creek (Fig. 32). These reaches also have the best spawning and rearing habitat. Reach 3 meanders for about 7 km through a broad valley bottom with considerable off channel habitat, provided by alder marsh and beaver ponds. Large, deep pools, punctuated with short stretches of riffle and/or run, are common to this section of stream (Photo 62). Similar to reach 3, beaver ponds and alder marsh also provide good off channel habitat in reach 4, but the valley narrows in this section of stream and the channel becomes straighter (photo 63). Reach 3 has more pool but less riffle area than

reach 4 (Table 36). Both reaches have high proportions of gravel in their substrate (50% to 60%), although the gravel in reach 3 is less compacted.

Fish

Only rainbow trout were observed in Pat Creek, all of which were captured upstream of the major barrier. For this reason, these rainbow trout are considered a resident stock. The mean size of these fish decreased as sampling progressed upstream (Table 37). No rainbow trout captured in Pat Creek were over 2 years old, but 2 large, and presumably older, fish escaped during sampling at the reach 2 site.

Dolly Varden, presumably bull trout, once utilized the section of stream flooded below the falls which now exists at the mouth of Pat Creek (Martin, 1976). High flows prevented electroshocking immediately upstream of the small falls at the mouth, so it is unknown if bull trout still utilize reach 1 of Pat Creek. Habitat available to lake resident bull and/or rainbow trout is restricted to reach 1 below the 10 m high falls at km 4, assuming the smaller barriers downstream of this falls are negotiable by large bull and rainbow trout.

Logging

The Pat Creek Valley has been logged throughout its drainage at both high and low elevations. Future logging plans include clearcutting approximately 322 ha of land in 1992, 94 and 95.

The creek is easily accessed from a number of points along the logging road servicing the north side of the creek valley, although this road can only be reached by ferry. In some instances, the road follows steep banks adjacent the stream, which are prone to erosion. Site 2 on Pat Creek represents one such area. The road has been built over an unstable bank and erosion caused by runoff is presently threatening a total collapse of this road into the stream. The relatively large amount of cut blocks may impact upon water quality in Pat Creek. A single night of rain resulted in crystal clear water becoming so turbid, visibility was reduced to only 20 cm.

Enhancement Opportunities

Pat Creek may be able to support a recreational fishery, but, sports fishing activities would have to be closely monitored to ensure the stock remains self sustaining. An extensive network of logging roads makes Pat Creek very accessible to sports fisherman, although ferry transportation is required to transport vehicles to these roads. Any enhancement activities for Pat Creek should involve resident fish only. More information is required, prior to recommending potential enhancement projects.

Figure 32: The stream profile for Pat Creek (not to scale).

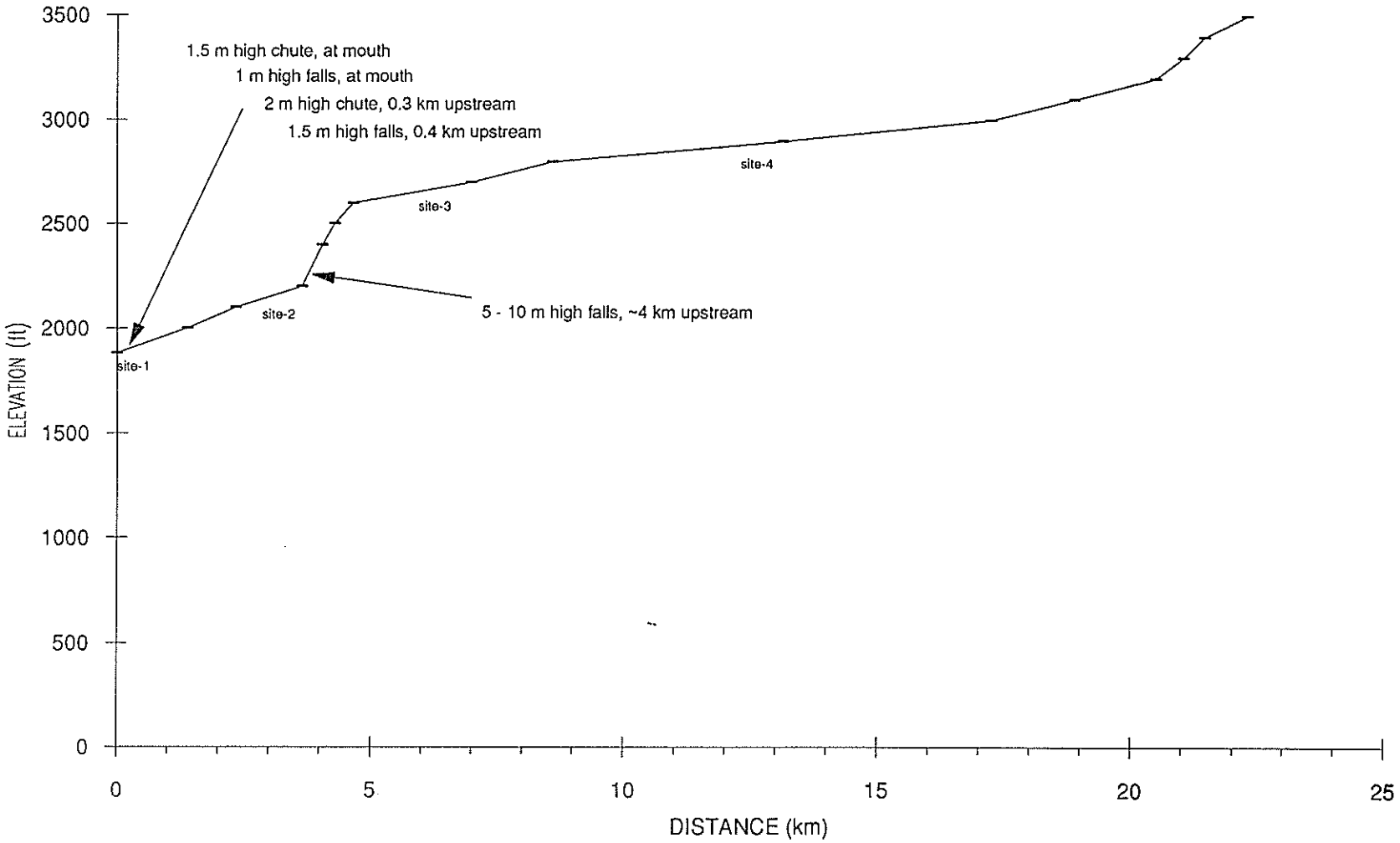


Table 36: Summary of biophysical habitat parameters for Pat Creek.

						COVER			STREAM CHARACTER				SUBSTRATE			VALLEY CHAR.		
Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	4.7	2.5	32,500	3,250	b/dp	325	3,250	16,250	9,750	3,250	n/a	n/a	n/a	20	EN	0 - 2
mainstem	2	2	2.5	2.4	30,960	7,740	b/dp	929	4,644	13,932	10,836	1,548	3,096	3,096	L	110	CO	2 - 5
mainstem	3	3	0.5	6.7	130,650	52,260	dp/l	26,130	65,325	32,663	32,663	0	45,728	78,390	L	200	OC	5 - 10
mainstem	4	4	0.7	7.8	156,000	31,200	dp/l	7,800	39,000	62,400	54,600	0	23,400	78,000	M	150	FC	2 - 5
Total 1+2+3+4:				19.3	350,110	94,450		35,184	112,219	125,245	107,849	4,798	72,224	159,486		120		

Summary of geographical parameters.

Location:	Northern area of Revelstoke Lake, west side.
Length:	29 km
Barriers:	A series of falls and chutes ranging from 1 to 2 m high exist in canyon, at start right at the mouth. A 4 m falls is located approx. 1.8 km upstream.
No. of Reaches:	8
No. of Reaches Sampled:	4
Total length of stream below barriers:	Potentially none at low lake levels, but possibly up to 1.8 km.
Major Tributaries:	2 small unamed creeks entering the mainstem at km 12.5 and km 15.5 (approx.).
Water Source:	Numerous small lakes and ponds in the headwaters. Water crstal clear, except after a brief rain storm.
Resource use:	Extensive logging throughout the valley bottom and mid and upper slopes of the watershed. This includes an extensive road network, some of which are being actively constructed upstream of km 14.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 37: Electroshocking results (a), as well as fish size and age data (b) for Pat Creek.

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	2	2	2	RBT	p	0.008	0.008	**0.016**	0.005	0.005	**0.010**
mainstem	3	6	1	RBT	p	0.015	0.003	**0.018**	n/a	n/a	**n/a**
mainstem	4	3	1	RBT	p	0.011	0.004	**0.014**	0.012	0.004	**0.016**
Total:		11	4	Mean:		0.011	0.005	0.016	0.008	0.004	0.013

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yr)	N
2	RBT	153	121 - 184	31.81	18.33 - 45.29	0.88	2	n/a*	-
3	RBT	123	103 - 144	20.39	12.99 - 31.34	1.06	6	1 - 2+	4
4	RBT	67	35 - 96	4.23	0.41 - 8.97	1.09	4	0 - 1	3
2 + 3 + 4	RBT	109	35 - 184	16.91	0.41-45.29	1.04	12	0 - 2	7

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available



Photo 61 This 10 m falls (est.), approx. 4.0 km upstream at the top end of the canyon, is the last and largest of many barriers encountered on Pat Creek.

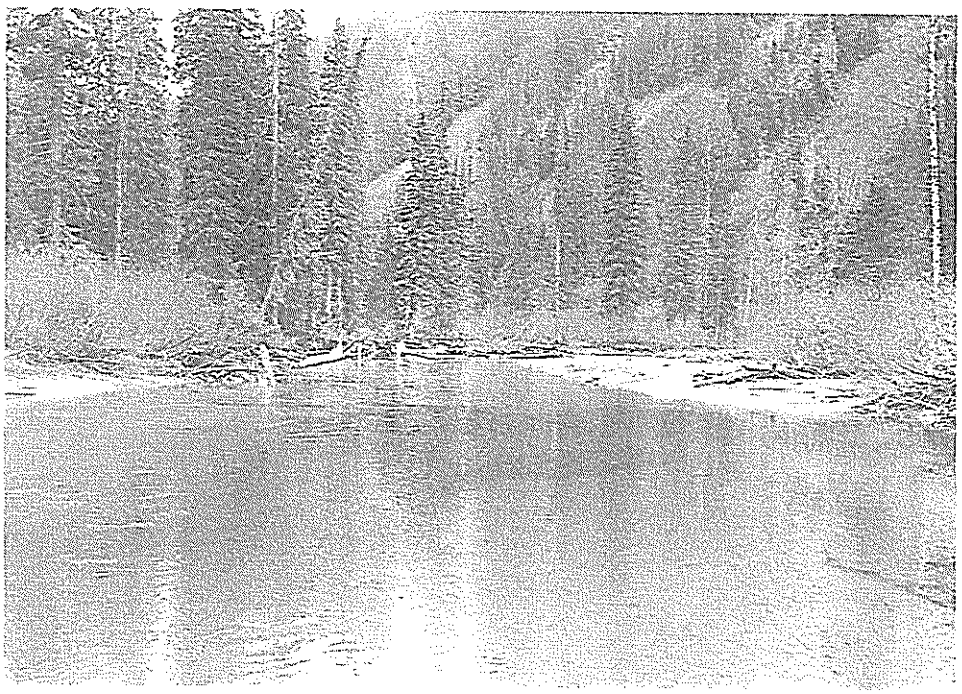


Photo 62 Deep pools, extensive gravel substrate and large accumulations of LOD provide reach 3 of Pat Creek with good spawning and rearing habitat.



Photo 63 Reach 4 of Pat Creek has a slightly higher gradient, but still provides good habitat for resident rainbow trout.

4.5.15 Horne Creek

A narrow canyon forms reach 1 of Horne Creek, and extends upstream from the creek mouth for 1.0 km. A series of 3 falls located in this canyon, between 800 to 850 m upstream of the creek mouth, have a combined total drop of 15 m and represent an impassable barrier to fish migration (photos 64).

Reach 2 and 3 have a similar totals of wetted area and of cover, although there is slightly more gravel in reach 2 (Photo 65). Large amounts of pool habitat and more diverse types of cover provides reach 2 with better rearing habitat than reach 3 (Table 38).

Horne Creek was not surveyed upstream of km 6.3 km, but the gradient profile suggests habitat accessible to stream resident rainbow trout is probably restricted to within km 8 to 10 (Fig. 33). Water clarity in Horne Creek was crystal clear at the time of sampling, although small glaciers within the drainage probably contribute sediment during spring and summer months.

Fish

Similar to Pat and Soards Creeks, Horne Creek has a resident rainbow trout population. Rainbow trout were captured in reach 2 and 3 although they were more prevalent, but smaller, in reach 3 (Table 39). One 4 year old rainbow trout, captured in reach 2, was 229 mm long and weighed over 120 g. Lindsay (1977) reported mountain whitefish utilized Horne Creek prior to flooding of the Columbia River. No other species were reported using this system.

Logging

There is no logging presently occurring in the Horne Creek watershed, but old cutblocks exist in the valley bottom and lower slopes, primarily on the north side of the stream. The upstream extent of logging is presently about 6 km, however, the road servicing the uppermost cutblocks has collapsed so vehicle access is restricted to approximately 4.5 km upstream. A vehicle ferry is required to access the logging roads in this watershed. The B.C. Forest Service has experimentally treated specific cutblocks, approximately 1.4 and 4 km upstream of the creek mouth, with "Vision" a

glyophosphate based herbicide. This herbicide is toxic to fish, although it does not bio-accumulate (Newton et al, 1984 and Wan 1984). The B.C. Forest Service also follows a documented protocol regarding the application of herbicides near streamsides to minimize potential detrimental effects on fish stocks (In house circular, BCFS).

Enhancement Opportunities

Like Pat and Soards Creeks, enhancement activities for Horne Creek should be directed at the resident rainbow population. Managing the existing resources should be a priority in maintaining and/or increasing existing fish stocks. Horne Creek may be able to support recreational fishing although strict monitoring would be necessary to ensure overfishing does not occur, and that spawners and spawning habitat are protected against pressures such as overfishing or logging impacts.

Figure 33: The stream profile for Horne Creek (not to scale)

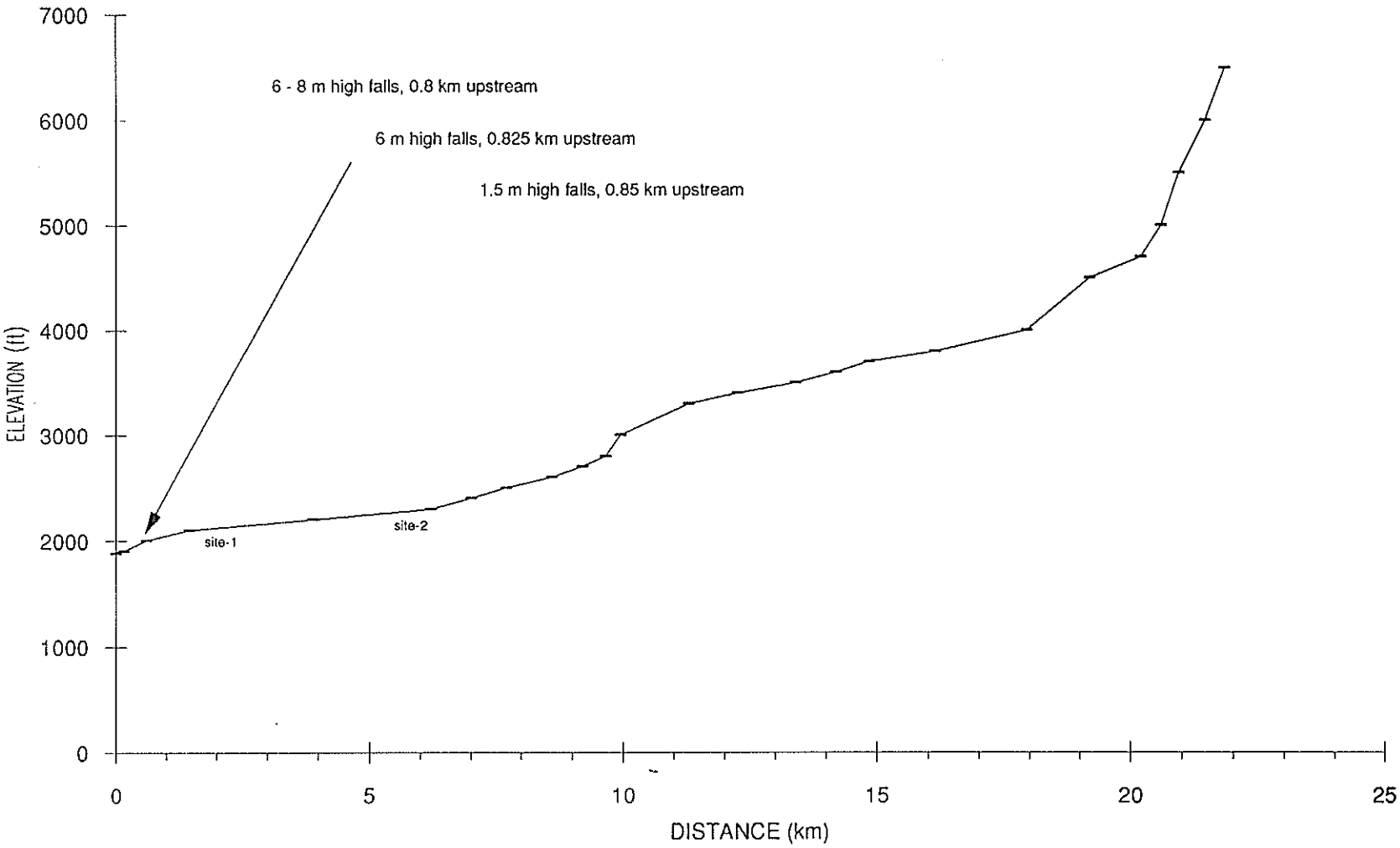


Table 38: Summary of biophysical habitat parameters for Horne Creek.

						COVER			STREAM CHARACTER				SUBSTRATE			VALLEY CHAR.		
Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	2	1.3	3.1	105,000	10,500	dp/ov	3,150	26,250	26,250	52,500	0	15,750	42,000	M	100	UC	5 - 10
mainstem	2	3	2.5	4.0	106,000	10,600	b	3,180	15,900	47,700	37,100	5,300	10,600	47,700	L	70	OC	5 - 10
Total				7.1	211,000	21,100		6,330	42,150	73,950	89,600	5,300	26,350	89,700		85		

Summary of geographical parameters.

Location:	North central area of Revelstoke Lake, west side.
Length:	21.85 km
Barriers:	3 falls, from 1.5 to approx. 8 m high are located between 800 and 850 m upstream. A 4 m falls is located approx. 1.8 km upstream.
No. of Reaches:	6+
No. of Reaches Sampled:	2
Total length of stream below barriers:	0.8 km
Major Tributaries:	1 unamed creeks entering the mainstem at km 9.0 (approx.).
Water Source:	Numerous small lakes and ponds in the headwaters of both the mainstem and tributaries..
Resource use:	Extensive logging throughout the valley bottom to km 5 (approx). Experimental use of the herbicide "Vision" by the B.C.F.S. in two cut blocks adjacent the stream.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 39: Electroshocking results (a), as well as fish size and age data (b) for Horne Creek.

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	2	3	0	RBT	a/f	0.005	0.000	0.005	0.003	0.000	0.003
mainstem	3	3	5	RBT	p	0.007	0.011	0.018	0.003	0.005	0.007
Total:		6	5	Mean:		0.006	0.006	0.011	0.003	0.002	0.005

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	N	Conditon Factor (k)	N	Age Range (yr)	N
2	RBT	120	73 - 229	>42.25	2.27 ->120.00	3	1.13	3	4	1
3	RBT	124	111 - 134	21.28	1.04 - 1.24	3	1.12	3	1 - 2	2
2 + 3	RBT	122	73 - 229	>31.76	1.04 ->120.00	6	1.12	6	1 - 4	

* 1 scale sample was unreadable

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available



Photo 64 This 6 m falls (est.) is one of 3 obstructions to fish migration on Horne Creek, located between 800 and 850 m upstream (Note the 1.7 m high dip net at the right of the photo).



Photo 65 Looking upstream at Horne Creek valley towards site 3.

4.5.16 Hoskins Creek

Hoskins Creek, is a glacial stream located immediately south of Ruddock Creek on the east side of the reservoir. This creek has two identified barriers on it. The first barrier, 1.55 km upstream of the creek mouth, is a 2 m high chute which is probably negotiable by rainbow trout, bull trout and possibly kokanee. A second barrier, consisting of a 2.5 m falls and a 5 m high x 40 m long chute, 2.3 km upstream of the creek mouth is not negotiable to fish (photo 66).

Hoskins Creek valley becomes more confined the further upstream one progresses. Reach 1 flows straight, through a broad flat plain before entering the lake. A gradient of 1.5% (Fig. 34) and a moderate amount of somewhat compacted gravel in the substrate (35%) offers some habitat for spawning in reach 1, but a lack of cover or pools offers little habitat for rearing salmonids.

Reach 2 and 4 had the best rearing habitat of the reaches surveyed on Hoskins Creek (Photo 67, 68). Reach 2 is situated between the two previously identified barriers and is braided in the area immediately upstream of the first barrier. Considering the short length of this reach, it has a comparatively large amount of cover and gravel within it (Table 40).

Reach 3 includes the gorge and falls which forms the second barrier to fish migration.

The valley bottom broadens somewhat in reach 4. There is more gravel area in reach 4 than in reach 2, but this is indicative of the larger wetted area of this reach since gravel constitutes a smaller percentage of the substrate in reach 4 than in reach 2. The mean gradient in reach 4 is highest of all reaches sampled. The percentage of total cover in reach 4 is the same as that observed in reach 2, although, because of it's longer length, more cover area is available in reach 4. The type of cover shifts from mainly overhead vegetation in reach 2 to boulders in reach 4.



Photo 61 This 10 m falls (est.), approx. 4.0 km upstream at the top end of the canyon, is the last and largest of many barriers encountered on Pat Creek.



Photo 62 Deep pools, extensive gravel substrate and large accumulations of LOD provide reach 3 of Pat Creek with good spawning and rearing habitat.



Photo 63 Reach 4 of Pat Creek has a slightly higher gradient, but still provides good habitat for resident rainbow trout.

4.5.15 Horne Creek

A narrow canyon forms reach 1 of Horne Creek, and extends upstream from the creek mouth for 1.0 km. A series of 3 falls located in this canyon, between 800 to 850 m upstream of the creek mouth, have a combined total drop of 15 m and represent an impassable barrier to fish migration (photos 64).

Reach 2 and 3 have a similar totals of wetted area and of cover, although there is slightly more gravel in reach 2 (Photo 65). Large amounts of pool habitat and more diverse types of cover provides reach 2 with better rearing habitat than reach 3 (Table 38).

Horne Creek was not surveyed upstream of km 6.3 km, but the gradient profile suggests habitat accessible to stream resident rainbow trout is probably restricted to within km 8 to 10 (Fig. 33). Water clarity in Horne Creek was crystal clear at the time of sampling, although small glaciers within the drainage probably contribute sediment during spring and summer months.

Fish

Similar to Pat and Soards Creeks, Horne Creek has a resident rainbow trout population. Rainbow trout were captured in reach 2 and 3 although they were more prevalent, but smaller, in reach 3 (Table 39). One 4 year old rainbow trout, captured in reach 2, was 229 mm long and weighed over 120 g. Lindsay (1977) reported mountain whitefish utilized Horne Creek prior to flooding of the Columbia River. No other species were reported using this system.

Logging

There is no logging presently occurring in the Horne Creek watershed, but old cutblocks exist in the valley bottom and lower slopes, primarily on the north side of the stream. The upstream extent of logging is presently about 6 km, however, the road servicing the uppermost cutblocks has collapsed so vehicle access is restricted to approximately 4.5 km upstream. A vehicle ferry is required to access the logging roads in this watershed. The B.C. Forest Service has experimentally treated specific cutblocks, approximately 1.4 and 4 km upstream of the creek mouth, with "Vision" a

glyophosphate based herbicide. This herbicide is toxic to fish, although it does not bio-accumulate (Newton et al, 1984 and Wan 1984). The B.C. Forest Service also follows a documented protocol regarding the application of herbicides near streamsides to minimize potential detrimental effects on fish stocks (In house circular, BCFS).

Enhancement Opportunities

Like Pat and Soards Creeks, enhancement activities for Horne Creek should be directed at the resident rainbow population. Managing the existing resources should be a priority in maintaining and/or increasing existing fish stocks. Horne Creek may be able to support recreational fishing although strict monitoring would be necessary to ensure overfishing does not occur, and that spawners and spawning habitat are protected against pressures such as overfishing or logging impacts.

Figure 33: The stream profile for Horne Creek (not to scale)

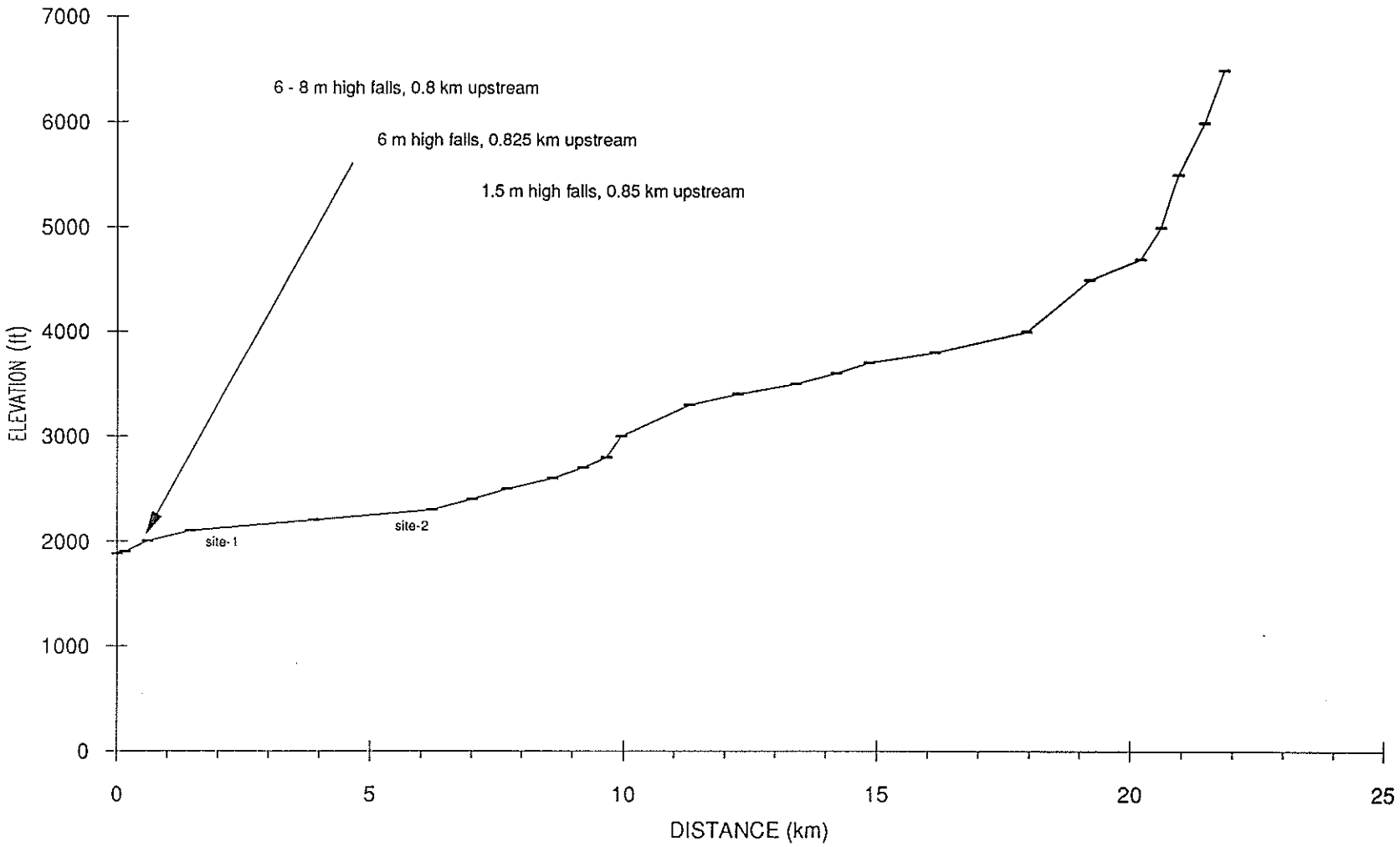


Table 38: Summary of biophysical habitat parameters for Horne Creek.

						COVER			STREAM CHARACTER				SUBSTRATE			VALLEY CHAR.		
Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	2	1.3	3.1	105,000	10,500	dp/ov	3,150	26,250	26,250	52,500	0	15,750	42,000	M	100	UC	5 - 10
mainstem	2	3	2.5	4.0	106,000	10,600	b	3,180	15,900	47,700	37,100	5,300	10,600	47,700	L	70	OC	5 - 10
Total				7.1	211,000	21,100		6,330	42,150	73,950	89,600	5,300	26,350	89,700		85		

Summary of geographical parameters.

Location:	North central area of Revelstoke Lake, west side.
Length:	21.85 km
Barriers:	3 falls, from 1.5 to approx. 8 m high are located between 800 and 850 m upstream. A 4 m falls is located approx. 1.8 km upstream.
No. of Reaches:	6+
No. of Reaches Sampled:	2
Total length of stream below barriers:	0.8 km
Major Tributaries:	1 unamed creeks entering the mainstem at km 9.0 (approx.).
Water Source:	Numerous small lakes and ponds in the headwaters of both the mainstem and tributaries..
Resource use:	Extensive logging throughout the valley bottom to km 5 (approx). Experimental use of the herbicide "Vision" by the B.C.F.S. in two cut blocks adjacent the stream.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 39: **Electroshocking results (a), as well as fish size and age data (b) for Horne Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	2	3	0	RBT	a/f	0.005	0.000	**0.005**	0.003	0.000	**0.003**
mainstem	3	3	5	RBT	p	0.007	0.011	**0.018**	0.003	0.005	**0.007**
Total:		6	5	Mean:		0.006	0.006	0.011	0.003	0.002	0.005

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	N	Conditon Factor (k)	N	Age Range (yr)	N
2	RBT	120	73 - 229	>42.25	2.27 ->120.00	3	1.13	3	4	1
3	RBT	124	111 - 134	21.28	1.04 - 1.24	3	1.12	3	1 - 2	2
2 - 3	RBT	122	73 - 229	>31.76	1.04 ->120.00	6	1.12	6	1 - 4	

* 1 scale sample was unreadable

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available

4.5.11 Mica Creek

There may be limited spawning or rearing habitat available to lake resident fish in Mica Creek. Reach 1 extends 500 m upstream and has mostly cobble and boulder in its substrate. Gravel is limited to small pockets in backeddies behind large boulders. Substantial riparian and boulder cover, complemented with some deep pool and cutbank cover, provides diverse rearing habitat for juvenile fish.

Reach 2 encompasses a steep sided canyon and a series of barriers. Two chutes 2 and 3 m in height followed by 2 falls, approximately 2 m in height each, begin at the start of this reach and extends for 100 m upstream (Photo 53). Another barrier, approximately 1.4 km upstream and estimated to be 3 m high, was observed during a helicopter overflight.

Reach 3 is characterized by evenly spaced pools and runs separated by riffle/cascade "steps". No single step amounts to more than 0.5 m rises in stream level. A large percentage of moderately compacted gravel in the substrate provides a suitable spawning medium for bull trout while extensive cover supplies the habitat necessary for rearing fish (Table 30).

Two weeks of freezing temperatures during a cold spell near the end of October, prior to sampling at site 3, created shore and frazzle ice, limiting access to open for both fish and the field crew (photo 54). This build up of both shore and anchor ice may be indicative of winter conditions for Mica Creek. If such freezing is common place during the winter months, high mortality may be expected. Bull trout fry prefer the shallow, slow moving water near stream margins which is prone to freezing (Pratt, 1985).

Fish

Only three bull trout were caught from Mica Creek, one from reach 1 and 2 from reach 3. Bull trout captured in reach 3 were considerably larger than the single bull trout caught in reach 1 (Table 31). Scale analysis indicated reach 3 specimens were 3^+ and 4^+ years old, within the age range of sexual maturity (Ford et. al 1992, Scott and Crossman 1973). Fish were not captured in reach 2 but three large bull trout (estimated >400 mm) were observed in a pool below a 2.5 m falls. One of these fish

was observed attempting to jump this falls, but was unsuccessful after three tries. Barriers within reach 2 definitely restrict the upstream movement all kokanee but possibly not large bull or rainbow trout. The only evidence that suggests bull trout found in reach 3 are resident is the fact they were captured above suspected barriers.

Historical data indicates bull trout, rainbow trout, whitefish and kokanee utilized Mica Creek prior to the creation of the 1880 reservoir level (Martin, 1976). Mica Creek still does support limited spawning habitat for kokanee, although none were seen during this years' surveys (Pers. comm. Brian Gadbois, B.C. Hydro Tech.).

Logging

Logging in the Mica Creek watershed is limited primarily to the south side of the creek within the first 2 km of the stream mouth. Cutblocks are located at midslope and higher elevations. As of yet, there is no road access into the valley bottom although a new road was being built along the north face of the valley above reach three, about 3 km upstream of the mouth. During a helicopter overflight of Mica Creek on October 25, road construction was contributing sediment into the mainstem from a small tributary crossed by the new road approximately 3 km upstream. The effect of this sediment input upon water turbidity was first observed at the mouth of Mica Creek. Also, a small land slide on the south side of Mica Creek originates from a cutblock which borders the top of the canyon within the first 300 m of reach 2, behind the Mica Creek town site. Westar has planned to remove 284.1 ha. from the Mica Creek drainage from 1991 to 1993, however, the status of this planned logging may be affected by the impending sale of Westar.

Enhancement Opportunities

Redirecting a portion of Mica Creek's discharge into a drainage ditch which runs parallel to the Big Bend Highway, adjacent to the village of Mica Creek, provides a strip approximately 500 m long which could be utilized to construct a spawning channel (photo 55). A clear water supply is conducive to positioning a spawning channel at this site. Kokanee which have been observed to accumulate at the base of the Mica Creek Dam could utilize this channel, as might spawning bull trout. The presence of the drainage ditch along the Big Bend Highway would reduce the

amount of excavation necessary to build a spawning channel and thereby reduce the costs of constructing such a structure. A flow control structure at the upstream end of the channel would be necessary to prevent damage to the spawning channel, and protect against the possibility of flooding in the village during peak flows. Also the terminus of the spawning channel would have to rejoin Lake Revelstoke downstream of Mica Creek, thereby requiring a highway crossing.

Barrier removal may facilitate upstream migration of spawning bull trout, but at least 3, possibly more, barriers would have to be modified or removed. A thorough examination of the canyon in reach 2 of Mica Creek would be required before barrier removal is considered. Furthermore, the origin of bull trout captured in reach 3 would have to be addressed if stock competition is a concern.

Figure 29: The stream profile for Mica Creek (not to scale)

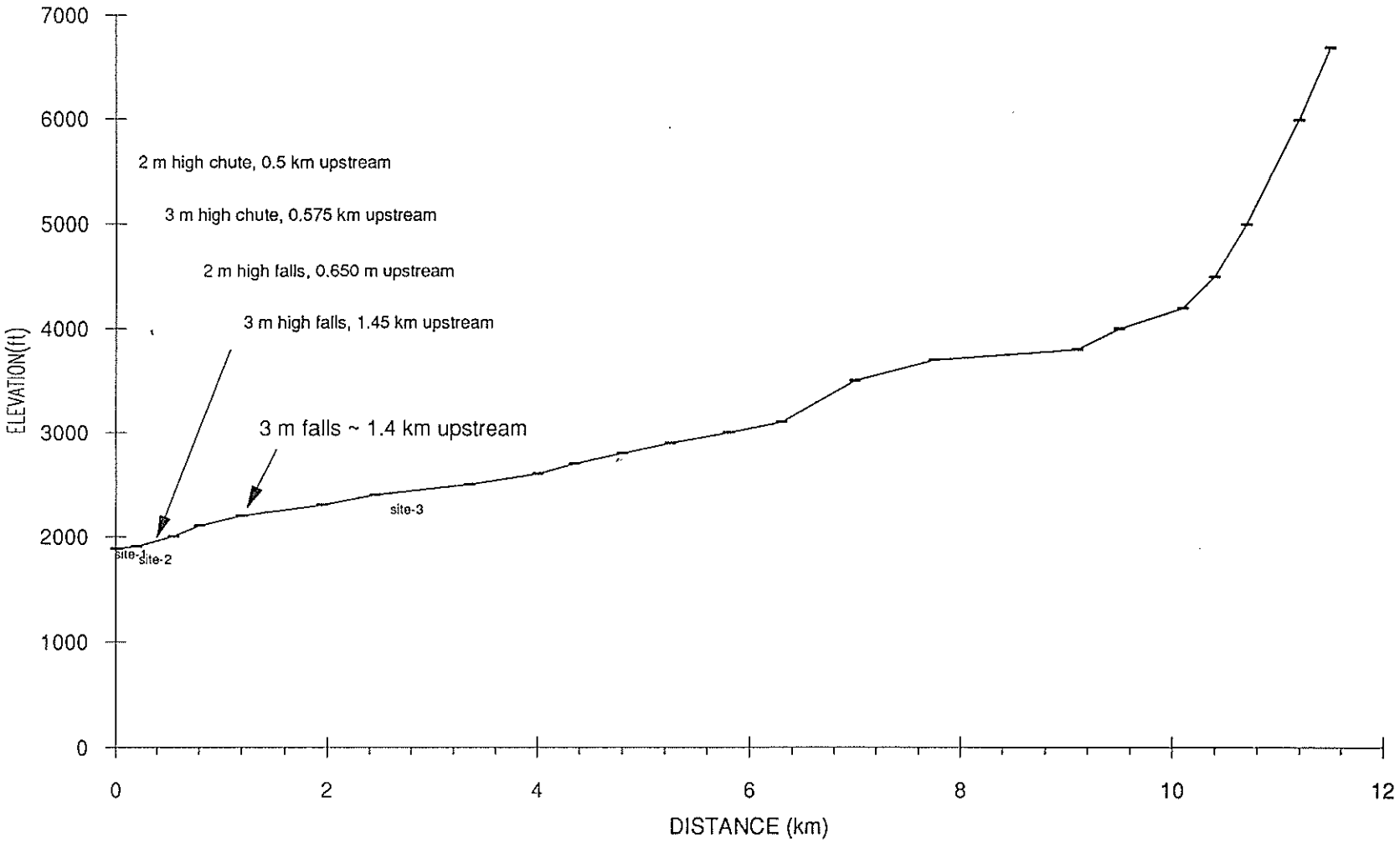


Table 30: Summary of biophysical habitat parameters for Mica Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	4.0	0.4	3,360	1,344	ov/b/dp	101	1,008	672	672	1,008	504	672	M	100	CO	0 - 2
mainstem	2	2	6.4	2.0	12,000	4,800	dp/b	1,200	4,800	600	4,800	1,800	1,800	0	M	100	EN	0 - 2
mainstem	3	3	6.0	2.3+	31,050	9,315	dp/lod/b	1,553	9,315	9,315	12,420	0	3,105	10,868	M	90	CO	2 - 5
Total 1+2+3				4.7+	46,410	15,459		2,853	15,123	10,587	17,892	2,808	5,409	11,540		97		

Summary of geographical parameters.

Location:	Northern most tributary entering Revelstoke lake, east side.
Length:	12 km
Barriers:	2.0 - 3.0 m chutes & falls starting 500 m upstrteam, also a 3 m falls approx. 1.5 km upstream.
No. of Reaches:	4.7+ km
No. of Reaches Sampled:	3
Total Length below barriers:	~0.5 km
Major Tributaries:	None
Water Source:	Small lakes and small glaciers
Resource use:	Along upper slopes of reach 2 and the start of reach 3.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 31: **Electroshocking results (a), as well as fish size and age data (b) for Mica Creek.**

(a) Electroshocking results,

Site	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	1	1	0	bt	p	0.005	0.000	0.005	n/a	n/a	n/a
mainstem	3	2	0	bt	a/p	0.009	0.000	0.009	n/a	n/a	n/a
Total:		3	0		Mean:	0.007	0.000	0.007	n/a	n/a	n/a

Note: 3 adult bull trout were observed in a pool at the base of the third falls (~ 3.0 m high). One bull was unsuccessful in 3 attempts to jump the falls. These fish were likely spawners.

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yrs)	N
1	BT	86	-	6.28	-	0.99	1	n/a	0
3	BT	207	202-211	92.98	82.44-103.51	1.03	2	3 - 4+	2
1 + 3	BT	166	202-211	69.30	82.44-103.51	1.05	2	3 - 4+	2

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available



Photo 53 Bull trout were observed attempting to jump this 2.5 m falls located approximately 650 m upstream on Mica Creek.



Photo 54 Extensive frazzle, anchor and surface ice made sampling at reach 3 of Mica Creek difficult, and reduced available habitat for rearing bull trout.



Photo 55 A drainage ditch which parallels the highway near the mouth of Mica Creek could be made into a spawning channel.

4.5.12 Nicholls Creek

Two submerged culverts exist at the mouth of Nicholls Creek under the Big Bend Highway. A small pond which has formed between the highway and the mouth of the Creek, collects driftwood flushed out of Nicholls Creek. This pond, associated with the large amount of LOD, probably provides good rearing habitat for juvenile fish, but the LOD may also contribute to a blockage of the culverts. The proximity of floating LOD to the culverts may result in water logged wood settling on top of the culverts or if the pond level drops in conjunction with lowering reservoir levels.

Reach one is a short, braided section of stream with approximately 30% cover. Low to moderately compacted gravel comprises about 25% of the stream bed material, while cobble and boulders account for 60% of the bed material.

Nicholls Creek becomes entrenched in a narrow gorge within the first few hundred m of reach 2, after which elevation increases rapidly (Fig. 30). Large debris accumulations were observed in the first section of reach 2, although most of this LOD was not within the wetted channel at the time of the survey. Numerous small falls and logjams exist in reach 2 of Nicholls Creek, although many of these barriers may be negotiable at high water. The largest single barrier is a 5 m falls located 2.3 km upstream and likely presents the upstream limit of migration for lake resident fish (photo 57). Gravel retainment was observed upstream of these barriers. Stream gradient varied between 9% and 14% in this reach, although short sections of creek with gradients as low as 2.5% often occurred between 2 sets of falls. These short sections were found to provide good rearing and spawning habitat for rainbow trout. Reach 2 of Nicholls Creek has the most cover and pool area of any of the reaches surveyed although it contains less wetted area than reach 3 (Table 32).

Nicholls Creek is braided, and less confined in reach 3 than in reach 2 and relatively flat (~4% slope) for short sections of stream (Photo 58). Surface ice was forming along the margins of Nicholls Creek during the survey of the reach 3 sample area (site 5), but this ice did not impinge on fish habitat as much as it added extra cover. Anchor ice was not observed. Pools associated with LOD provide excellent rearing

Fish

Bull trout were captured in all reaches sampled, whereas rainbow trout and cottids were observed only in reach 1 (Table 41a). The falls/chute at km 2.3 is undoubtedly a barrier to fish migration, but the absence of cottids and rainbow trout in reach 2 may indicate that the chute at km 1.55 is also a migrational barrier. The highest fish densities and CPUE were recorded in reach 2, although, bull trout upstream of the second barrier were, on average, larger than those below the barrier (Table 42b). Because of the presence of the 2.3 km obstruction, it is likely bull trout found upstream of this barrier are resident fish.

Lindsay (1977) and Martin (1976) report kokanee spawned in Hoskins Creek prior to impoundment of the Columbia River, but the extent of this use is unknown. There were no kokanee observed in Hoskins Creek during foot surveys or helicopter overflights on October 25 and 30.

Logging

Logging along Hoskins Creek is confined to reach 1, which is private land managed by Beaumont Timber Co. The topography of land adjacent to reach 1 is relatively flat. A green strip was not left during logging of this section of stream although alder thickets do border much of the streambank in reach 1 (photo 69). The logging road, accessible only by ferry, crosses the creek approximately 1 km upstream, but only reach 1 can be approached from the road. Hoskins Creek above reach 1 is crown land, but there are no plans to log this area.

Enhancement Opportunities

Bypassing the 2.3 km barrier on Hoskins Creek could be achieved but would likely be more expensive than bypassing the falls on Nagel or Park Creeks. Removing the falls at km 2.3 would make reach 4, approximately 83,000 m^2 of wetted area, available to rainbow and bull trout. Modifying the chute at km 1.5 should also be considered to facilitate passage to the upstream barrier. Road access to the second obstruction may be required and a constructed fishway, opposed to blasting to create pools and weirs, would likely be necessary. More stream surveys upstream of the second obstruction should also be considered prior to implementing any barrier

removal projects to ensure other obstacles to fish migration do not exist upstream of those already identified.

Barrier removal may have detrimental impacts on resident bull trout in reach 4 of Hoskins Creek, due to stock competition, so the importance of developing adfluvial fish stocks at the expense of the resident bull trout stock must be considered. Finally, should barrier removal commence, a hatchery program outplanting rainbow and/or bull trout could also be considered.

Spawning habitat in reach 1 of Hoskins Creek could be improved by gravel placement in conjunction with complexes to increase rearing habitat and ensure placed gravel does not wash downstream during high flows in June. Bull trout, rainbow trout and kokanee could benefit from improved spawning habitat in reach 1.

It should be noted that passage through private land in reach 1 may be necessary to conduct any enhancement work on Hoskins Creek.

Figure 34: The stream profile for Hoskins Creek (not to scale)

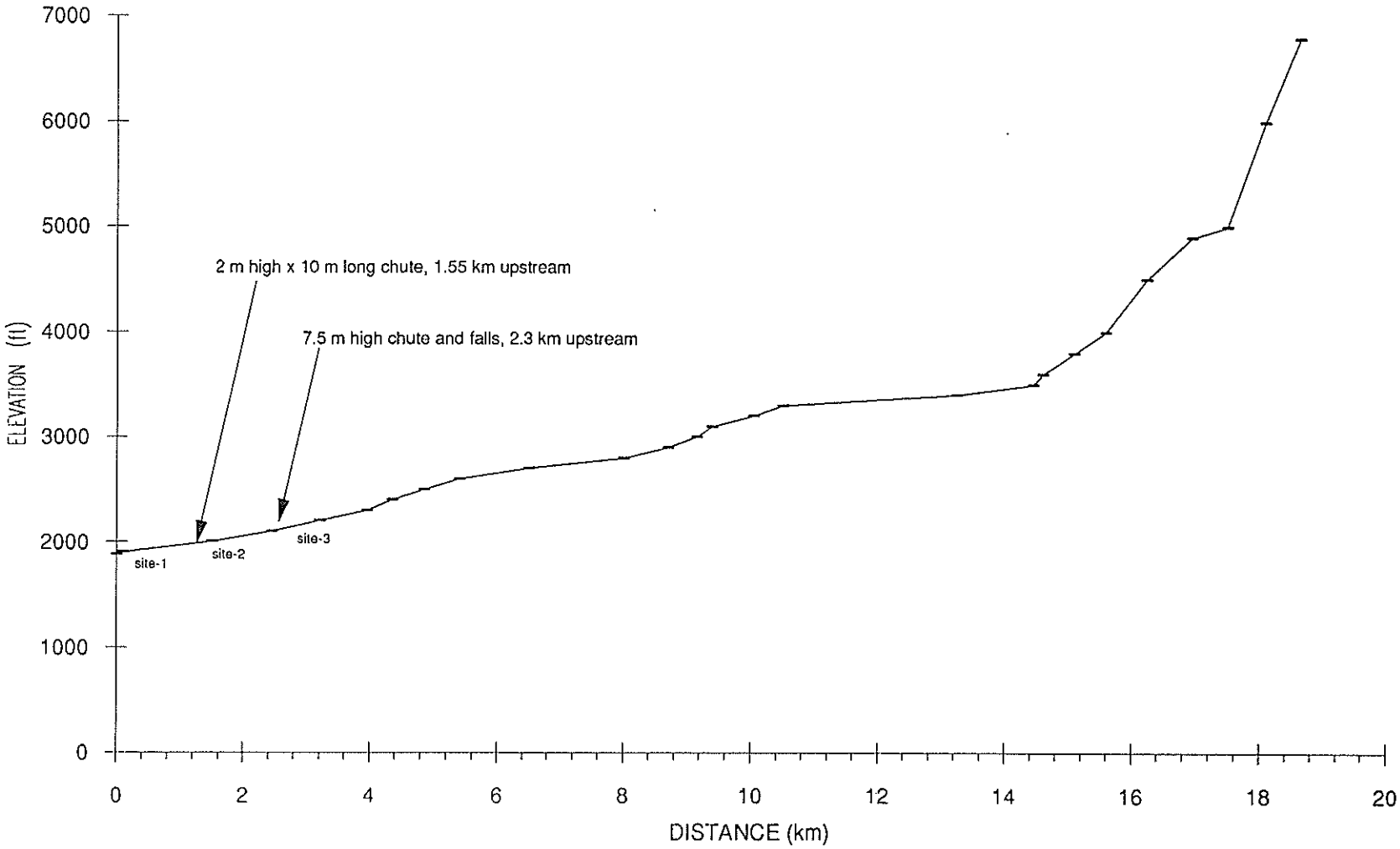


Table 40: Summary of biophysical habitat parameters for Hoskins Creek.

						COVER			STREAM CHARACTER				SUBSTRATE			VALLEY CHAR.		
Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	2.5	1.6	20,800	2,080	ov/b	416	2,080	6,240	12,480	0	2,080	7,280	M	80	UC	10 +
mainstem	2	2	1.5	0.7	10,290	1,544	ov	515	1,544	2,573	6,174	0	1,544	5,145	L	80	OC	5 - 10
mainstem	3	4	4.3	4.9	83,300	12,495	b/dp	2,499	12,495	29,155	41,650	0	8,330	29,155	M	120	UC	10 +
Total				7.2	114,390	16,119		3,430	16,119	37,968	60,304	0	11,954	41,580		93		

Summary of geographical parameters.

Location:	Central area of resevoir, west side.
Length:	19 km
Barriers:	2 m chute at km 1.5, and a 5.0 m chute and 2.5 m falls at km 2.3
No. of Reaches:	7
No. of Reaches Sampled:	3
Total length of stream below barriers:	A minimum of 1.5 km but possible to 2.3 km.
Major Tributaries:	none
Water Source:	Primarily glaciers, although numerous small lakes and ponds exist through the watershed.
Resource use:	Logging along the valley bottom on either side of reach 1 only.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 41: **Electroshocking results (a), as well as fish size and age data (b) for Hoskins Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	1	1	1	RBT	f	0.002	0.002	**0.004**	0.001	0.001	**0.003**
mainstem	1	4	2	BT	f/p	0.007	0.004	**0.011**	0.005	0.003	**0.008**
mainstem	1	1	0	CC	a	0.002	0.000	**0.002**	0.001	0.000	**0.001**
total, reach 1:		**6**	**3**	**mean**		**0.004**	**0.002**	**0.005**	**0.003**	**0.001**	**0.004**
mainstem	2	8	3	BT		0.018	0.007	**0.025**	0.010	0.004	**0.014**
mainstem	4	5	0	BT		0.013	0.000	**0.013**	0.006	0.000	**0.006**
Total (mainstem):		19	6	Mean:		0.011	0.003	0.014	0.006	0.002	0.008

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yrs)	N
1	RBT	37	-	0.51	-	1.01	1	n/a	-
1	BT	63	50 - 87	2.63	1.13 - 5.96	0.91	4	0+	1
2	BT	72	46 - 142	6.37	0.97 - 25.16	0.98	8	1+	3*
3	BT	176	158 - 194	51.71	36.52 - 68.91	0.94	5	2 - 3	5
1 + 2 + 3	BT	105	46 - 194	24.34	0.97 - 68.91	0.95	17	0 - 3	9

* one scale sample unreadable

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available

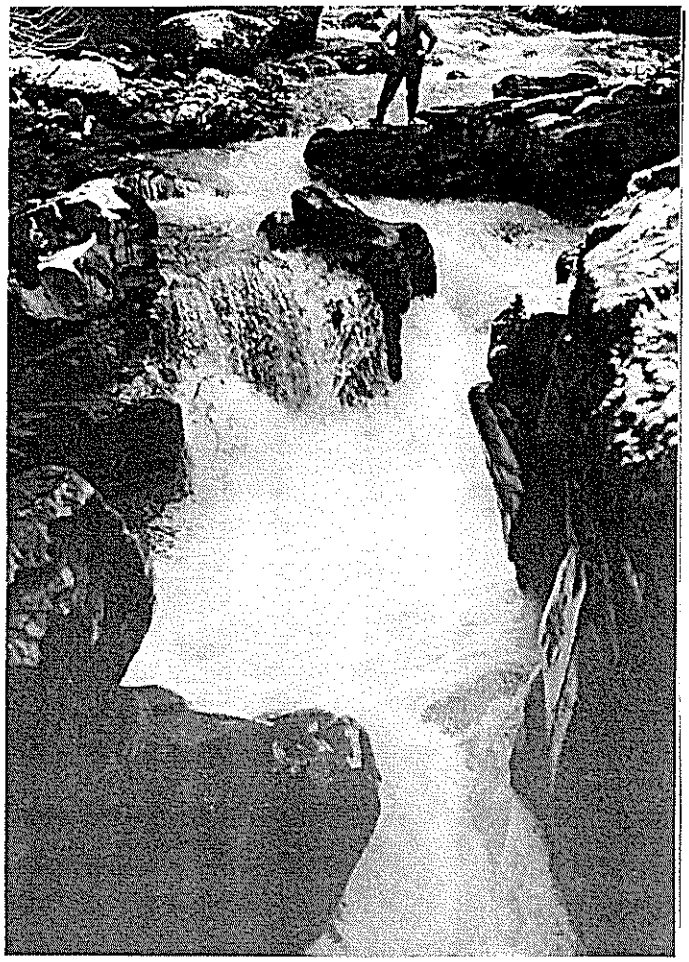


Photo 66 This 5 m high x 35 m chute, preceded by a 2.5 m falls, represents the upstream limit of migration into Hoskins Creek for lake resident fish.

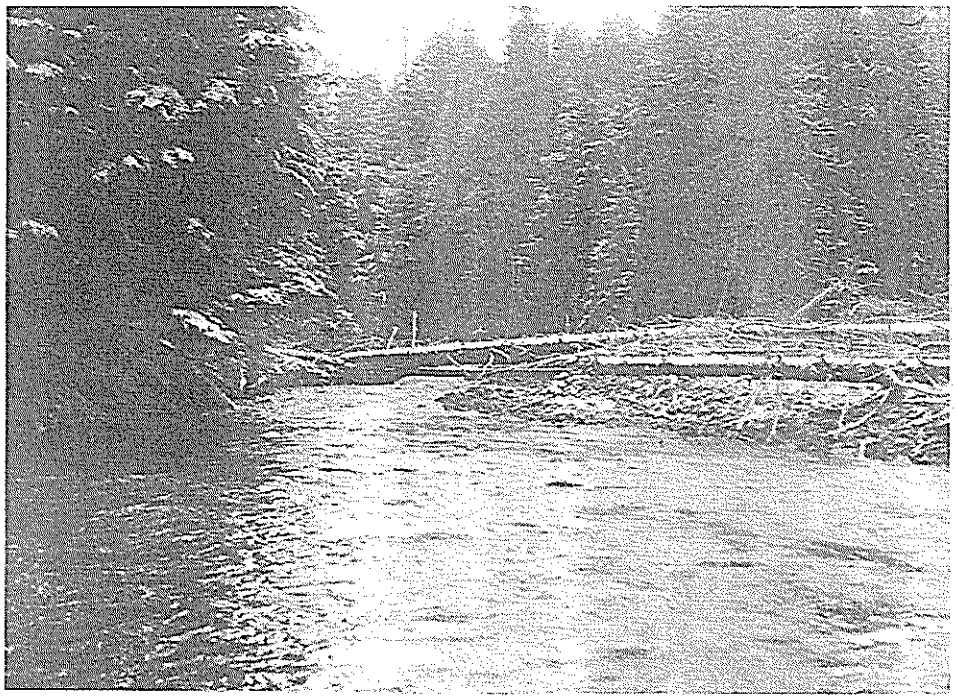


Photo 67 Reach 2 of Hoskins Creek is short in length but has good habitat.

Table 37: **Electroshocking results (a), as well as fish size and age data (b) for Pat Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	2	2	2	RBT	p	0.008	0.008	**0.016**	0.005	0.005	**0.010**
mainstem	3	6	1	RBT	p	0.015	0.003	**0.018**	n/a	n/a	**n/a**
mainstem	4	3	1	RBT	p	0.011	0.004	**0.014**	0.012	0.004	**0.016**
Total:		**11**	**4**	**Mean:**		**0.011**	**0.005**	**0.016**	**0.008**	**0.004**	**0.013**

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (K)	N	Age Range (yr)	N
2	RBT	153	121 - 184	31.81	18.33 - 45.29	0.88	2	n/a*	-
3	RBT	123	103 - 144	20.39	12.99 - 31.34	1.06	6	1 - 2+	4
4	RBT	67	35 - 96	4.23	0.41 - 8.97	1.09	4	0 - 1	3
2 + 3 + 4	**RBT**	**109**	**35 - 184**	**16.91**	**0.41-45.29**	**1.04**	**12**	**0 - 2**	**7**

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available



Photo 68 Stream gradient becomes steeper upstream of the barrier on Hoskins Creek, but off channel habitat and boulders provide refuge for resident bull trout population.



Photo 69 Logging on private land has left reach 1 of Hoskins Creek with no green strip, but alder scrub still affords some cover for rearing fish.

4.5.17 Birch Creek

Birch Creek is a small clear water stream which increases in elevation rapidly upstream of its mouth (Fig. 35). A set of 3 culverts formed an impassable barrier 400 m upstream of the lake at the Big Eddy Highway, however, work carried out by the Revelstoke Rod and Gun Club members bypassed this barrier by the creation of a pool and weir system.

Reach 1 of Birch Creek, although short in length, provided extensive LOD cover, supplemented by well developed riparian vegetation.

Reach 2 flows through a broad plain and provides the single longest stretch of low gradient stream, although riffle dominated this area with little pool habitat evident. This reach was estimated to have the most gravel of the 3 reaches sampled, although this gravel was moderately compacted (Table 42).

Reach 3 probably provides the best rearing habitat in Birch Creek, although access for fish into this area may be limited by a number of small debris jams and a steadily increasing gradient as the creek climbs into a canyon.

Fish

Bull trout fry and cottids were the only species of fish observed in Birch Creek (Table 43). All the bull trout were captured below the culvert barrier but upstream of a large debris jam.

Observations by Rod and Gun Club members, after barrier modification, indicated that approximately 15 kokanee went upstream of the highway culverts but this was not confirmed (Pers. comm. B. Gadbois B.C. Hydro).

Logging

Logging has occurred on either side of reach 2, and higher elevations within the first few hundred meters of reach three have been cleared for the power transmission

line right of way. There are no plans for other logging to occur within this watershed within the next 5 years.

Enhancement Opportunities

The modification of the culvert barrier near the mouth of Birch Creek appears to have been successful, if reports of kokanee seen above these barriers are factual. However, ensuing problems have already occurred since removal of this barrier. The cold spell at the end of October resulted in an ice dam upstream of the highway culverts, causing water to overflow the highway.

The effects of barrier removal on reach one habitat is also a concern. A road built to access the stream resulted in removal of riparian vegetation on the north side of the river. This coincides with the area where bull trout fry were sampled from and provided extensive cover. This lost cover should be replaced through rehabilitation of riparian habitat by placement of cuttings and or transplants.

A large debris jam was also removed from reach one, which likely provided good cover for rearing bull trout. While this jam may have been a barrier for kokanee, bull trout were able to negotiate it, proven by the presence of bull trout fry above this jam. Triton, (1991) suggested minimal LOD be displaced during barrier removal . A case can be made for removal of this lower logjam, but there has been interest in removing upstream debris jams and beaver dams which are not necessarily barriers to bull or rainbow trout. Efforts may be better directed to build spawning platforms within the lower section of reach 2 to improve spawning habitat for kokanee.

Finally, there is concern that the pool and weir system used to bypass the highway culverts may be damaged during freshet. This concern, and also the need to determine if areas upstream of the culvert are being utilized by fish species requires that Birch Creek be monitored to determine the success of barrier removal.

Figure 35: The stream profile for Birch Creek (not to scale).

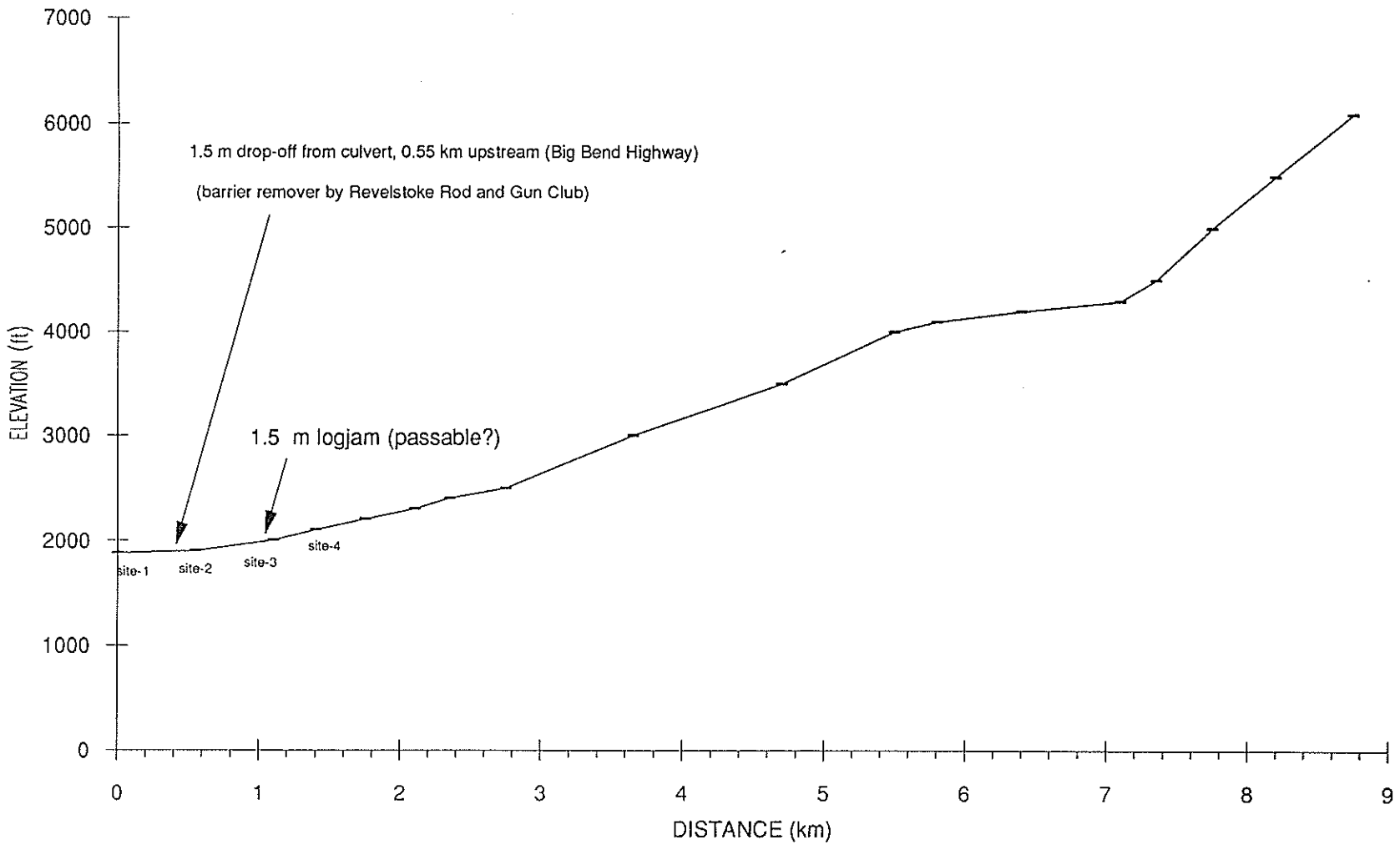


Table 42: Summary of biophysical habitat parameters for Birch Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	5.0	0.2	800	120	l	80	0	640	160	0	40	320	M	40	UC	10 +
mainstem	2,3	2	2.5	0.7	8,400	665	l/ov	560	490	6,580	1,330	0	420	2,940	M	35	UC-OC	10+
mainstem	4	3	5.0	1.1	7,150	4,290	b/ov/l	7,079	2,145	1,430	3,575	0	715	1,788	L	35	FC	0 - 2
Total 1+2+3:				2.0	33,150	5,405		8,839	3,615	21,810	7,725	0	2,015	10,928		37		

Summary of geographical parameters.

Location:	Northern area of resevoir, east side.
Length:	9 km
Barriers:	Possibly in Canyon
No. of Reaches:	4
No. of Reaches Sampled:	3
Total length of stream below barriers:	At least 2.0 km (after culvert was bypassed)
Major Tributaries:	none
Water Source:	Unkownn
Resource use:	Limited, mainly in reach 2, some logging in upper slopes of lower reach 3.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 43: **Electroshocking results (a), as well as fish size and age data (b) for Birch Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
Mainstem	1	4	0	bt	f	n/a	n/a	n/a	n/a	n/a	n/a
Mainstem	2	0	0	-	-	n/a	n/a	n/a	n/a	n/a	n/a

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yr)	N
1	BT	33	31-37	0.46	0.7 - 2.23	1.250	8	n/a	0

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available

C CATEGORY STREAMS

4.5.18 Mars Creek

Mars Creek is a steep creek which flows into the east side of Revelstoke Lake, approximately 40 km north of the Revelstoke dam. Gradient at the mouth of Mars Creek (5.5%) increases steadily, reaching 11% within the first 2.8 kms of the creek (Fig. 36). Mars Creek's ascent towards its head waters progresses in a stepwise fashion, with numerous small cascades separating pools. Gravel within these pools is uncompacted and provides a good spawning medium. Turbulent water in pools at the base of cascades and large boulder substrate provide good cover for rearing salmonids. Numerous small chutes, falls and debris jams exist within the first 2.8 km stretch of creek, but a short gorge 2500 m upstream which has a gradient between 16% and 18%, appears to be the upstream limit of migration for spawning fish since no fish were observed or captured upstream of this gorge (Photo 70, 71).

Not surprising, the percentage of gravel steadily decreased with progression upstream of the mouth compared to an increasing percentage of boulder and cobble. Total cover remained similar (30% to 35%) between sample sites but the type of cover shifted from predominantly LOD and pools in reach 1 to pools and boulders upstream (Table 44).

Fish

Mars Creek is identified by numerous sources as an important bull trout producing stream. (Mason 1985, Lindsay 1977, and Martin 1976). This may be due, in part, to a good food supply for rearing fish. ERC (1976) identified 13 taxa of insects residing in Mars Creek, at densities of 2 to 10 times greater than other Lake Revestoke tributaries sampled. Crystal clear water undoubtedly adds to Mars Creek's productivity. Both bull trout and rainbow trout were found in Mars creek, although bull trout was the predominant and most widely distributed species captured. One adult bull trout, likely a spawner, was observed holding in a plunge pool below a small chute 1800 m upstream. An attempt to capture this fish for closer inspection failed. Bull trout were, on average, larger and older in reach 3 than the lower reaches (Table 45). It is possible that fish captured in reach 3 were resident since numerous large

obstructions, which appeared capable of impeding fish migration, existed below sample site 3.

Rainbow trout were captured near the mouth of Mars Creek, in reach 1. Lindsay (1977) suggests rainbow trout in Mars Creek are resident, and not migratory. Despite the close proximity to the lake, a 5^{+} year old rainbow trout (234mm long, weight >120.00 g) captured in reach 2 appears to coincide with Lindsay's conclusion. Mason (1985) indicated cutthroat trout reside in Mars Creek, however, this was not verified during this years' survey.

Logging

Logging has not yet occurred in this watershed, and a lack of associated logging roads makes access to Mars Creek difficult. The mouth of Mars Creek can be reached by boat or foot. Helicopter access is also limited within the first 5 km of this stream because of the steep banks and gorges which occur in this area. There are no plans for logging to occur within the Mars drainage over the next 5 years.

Enhancement Opportunities.

The gradient, size and confinement of Mars Creek, restricts habitat available to lake resident fish utilizing this stream. The present level of utilization by rainbow and bull trout in Mars Creek may indicate this stream has reached its carrying capacity. For the above reasons, there are limited enhancement options for this stream. More fish could be produced through use of stream side incubation boxes, but the small size of Mars Creek suggests insufficient rearing habitat is available to accommodate increased densities of rearing fish. The restricted access and narrow canyon prevent increasing the rearing habitat in this stream, and the steep gradient likely limits the extent of which kokanee can migrate upstream.

Despite limited enhancement options for Mars Creek, it is a proven productive stream, and efforts should be made to ensure this productivity is not affected by human activities. Furthermore, Mars Creek could prove to be a valuable source of brood stock for satelliting bull trout into other tributaries of Revelstoke Lake if an outplanting program is to be considered for some of Lake Revelstoke's tributaries.

Figure 36: The stream profile for Mars Creek (not to scale).

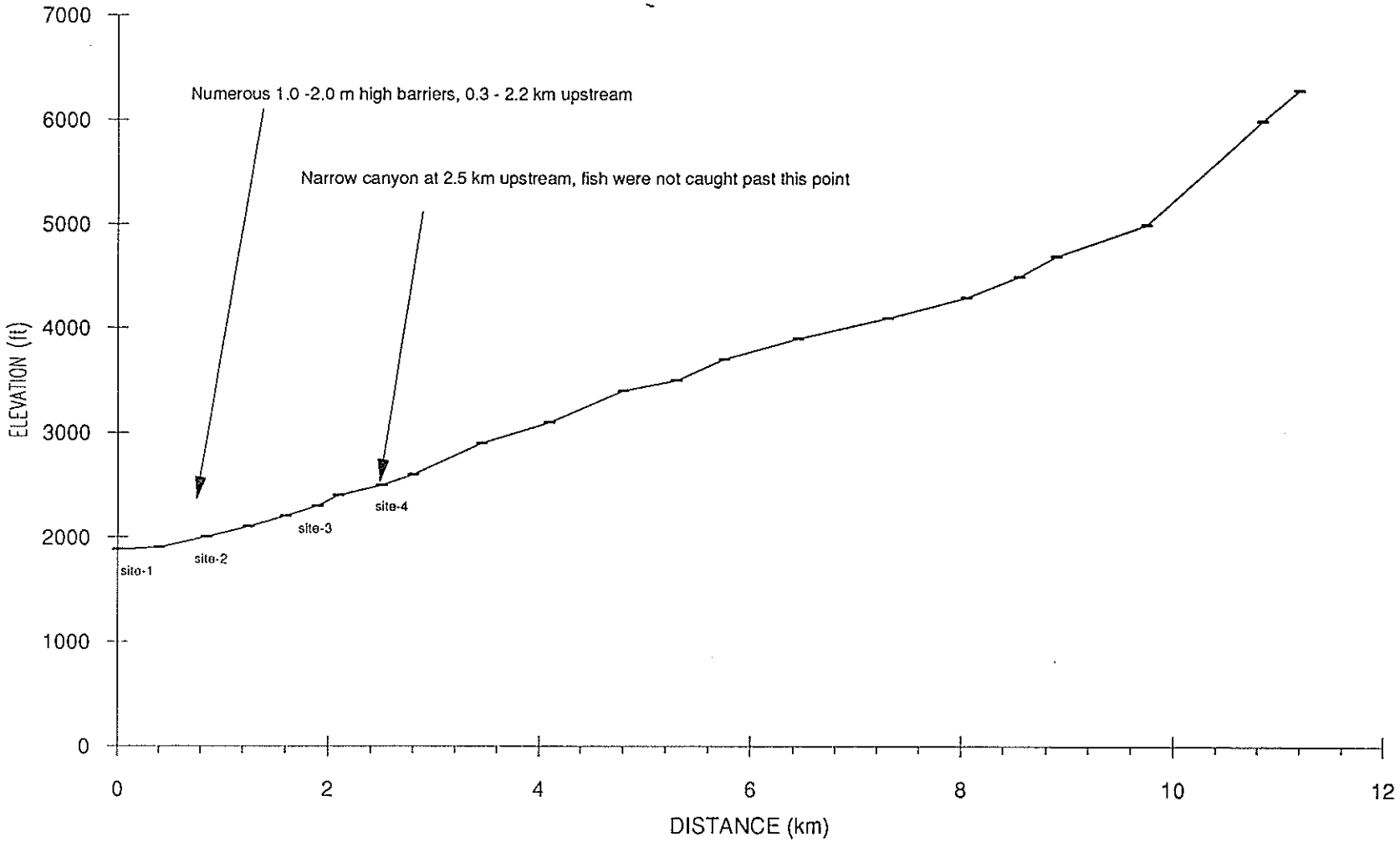


Table 44: Summary of biophysical habitat parameters for Mars Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	5.5	0.1	2,450	735	l/dp	490	613	980	613	245	245	1,103	L	100	EN	0 - 2
mainstem	2	2	6.5	1.2	8,040	2,814	b/dp	161	2,412	2,412	2,412	804	402	2,412	L	100	CO	0 - 2
mainstem	3,4	3	10.5	4.7	38,070	12,208	dp/b	1,274	15,228	3,807	9,847	6,956	1,904	5,711	L	100	EN	0 - 2
Total				6.0	48,560	15,757		1,925	18,253	7,199	12,871	8,005	2,551	9,225		100		

Summary of geographical parameters.

Location:	Southern area of Revelstoke Lake, east side.
Length:	11.2 km
Barriers:	2-3 m log jam at 1.8 km, 1.5 m chute at 2.3 km, steep gorge (17.5%) at km 2.5
No. of Reaches:	4
No. of Reaches Sampled:	3
Total length of stream below barriers:	Possibly 2.5 km.
Major Tributaries:	None
Water Source:	Numerous small lakes and ponds in the headwaters.
Resource use:	No logging observed in watershed.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 45: **Electroshocking results (a), as well as fish size and age data (b) for Mars Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	1	5	5	RBT	p	0.017	0.002	**0.034**	0.036	0.036	**0.071**
mainstem	1	1	2	BT	p	0.003	0.007	**0.010**	0.007	0.014	**0.021**
total, reach 1:		**6**	**7**	**mean:**		**0.026**	**0.011**	**0.041**	**0.043**	**0.050**	**0.093**
mainstem	2	2	1	RBT	p/a	0.012	0.006	**0.018**	0.010	0.005	**0.015**
mainstem	2	4	2	BT	p	0.024	0.012	**0.036**	0.020	0.010	**0.030**
total, reach 2:		**6**	**3**	**mean:**		**0.036**	**0.018**	**0.054**	**0.030**	**0.015**	**0.045**
mainstem	3	4	3	BT	p/j	0.021	0.015	**0.036**	0.014	0.011	**0.025**
Total, 1 + 2+ 3:		16	13	Mean:		0.024	0.020	0.044	0.026	0.021	0.046

Note: One adult bull trout , approx. 500 mm long was observed hold in a plunge pool below a small falls 1800 m upstream (

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (K)	N	Age Range (yrs)	N
1	RBT	59	33 - 137	8.46	0.33 - 39.33	1.16	5	0 - 2+	2
2	RBT	165.3	139 - 234	>57.21	32.47->120.00	1.04	2	5+	1*
1	BT	97	-	8.58	-	0.94	1	n/a	0
2	BT	117.6	90 - 139	17.04	6.89 - 25.63	0.96	4	n/a***	0
3	BT	219	171 - 283	91.32	47.59 - 114.85	0.93	4	3 - 4+	4
1 + 2	RBT	96	33-234	>27.81	0.33 - >120	1.13	7	0 - 5+	3**
1 + 2 + 3	BT	163	90-283	50.05	6.89-114.85	0.95	9	3 - 4+	4

* 1 scale sample was unreadble

** 4 scale samples were unreadable

*** 1 scale sample was unreadable

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available

CC=cottid, CT=Cutthroat, RBT=Rainbow trout, BT=Bull Trout, LKC=Lake chubb, SKR=Sucker, WF=whitefish.

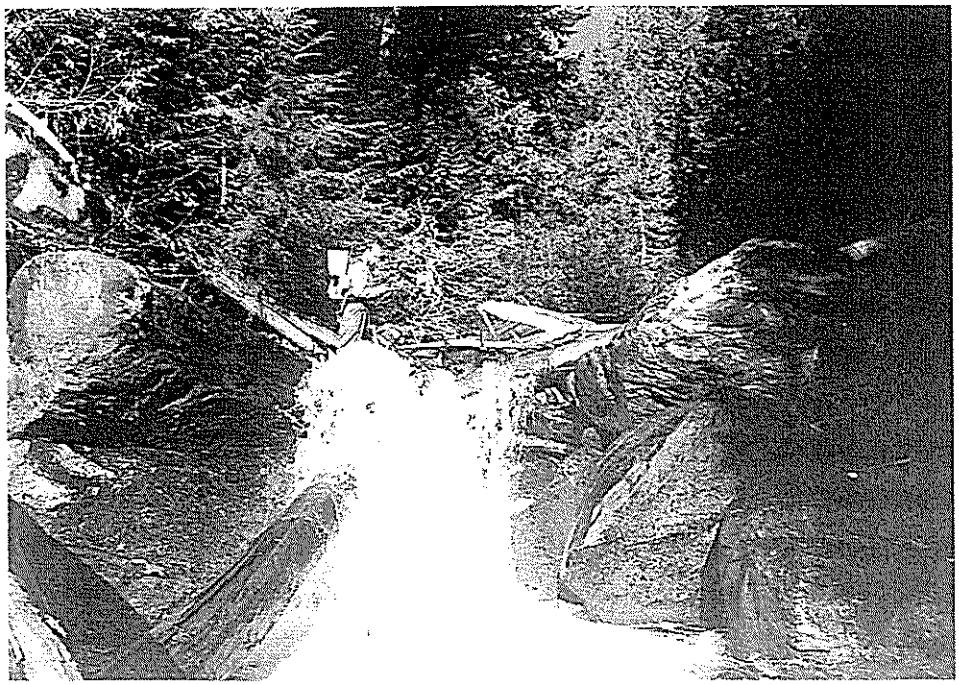


Photo 70 This 2.5 m high debris jam is one of numerous obstructions encountered within the first 2.8 km of the Mars Creek mouth.

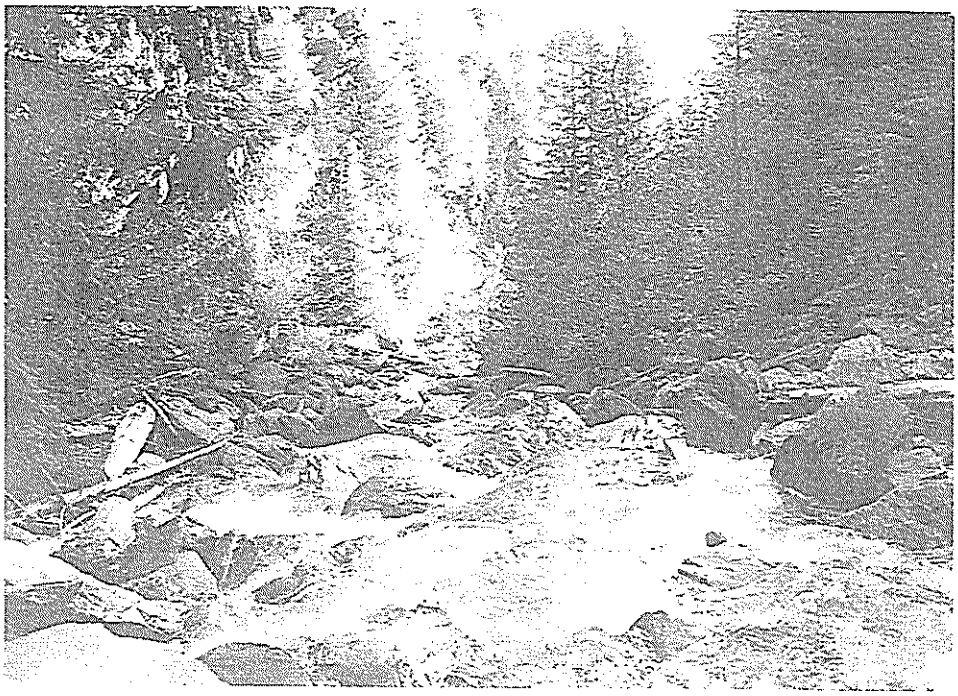


Photo 71 A short gorge 2.5 km upstream has a gradient of approximately 17.5%, and probably presents an impassable barrier to migrating fish. No fish were captured upstream of this gorge.

4.5.19 Big Eddy Creek

A series of 2 chutes and 1 falls, totaling 4.5 m high are located 200 m upstream of the mouth of Big Eddy Creek and probably represents the limit of migration for lake resident fish. This set of barriers also marks the start of a steep canyon, which extends 600 m upstream of the creek mouth. Two more falls, 5.0 and 4.5 m high, are located in this canyon (Photo 72).

The Big Eddy valley broadens upstream of the canyon and a 2.4 km stretch of stream divided into 2 reaches (3 and 4) provides ideal salmonid habitat. Ample cover, large deep pools and extensive LOD furnishes reach 2 with excellent habitat for rearing salmonids (Photo 73). Reach 4 has less rearing habitat available and a steeper gradient (average of 3.0% compared to 1.5%) than reach two, but each reach had substantial amounts of gravel in the substrate (Table 46).

Fish

Despite suitable habitat upstream of the barriers on Big Eddy Creek, white fish and bull trout were observed in reach 1 only and no fish were captured above the canyon (Table 47). Mason (1985) reports cutthroat trout were observed in Big Eddy Creek and large schools of whitefish have been reported to congregate at the creek mouth of Big Eddy Creek (Pers. Comm. Volker Scherm, Owner operator, Monashee Outfitting).

Logging

Logging activities are presently limited to a single cutblock, adjacent the canyon in reach 2, on the north side of Big Eddy Creek. The 5 year plan submitted by the Small Business Forest Enterprise Program indicates 50 ha within the Big Eddy drainage are to be clearcut in 1995 but there is no indication of additional road construction to accommodate this logging. There is presently no road access to Big Eddy Creek from the existing cutblocks

Enhancement Opportunities

Big Eddy Creek is almost 9 km long, but gradient and elevation increase quickly 3 km upstream of the mouth, leaving less than 2.5 km of low gradient habitat above the barriers in reach 2 (Fig. 37). Habitat which is available for spawning and rearing fish upstream of the barriers on Big Eddy Creek is excellent, but the number and height of barriers necessary to remove or bypass, and access to these obstructions would make barrier removal prohibitively expensive considering the benefits.

Similar to Bourne Creek, fish could be outlplanted above the barriers on Big Eddy Creek. The stream is easily accessible to hiking and could provide sports fishing potential, but considering the short length of stream above the barriers, only limited habitat would be provided for an introduced resident species. Furthermore, the glacial nature of Big Eddy Creek may limit primary productivity in this stream.

Figure 37: The stream profile for Big Eddy Creek (not to scale)

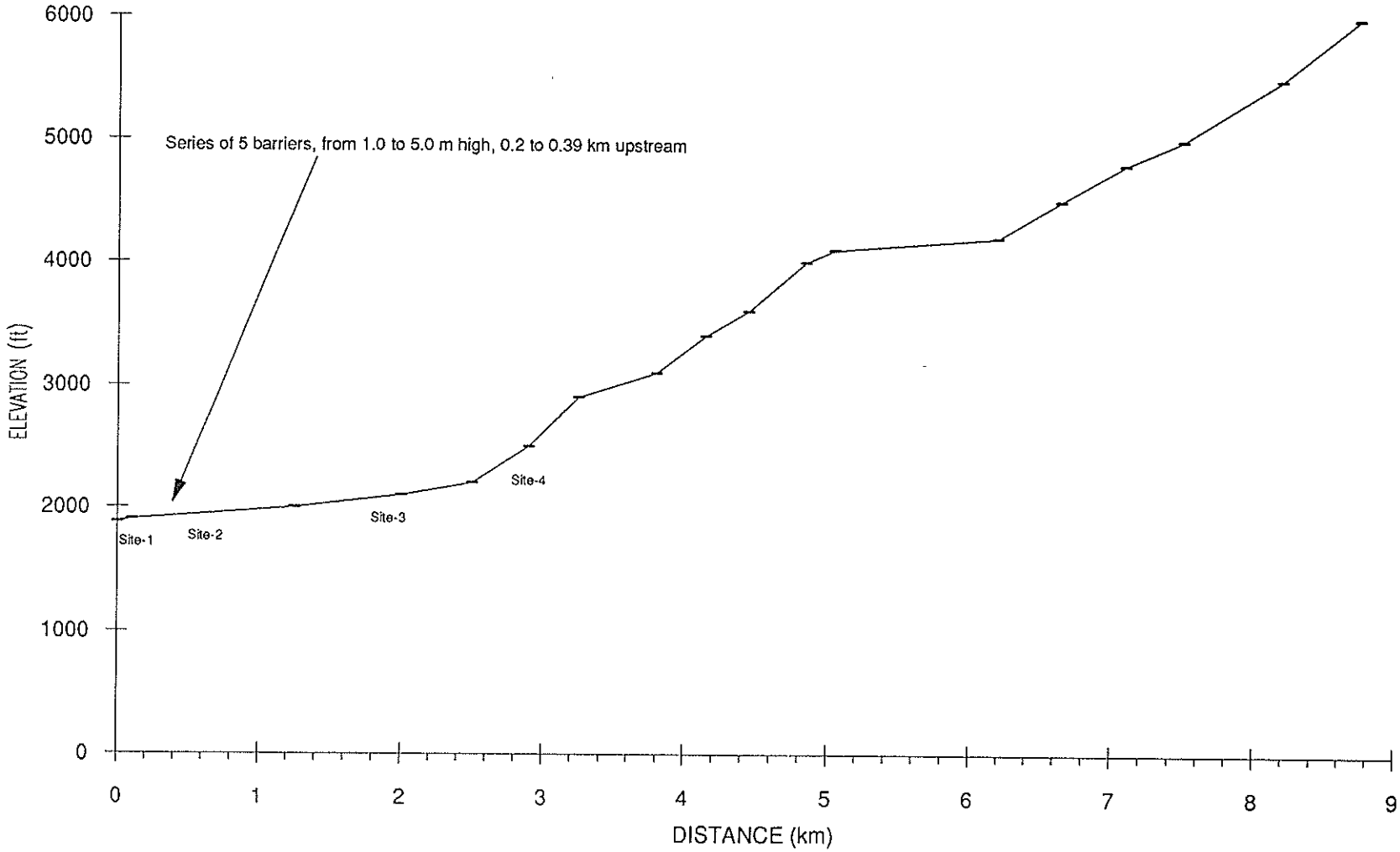


Table 46: Summary of biophysical habitat parameters for Big Eddy Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	1.5	0.2	2,340	468	b/dp/l	117	468	936	936	0	117	936	L	50	EN	0 - 2
mainstem	2,3	3	2.7	2.2	36,630	11,715	ov/dp/l	3,663	7,029	14,141	15,461	0	5,495	16,484	n/a	45	FC-OC	2 - 10
mainstem	4	4	4.0 +	1.6	15,040	3,760	b/dp/ov	451	4,512	4,512	4,512	1,504	1,504	3,008	M	40	CO	2 - 5
Total				4.0	54,010	15,943		4,231	12,009	19,589	20,909	1,504	7,116	20,428		41		

Summary of geographical parameters

Location:	Southern area of Revelstoke Lake, west side.
Length:	8.75 km
Barriers:	Series of falls and chutes from 1.5 to 5 m high, 200 to 390 m upstream.
No. of Reaches:	6
No. of Reaches Sampled:	3
Total length of steam below barriers:	0.2 km
Major Tributaries:	None
Water Source:	Primarily glacial, with one small lake near the headwaters of the creek.
Resource Use:	Limited logging with in first 600 m of creek mouth, north side only.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 47: **Electroshocking results (a), as well as fish size and age data (b) for Big Eddy Creek.**

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE Esc. or Obs.	CPUE Total	DENSITY (Fish/m^2) Caught	DENSITY Esc. or Obs.	DENSITY Total
mainstem*	1	2	3	bt	f/p	0.009	0.014	**0.023**	0.003	0.005	**0.009**
mainstem	3	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
mainstem	3	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
mainstem	4	0	0	-	f/p	0.000	0.000	**0.000**	0.000	0.000	**0.000**

* Reach 1 is downstream of an impassable barrier.

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yrs)	N
1	BT	158	87 - 276	>52.66	6.56 - >120.00	0.88	4	0 -1+	2**

** ages from fish < 98 mm in length, 2 scale samples unreadable.

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available

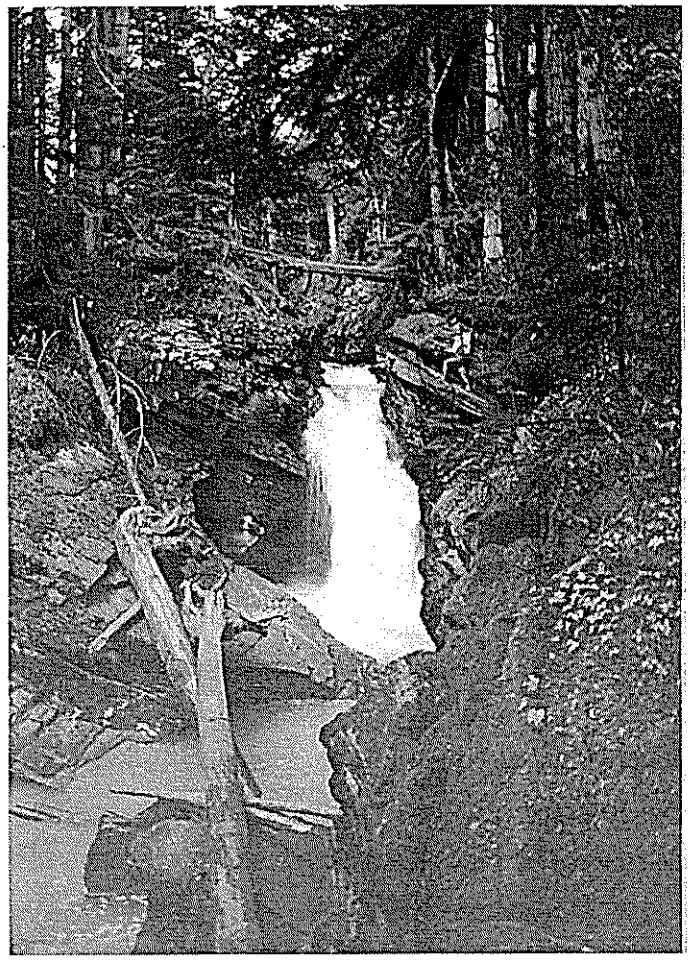


Photo 72 A 7 m falls located 270 m upstream of the mouth of Big Eddy Creek.



Photo 73 Looking upstream through sample site 3 of Big Eddy Creek, 2.2 km upstream. Side channels have good pool and riparian cover.

4.5.20 Frisby Creek

Frisby Creek is completely inaccessible to lake resident fish due to a 25 m (approx.) falls located at its outlet (Photo 76). A short narrow inlet leads from the lake to the outlet of Frisby Creek. Two additional falls are also located 7.6 and 13.6 km upstream of the mouth, and isolate reaches from each other (Fig. 38). The two upstream barriers are estimated to be 10 m high each. Frisby Creek is fed from numerous glaciers located within its watershed. Frisby Creek's largest tributary enters the south side of the mainstem from a hanging valley, which is approximate 9 km upstream. Water turbidity was high during initial foot surveys of the first falls, but it was quite clear during helicopter surveys and there was little evidence of sedimentation at any of the sites sampled.

Reach 2 has the most extensive wetted area within Frisby Creek, and represents that section of stream with the best fish habitat (Photo 74). A low gradient, substrate composed mostly of uncompacted gravel and extensive cover (in the form of deep pools and LOD) provides reach 2 with excellent spawning and rearing habitat. Also, considerable off channel habitat probably becomes available during higher flows.

Upstream reaches become progressively steeper, have less cover and the percentage of gravel within the substrate decreases (Table 48). Reach 4 is typified by long riffles separated by short runs and deep pools. Reach 5 is a series of evenly distributed runs, riffles and shallow pools interspersed by cascades and rapids. Cover in reach three is primarily deep pools, whereas cobble and boulder predominates the cover in reach 5.

Fish

Frisby Creek is almost completely devoid of fish. Cottids, of the species *C. rhotheus* (torrent sculpin), were the only type of fish caught in Frisby Creek. The cottids captured were few in number, and isolated to reach 1 (Table 49).

Preimpoundment data indicates both kokanee and bull trout were found in the area of Frisby Creek below the first falls (Martin 1976).

Logging

The Frisby Creek watershed has not been logged and will likely not be logged since the terrain surrounding this watershed makes it unaccessible by means other than helicopter or foot.

Enhancement Opportunities

The presence of a small population of cottids in Frisby Creek favors outplanting into this stream since impacts of introduced salmonids upon the resident species would be minimal and of little consequence. Side channel habitat made available at high water would likely provide good refuge for rearing fish during high water, however, the ability for Frisby Creek to support a resident population of fish requires more study. Furthermore, the lack of access into the Frisby watershed restricts recreational fishing opportunities, reducing the likelihood that such a resource would be used.

Bypassing or removing the barrier at the mouth of Frisby Creek is not a viable option since the expense of such an operation would be prohibitive and the benefits limited.

Figure 38: The stream profile for Frisby Creek (not to scale)

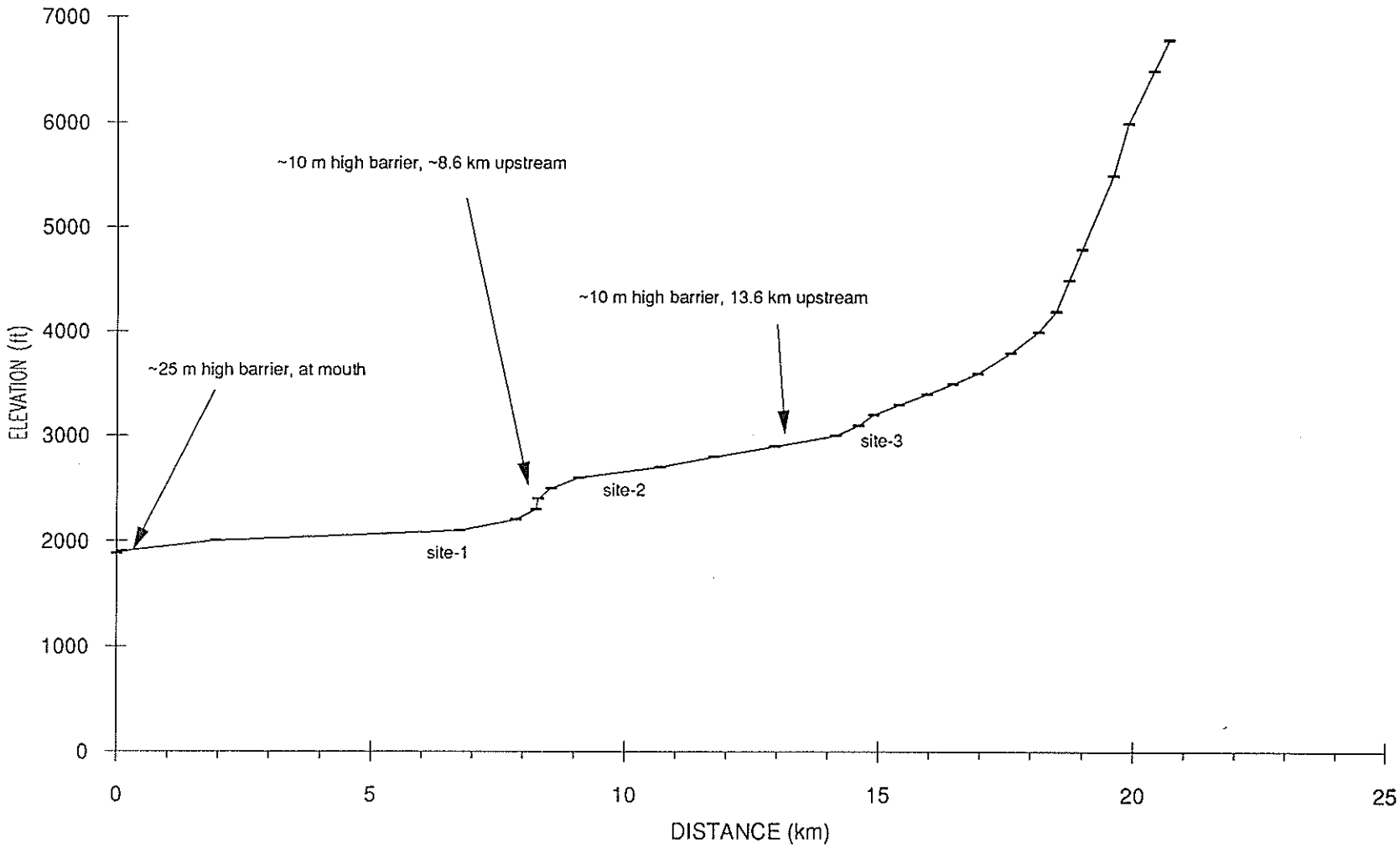


Table 48: Summary of biophysical habitat parameters for Frisby Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	2	0.7	6.9	110,400	27,600	l/dp	16,560	38,640	33,120	38,640	0	27,600	71,760	L	90	UC	10 +
mainstem	2	4	2.3	5.3	59,360	5,936	dp	1,187	14,840	29,680	14,840	0	5,936	26,712	M	60	FC	2 - 5
mainstem	3	5	7.2	3.8	44,840	8,968	b/dp	448	13,452	13,452	15,694	2,242	2,242	4,484	L	60	OC	2 - 5
Total 2+4+5:				15.9	214,600	42,504		18,196	66,932	76,252	69,174	2,242	35,778	102,956		70		

Summary of geographical parameters.

Location:	Southern area of Revelstoke Lake, west side.
Length:	21
Barriers:	25 m falls at mouth, 10 m falls 8.6 m upstream, 10 m falls 13.6 km upstream.
No. of Reaches:	6
No. of Reaches Sampled:	3
Total Length of Sampled Reaches:	15.9 km
Major Tributaries:	None
Water Source:	Glacial
Resource use:	None.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 49: Electroshocking results (a), as well as fish size and age data (b) for Frisby Creek.

(a) Electroshocking results,

Site	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	2	3	0	CC	-	0.007	0.000	**0.007**	0.003	0.000	**0.003**
mainstem	4	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**
mainstem	5	0	0	-	-	0.000	0.000	**0.000**	0.000	0.000	**0.000**

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	N	Conditon Factor (k)	Mean Age (yr)		N
2	CC	87	81 - 96	7.42	4.96 - 10.99	3	1.08	n/a	-	-

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available



Photo 74 This 25 m falls (est.) at the mouth of Frisby Creek prevents fish access to upstream areas.



Photo 75 Reach 2 of Frisby Creek had the best habitat within this system, although only sculpins were captured here.

4.5.21 Pitt Creek

Pitt Creek is a small, steep drainage entering the east side of Lake Revelstoke. The mouth of Pitt Creek is adjacent a small forestry campsite. Considering the size of this stream, it is remarkably productive since numerous fish were captured from 2 of 3 sample sites.

Reach 1 has a low gradient, with well developed riparian cover and a substrate comprised mainly of moderately compacted cobble and some large gravel. A culvert located 80 m upstream of the lake separates reach 1 from reach 2 but does not impede fish migration.

Stream gradient increases to between 14.5% and 16% in reach two, but numerous small cascades preclude the occurrence of any substantial barrier (Fig 39). A second culvert under the new highway, approximately 500 m upstream of the lake, sits 1 m above water level and is probably a barrier to fish migration. Reach 2 has diverse cover, dominated by large boulders (Photo 76). Pools between cascades both above and below the second culvert also provide some suitable gravel for spawning but this habitat is minimal and probably inaccessible to lake resident fish (Table 50).

Fish

Bull trout, cottids and rainbow trout utilize Pitt Creek (Table 51). The presence of rainbow trout, but not bull trout, upstream of the second culvert and also above a series of 2 m barriers 200 m upstream the new highway culvert suggests Pitt Creek has a resident stock of rainbow trout. High water conditions during spring freshet may facilitate adult rainbow trout migration through the new highway culvert and other upstream barriers, but this can not be confirmed.

Logging

The extent of logging within the Pitt Creek watershed was not determined, but there presently are no plans to remove lumber from the drainage area by any of the

logging concerns. A right of way for transmission lines which cross Pitt Creek has been cleared approximately 1.5 km upstream of the mouth.

Enhancement opportunities

The short length of stream available to lake resident fish provides little habitat for rearing and or spawning, and additional habitat is not readily available upstream of reach 1 because of the steep gradient and relatively short length of Pitt Creek. Resident rainbow trout may be detrimentally impacted through competition for food and habitat with other species if barriers were removed. Furthermore, the number of barriers necessary to remove for a marginal increase in available habitat makes such an option unfeasible.

Redirecting Pitt Creek to run parallel to the lakeshore so the creek mouth enters the reservoir approximately 500 m north of its present location, rather than its direct route into the lake, would create more spawning habitat for lake resident species utilizing Pitt Creek. The incorporation of pools, habitat complexes and riparian cover could provide additional rearing habitat within such a channel. Problems with this plan include the low flows during winter months which can result in freezing during cold spells. Water storage may be required to ensure sufficient water is available to ensure flow through the winter. Also spring freshet or other high water events may cause overflows of a channel at the point of its redirection. The option of creating a spawning channel is not feasible considering the costs to create a small amount of additional habitat.

Figure 39: The stream profiel for Pitt Creek (not to scale)

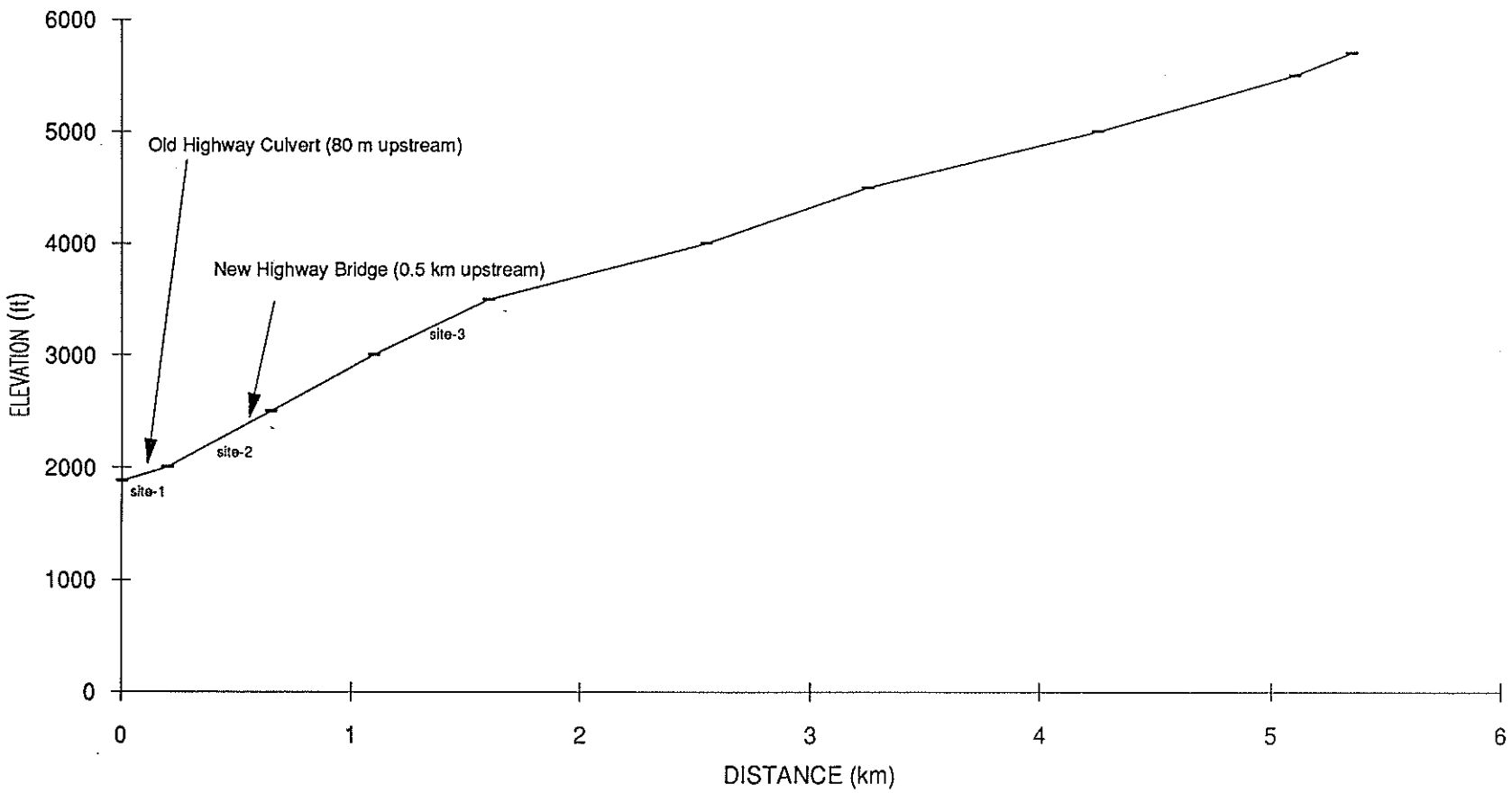


Table 50: Summary of biophysical habitat parameters for Pitt Creek.

						COVER			STREAM CHARACTER				SUBSTRATE			VALLEY CHAR.		
Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	3.5	0.1	4,480	1,792	b/ov/cb	4,435	448	2,240	1,568	224	224	1,344	M	150	EN	0 - 2
mainstem	2, 3	2	15.2	3.3	12,375	4,257	dp/b/cb	965	4,257	1,931	2,624	3,564	1,238	2,822	M	150	EN-FC	0 - 2
Total 1+2:				3.4	16,855	14,209		8,120	7,425	47,691	12,352	3,788	12,342	25,926				

Summary of geographical parameters.

Location:	Northern area of resevoir, east side.
Length:	5.35 km
Barriers:	1.0 m high culvert at highway, ~ 500 m upstream + numerous small chutes and falls upstream.
No. of Reaches:	3+
No. of Reaches Sampled:	2
Total Length 0f stream below barriers:	~ 0.5 km
Major Tributaries:	none
Water Source:	Other than snowmelt, unknown.
Logging:	Along right of way for power transmission line, and possibly in upper watershed.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 51: Electroshocking results (a), as well as fish size and age data (b) for Pitt Creek.

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	1	4	1	RBT	f	0.015	0.004	0.018	n/a	n/a	n/a
mainstem	1	1	0	BT	p	0.004	0.000	0.004	n/a	n/a	n/a
mainstem	1	7	0	CC	a	0.025	0.000	0.025	n/a	n/a	n/a
total, reach 1:		12	1	Mean		0.015	0.001	0.016	n/a	n/a	n/a
mainstem	2	1	0	BT	j	n/a	n/a	n/a	n/a	n/a	n/a
mainstem	2	5	0	RBT	p/f	n/a	n/a	n/a	n/a	n/a	n/a
total, reach 2:		6	0	Mean		n/a	n/a	n/a	n/a	n/a	n/a
mainstem	3	1	0	RBT	p	0.014	0.000	0.014	n/a	n/a	n/a
Total 1+2:		17	11	Mean		0.009	>.001	0.010	n/a	n/a	n/a

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yr)	N
1	BT	88	-	7.93	-	1.16	1	1+	1
2	BT	97	-	9.10	-	1.00	1	1+	1
1	RBT	41	41 - 42	0.74	0.36 - 0.81	1.05	4	n/a	0
2	RBT	131.8	39 - 209	44.73	0.83 - 111.00	1.37	5	2 - 4+	4
3	RBT	158	-	53.50	-	1.36	1	3+	1
1	CC								
1 + 2	BT	93	88 - 97	1.08	7.93 - 9.10	1.080	2	1+	2
1+2+3	RBT	98.2	39 - 209	28.01	0.65 - 111.0	1.24	10	2 - 4+	5

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.

Life stage: f = fry, p = par, j = juvenile, a = adult.

n/a = not available



Photo 76 LOD and large substrate provide suitable for cover resident rainbow trout rearing in reach 2 of Pitt Creek, but numerous barriers and a steep gradient restrict upstream movement of lake resident spawners. The dip net in the centre of the photo is 1.8 m long.

4.5.22 Seymour Creek

Seymour Creek is a clear water, lake-fed stream which flows into the west side of Revelstoke Lake. The Creek gains elevation rapidly and continues to climb as it enters a steep gorge which has a small falls at its entrance, 700 m upstream of the creek mouth (Photo 78). Gradient in the first 700 m of the creek ranges from 5 to 12%, and overall gradient of the stream is steep except for short sections by its lake sources (Fig. 40). Bedrock, boulders and large cobble dominate the substrate, although gravel has collected behind barriers. Cover, principally deep pools below barriers as well as that provided by boulders and large substrate, ranges from 25 to 35% of the wetted area at the two sample sites surveyed (Table 52).

Two submerged culverts, one of which is partially blocked by debris, under a logging road crossing the mouth of Seymour Creek may form a partial barrier to fish migration (Photo 78). A small pond, similar to that seen at Nicholls Creek has formed behind the culverts and probably provides good rearing habitat for trout. A series of small and large barriers ranging from 1.4 m to 5.0 m high are present starting 255 m upstream of the creek mouth and continue to 700 m upstream of the mouth (Photo 79). The smaller of these barriers are probably negotiable to bull trout and rainbow trout, however, a 15 m long by 5m high chute/falls 500 m upstream is probably impassable to fish. It is likely more barriers exist in the canyon within reach 2, but this area was not explored since it was inaccessible to hiking.

Fish

Rainbow trout were caught downstream and upstream of barriers in Seymour Creek, however, Pettipiece Lake, one of two lakes which feds Seymour Creek, has been stocked repeatedly by the Ministry of Environment (pers. comm. R. Lindsay) therefore the trout captured are probably resident fish (Table 53).

Logging and other Activities

Logging in the Seymour Creek area is presently limited to the foreshore of Revelstoke Lake (not in the watershed) and in the upland areas of the central portion of the watershed. The Seymour Creek watershed has not been identified for future logging activities in any of the 5 year plans submitted to the BCFS. Road

access to upper areas of the watershed can be achieved from a power line maintenance road which crosses Seymour Creek near Paramater Lake.

Enhancement Opportunities.

Numerous barriers, and poor quality habitat (i.e. steep gradient and canyon) above these barriers makes Seymour Creek a poor candidate for possible enhancement of adfluvial fish. Furthermore, attempts to increase habitat for lake resident fish would conflict with the existing strategy of establishing a resident stock of rainbow trout.

Figure 40: The stream profile for Seymour Creek (not to scale)

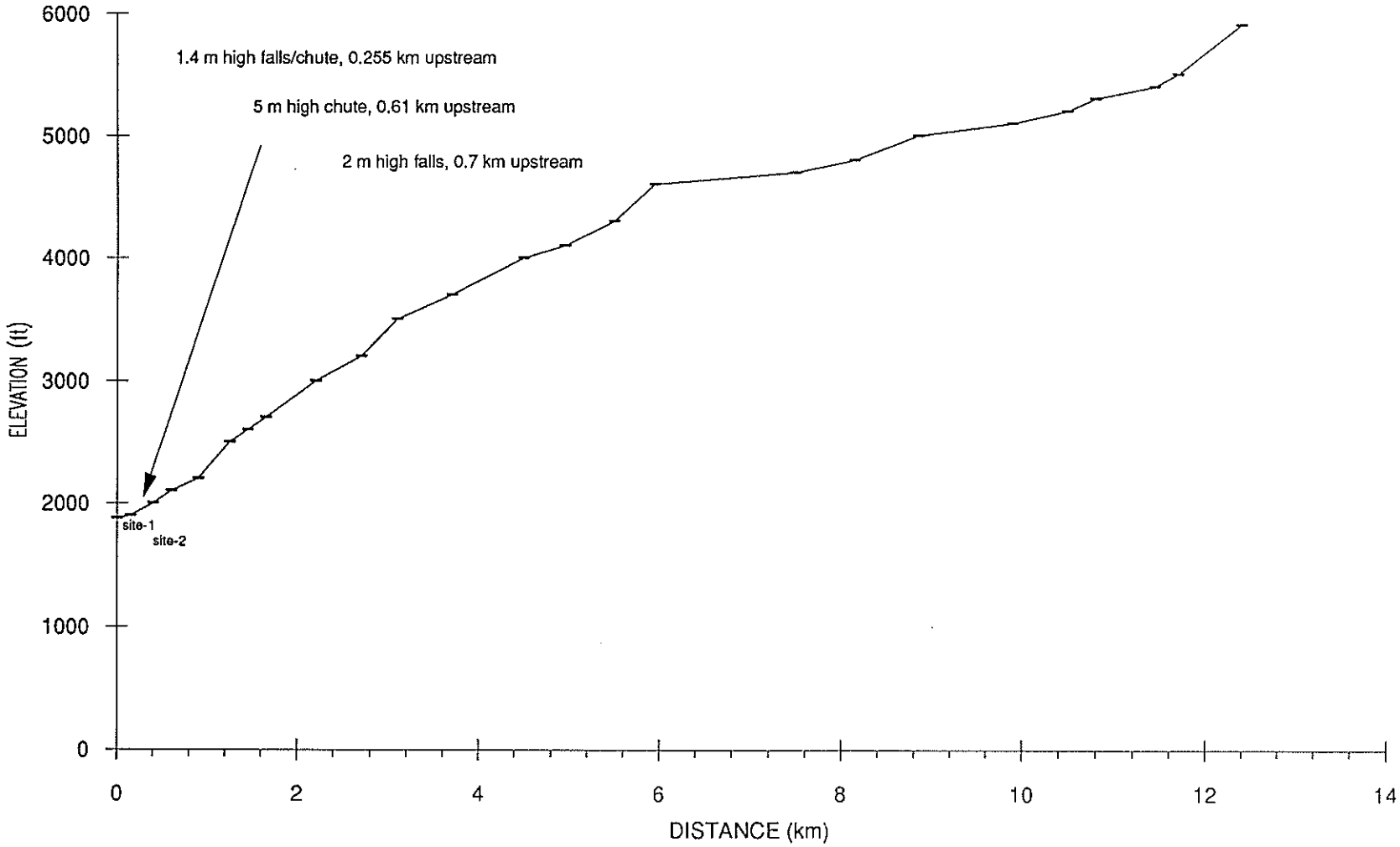


Table 52: Summary of biophysical habitat parameters for Seymour Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Length (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	1	12.0	0.3	1,800	450	dp/b	90	720	540	360	180	90	450	L	150	CO	0 - 2
mainstem	2	2	5.0	0.5	2,500	875	dp/b/l	375	1,000	500	625	125	125	750	L	150	EN	0 - 2
Total 1+2:				0.8	4,300	1,325		465	1,720	1,040	985	305	215	1,200	0	150		

Summary of geographical parameters.

Location:	North central area of resevoir, west side.
Length:	12.4 km
Barriers:	Buried culvert at mouth, and falls 1.4 m high and chutes 5-7 m high within 700 m of the mouth.
No. of Reaches:	6
No. of Reaches Sampled:	2
Total Length of Stream below barriers:	~ 0.7 km
Major Tributaries:	none
Water Source:	2 lakes (Parmater and Pettipiece Lakes).
Resource use:	Logging along the upper slopes of the mid section of the watershed. Powerline transmission route and access road crossed the upper reaches of the creek.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

Table 53: Electroshocking results (a), as well as fish size and age data (b) for Seymour Creek.

(a) Electroshocking results,

Site Description	Reach No.	No. Caught	No. Esc or Obs.	Species	Life Stage	CPUE (Fish/second) Caught	CPUE (Fish/second) Esc. or Obs.	CPUE (Fish/second) Total	DENSITY (Fish/m^2) Caught	DENSITY (Fish/m^2) Esc. or Obs.	DENSITY (Fish/m^2) Total
mainstem	1	2	3	rbt	p	0.009	0.014	0.023	0.007	0.011	0.019
mainstem	2	1	1	rbt	p	n/a	n/a	n/a	0.004	0.004	0.008
Total 1+3:		3	4	Mean		0.009	0.014	0.023	0.006	0.008	0.013

(b) Mean lengths, weights and conditions factors.

Reach No.	Species	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)	Conditon Factor (k)	N	Age Range (yr)	N
1 + 2	RBT	144	145 - 186	46.21	32.34 - 81.22	1.08	3	1-2+	2

Species: CC=cottid, CT=cutthroat trout, RBT=rainbow trout, BT=bull trout, WF= whitefish, LKC=lake chubb, u/s=unidentified salmonid.
Life stage: f = fry, p = par, j = juvenile, a = adult.
n/a = not available

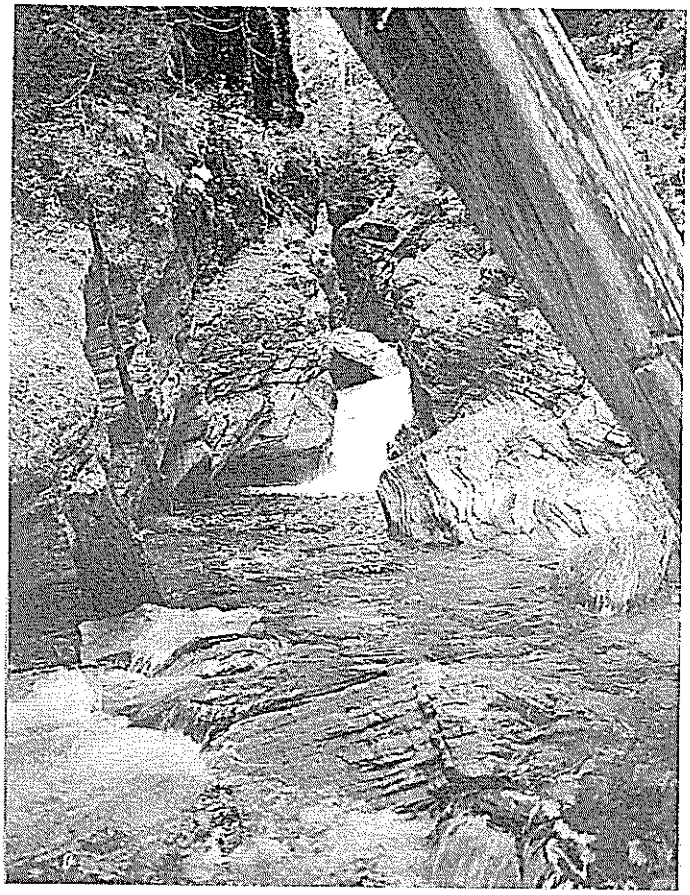


Photo 77 A 2 m falls marks the start of a steep, narrow gorge located in reach 2 of Seymour Creek. It is unlikely fish can migrate past this gorge.

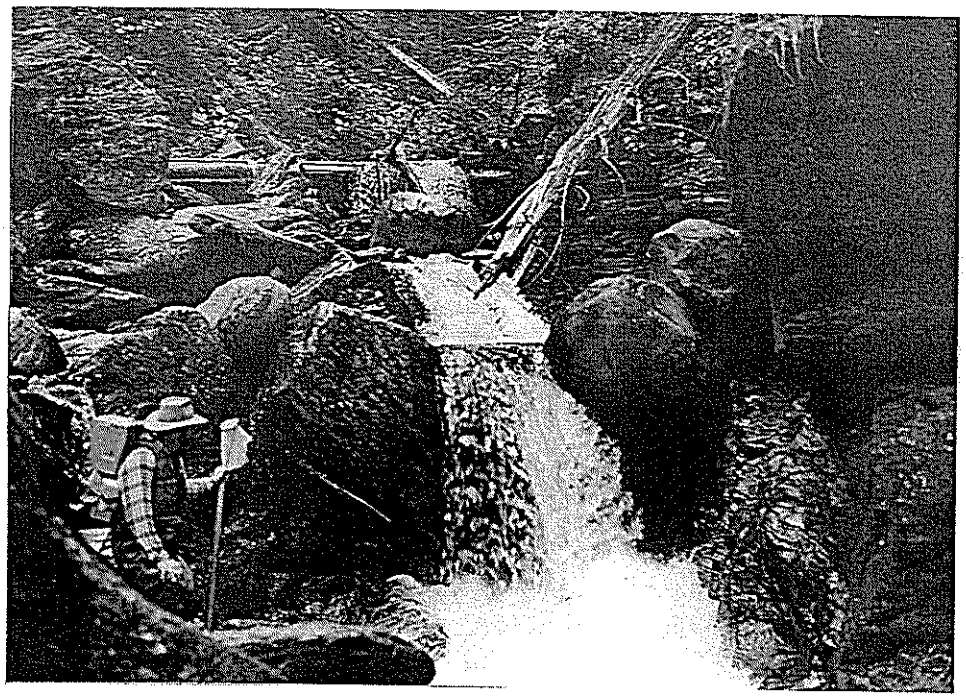


Photo 78 Numerous barriers in reach 1 of Seymour Creek prevent lake resident fish from migrating upstream.

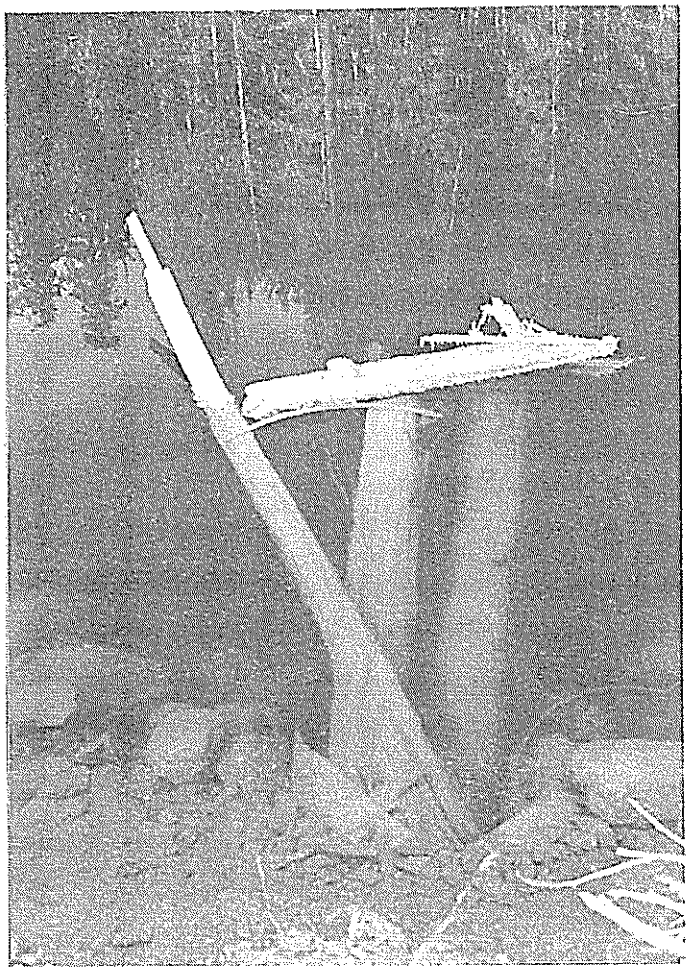
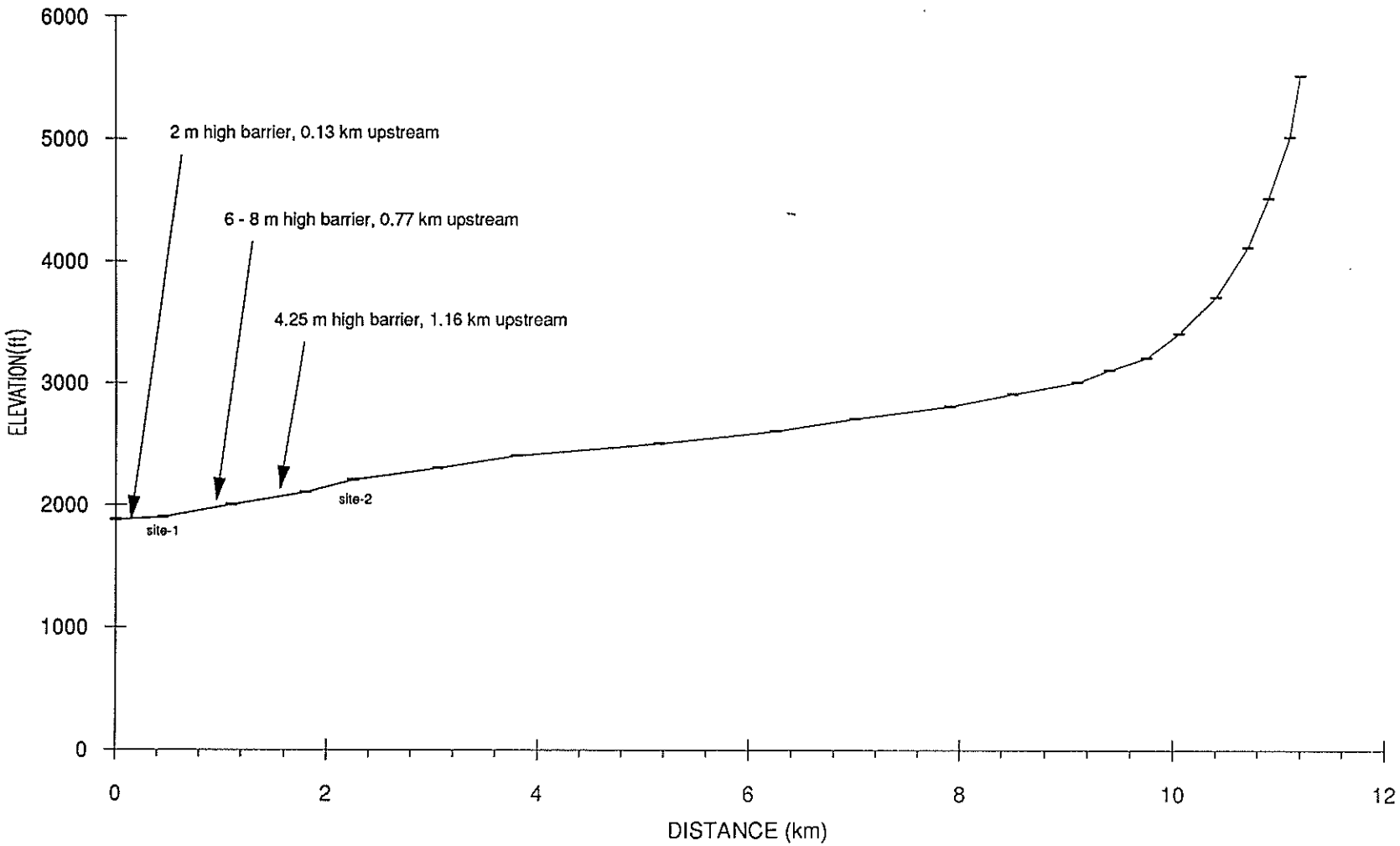


Photo 79 Partially plugged culverts at the mouth of Seymour Creek may limit access of lake resident fish into this stream. Similar to Nicholls Creek, a small pond has formed between the submerged culverts and the mouth of Seymour Creek.

Figure 41: The stream profile for Bourne Creek (not to scale).



4.5.23 Bourne Creek

Bourne Creek has 3 impassable barriers within the first 1.2 km from its mouth (Fig 42). A 2 m falls 130 m upstream from the mouth of Bourne Creek, a 6 to 8 m water falls 770 m upstream and, a 4.25 m high falls 1160 m upstream, prevent adfluvial fish species from accessing the upper reaches of this stream (Photo 80). A culvert was originally used to direct stream flow under a logging road which crosses the mouth of Bourne Creek, but repeated washouts required the culvert to be replaced with a log bridge.

Water clarity was high in Bourne Creek at the time of surveys, although this stream is glacier fed. A large percentage of diverse cover, supplemented with a high percentage of uncompacted gravel in the bed material, uniform channel flows and substantial side channels, provides areas upstream of barriers with excellent habitat for rearing and spawning salmonids (photo 81).

Fish

Electrofishing two sites, one between the first and second falls (reach 2) and the other upstream of the third falls (reach 3), resulted in no fish captured or observed.

Logging

There was no observed logging activities within the Bourne Creek watershed other than some cut blocks located near the mouth of the stream. Five year plans submitted to the BCFS indicate there are no planned logging activities for Bourne Creek.

Enhancement Opportunities

Bourne Creek's relatively short drainage limits the amount of habitat available for fish to use, although the habitat examined in the two reaches sampled was excellent. Out-planting bull trout or rainbow trout into Bourne Creek could be conducted without concern of impacts upon resident species, to establish either a resident or

adfluvial fish stocks, however, such a program would likely not warrant the incurred expense.

Three observed barriers on Bourne Creek would have to be removed to make upstream habitat accessible to lake resident species. Unfortunately, the removal of these barriers would probably be a costly undertaking since none are easily accessed and over 10 m of vertical height would have to be circumvented.

Creating a resident stock in Bourne Creek would require further study since it is unknown whether a resident stock could be supported by this stream. Furthermore, recreational fishing would be limited by the lack of access into Bourne Creek, likely deterring most fisherman from taking advantage of a resident stock in Bourne Creek.

Table 54: Summary of biophysical habitat parameters for Bourne Creek.

Site Name	Site No.	Reach No.	Mean Grad. (%)	Est. Reach Lngth (km)	Est. Wetted Area (m^2)	COVER Est. total Cover Area (m^2)	Est. Dominant Cover (m^2)	Est. LOD Area (m^2)	STREAM CHARACTER Est. Pool Area (m^2)	Est. Riffle Area (m^2)	Est. Run Area (m^2)	Est. Other Area (m^2)	SUBSTRATE Est. Fines Area (m^2)	Est. Gravel Area (m^2)	Cmpct	VALLEY CHAR. Turb. (cm)	Confine	Valley to Ch. Ratio
mainstem	1	2	2.5	0.6	6,420	1,605	b/dp/ov	321	1,284	2,247	2,247	642	642	2,247	L	70	OC	2 - 5
mainstem	2	3	0.8	2.8	32,200	8,050	l/ov	3,220	8,050	12,880	11,270	0	4,830	16,100	L	70	UC	5 - 10
Total				3.4	38,620	9,655		3,541	9,334	15,127	13,517	642	5,472	18,347		70		

Summary of geographical parameters.

Location:	Southern area of resevoir, west side.
Length:	11
Barriers:	2.0 m falls 130 m upstream, also 6-8 m falls 770 m upstream and 4.25 m falls/chute at km 1.2
No. of Reaches:	6
No. of Reaches Sampled:	2
Total Length of Sampled Reaches:	3.4 km
Major Tributaries:	none
Water Source:	Primarily glacial, some small lakes.
Human Activities:	Limited to some logging near the creek mouth.

Cover: iv = instream vegetation, ov = overhead vegetation, dp = deep pool, b = boulder, cb = cutbank, l = loose organic debris.
Confinement: EN = entrenched, CO = confined, FC = frequently confined, OC = occassionally confined, UC = unconfined, N/A = not applicable.

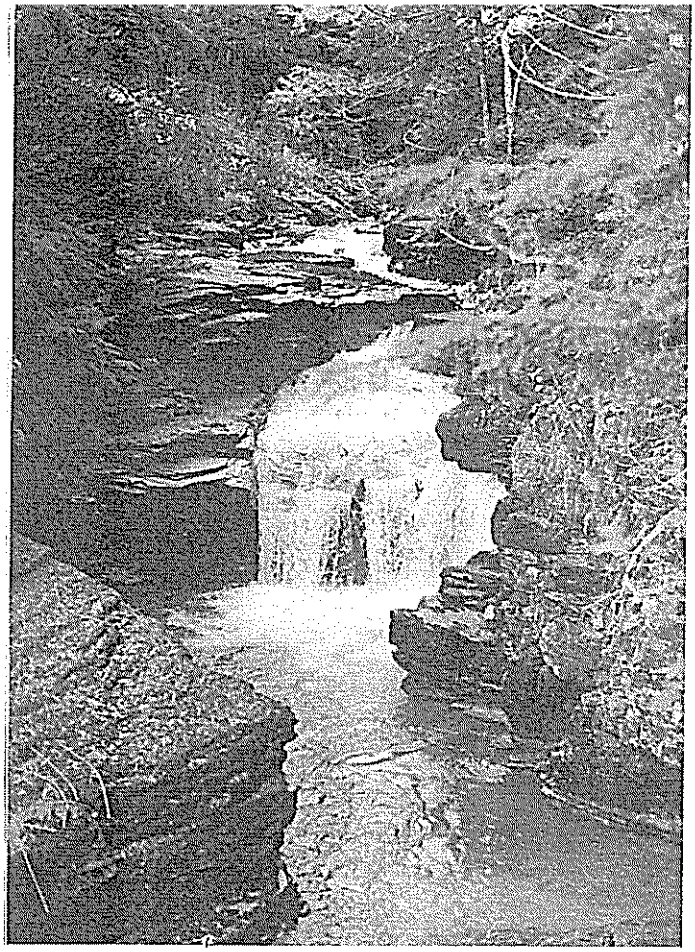


Photo 80 This 5 m falls at km 1.16 is the last of three barriers on Bourne Creek which start at km 0.2.

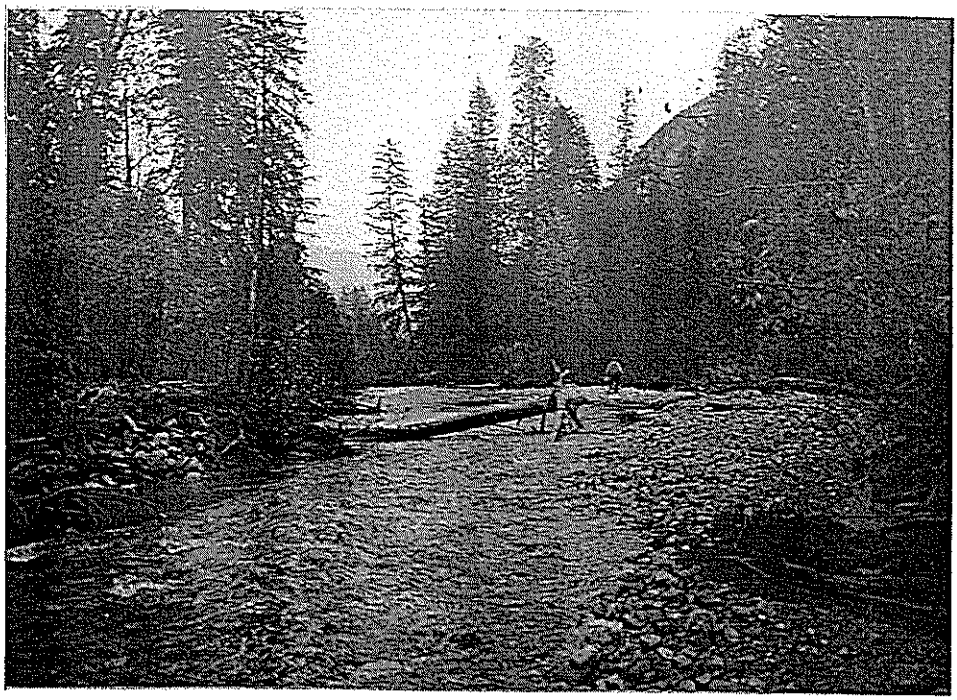


Photo 81 Excellent habitat is located upstream of barriers, in reach 3 of Bourne Creek.

5.0 DISCUSSION

5.1 Historical Utilization of Tributary Habitat by Sports Fish Species

Pre-impoundment studies on selected streams within Revelstoke Lake provide some baseline biological data concerning adult escapements into Seymour, Park, Mars, Pat, and Horne Creeks but little detail respecting areas utilized by spawning adults and rearing juvenile fish within these tributaries (Lindsay 1977, and Martin 1976). These studies indicated that spawning adult fish utilized habitat below migrational barriers, habitat which has since been inundated by water due to the creation of Lake Revelstoke.

Numerous authors (Mason 1985, Lindsay 1977, and Martin 1976) have indicated streams entering Revelstoke Lake prior to impoundment were utilized by Arrow Lake Fish. Lindsay (1977) observed "trophy" rainbow trout at the base of Mica Dam, commonly caught by recreational fisherman in Arrow Lake. Lindsay (1977) suggested more than one stock of rainbow trout were utilizing Columbia River tributaries, such as Arrow Lake "trophy stocks" and Columbia River mainstem stocks. Tagging studies of adult bull trout captured while migrating into La Forme and Park Creeks indicates these streams were utilized by non-resident bull trout which migrated from Arrow Lake to spawn (Martin, 1977). Hoskins Creek was also identified to be utilized by migrating bull trout, although not as extensively as La Forme Creek. The origins of bull trout spawners caught in Hoskins Creek were not determined, however it is reasonable to assume some of these fish also migrated from the Arrow Lakes.

Many of the remaining tributaries now have only short lengths of stream available to rearing and spawning fish before migrational barriers are encountered. Of the streams surveyed this year which likely contain adfluvial stocks of bull trout, only La Forme, Hoskins and Mars Creeks, had preimpoundment enumeration studies conducted on them (Mason 1976, Lindsay 1977). The later two streams lost most of their accessible spawning habitat when Lake Revelstoke was created, whereas La Forme Creek has become accessible to lake resident fish. Data concerning bull trout migrating into these 3 streams is incomplete due the difficulty experienced

when trying to position and maintain adult enumeration fences for an entire spawning season.

Attempts to enumerate spawning rainbow trout entering Lake Revelstoke's tributaries were impossible because of the logistical problems in erecting and maintaining fences during spring freshet, hence escapement data for this species is more sparse than for bull trout.

Despite the lack of good comparative data, existing data, combined with information gathered during this year's stream surveys, suggests bull and rainbow trout migrating from both the Arrow Lake (pelagic) and the Columbia River (riverine) utilized tributaries to the pre-impounded Columbia River to spawn. Consequently, their progeny likely utilized these streams to rear in as well. The exact proportion to which riverine stocks of bull and rainbow trout utilized these tributaries compared to Arrow Lake stocks of the same species is unknown, however, 5 of 200 tags placed on bull trout during the 1976 program were recovered in Arrow Lake (Lindsay 1977). These fish migrated between 96 and 158 km from the streams at which they were tagged. Considering the variables which may effect recovery of tags (mortality, tag loss, fishing effort, etc.), it is not unreasonable to assume that bull trout migrating from Arrow Lake accounted for a substantial proportion of those fish enumerated in tributaries upstream of Revelstoke.

Riverine fish stocks (such as rainbow trout and whitefish) were probably severely impacted by the loss of Columbia mainstem habitat when flooding occurred and may no longer be self sustaining. This coincides with the findings of Fleming and Smith, (1987) who indicate a decline in whitefish and rainbow trout populations within Lake Revelstoke whereas bull trout and coarse fish populations appear to be on the increase. The apparent increasing trend observed for bull trout may reflect this species adaptability to new habitat. Mason (1985) indicates some bull trout unable to migrate upstream due to the presence of Revelstoke Dam sought alternative spawning habitat, such as in the Jordan and Illecillewaet Rivers. This is supported by literature reviewed by Ford et. al. (1992) which suggests bull trout sometimes change spawning grounds. McPhail and Murray (1979) suggest large bull trout seek out larger streams to spawn in. It is unknown if bull and rainbow trout densities observed in tributaries surveyed this year are similar to what may have existed prior to the creation of Lake Revelstoke. Most of the habitat sampled in

previous reports has since been flooded, whereas La Forme Creek became accessible to adfluvial fish.

Many of the streams surveyed prior to impoundment of the Columbia River upstream of Revelstoke were utilized by kokanee, however, only Carnes and Downie Creeks were observed to be utilized by spawning kokanee this year, albeit few in number. Creel and gill net surveys have show kokanee are almost absent in Lake Revelstoke (Fleming and Smith 1991). Recent increases in the kokanee numbers, such as those seen accumulating at the base of Mica Dam, are probably a result of entrainment out of the Kinbasket Reservoir (Hirst 1991). Consequently, approximately 6000 kokanee observed in Downie Creek in 1989, the same year kokanee accumulated below Mica Dam, were considered to be Kinbasket fish due to the morphological similarities of fish captured at each location (pers. comm. R. A. Lindsay). Periodic increases in kokanee populations seen in Lake Revelstoke are likely attributable to conditions occurring in the Kinbasket Reservoir.

5.2 Factors Limiting Production in Revelstoke Tributaries

Hirst (1991) indicates that run of the river type reservoirs have low to moderate sports fish potential, typically due to changes in water quality because of rapid flushing of nutrients and water. Hirst also points out that other factors such as limited tributary habitat may be an important factor that could effect productivity in run of the river type reservoirs.

Given the scope of this year's project, it is difficult to determine specific factors which are limiting fish production within tributaries to Lake Revelstoke, but, Lake Revelstoke may be unique amongst run of the river type reservoirs since substantial habitat is available to adfluvial fish stocks. Accessible habitat is not all of prime quality, but the 7 streams which do not have obstructions to fish migration represent an estimated 2,100,000 m^2 of wetted area or approximately 125 km of stream length. Not all the tributaries entering some of the larger streams were explored, hence it is likely the above figures are an underestimate of available habitat.

It is unknown if these 7 streams have reached their carrying capacity, however, the highest observed mean fish density was 4.6 fish per 100 m^2 for Mars Creek and densities of between 1 and 3 fish per 100 m^2 were not uncommon.

Such low densities can be attributed to a number of factors, but it is not unreasonable to assume that fish stocks utilizing tributaries entering Lake Revelstoke are still rebounding from reduced escapement due to the impasse created by Lake Revelstoke. This reduced escapement into tributaries was likely further compounded by severe flooding which occurred during July of 1983, the same year flooding of the Columbia River behind Revelstoke Dam commenced.

In 1983, instantaneous measurements at Water Survey of Canada gauging stations used to predict stream discharges in this report, were approximately twice as high as the mean for these systems. Predicted return rates for the instantaneous measurements taken at the Goldstream and Illecillewaet Rivers were approximately 50 years and 20 years for Downie Creek (Appendix 3). Floods of this magnitude probably contributed to reductions in the standing stock of rearing juvenile fish within Lake Revelstoke tributaries. Non volitional movement of juvenile fish out of rearing streams and changes in stream morphology which could affect the quantity and quality of rearing and spawning habitat are commonly associated with flood events. The effects of such floods might be carried through to following years, and spawning and rearing habitat may take some time to recover to pre-flood conditions.

Low levels of primary production due to limitations in available nutrients will effect food supply for rearing salmonids, restricting a stream's carrying capacity, and thereby limiting fish production (Slaney et. al. 1986). Glacial input during the growing season, common to many of the streams entering Lake Revelstoke, may contribute additional nutrients but, it also effects primary production since turbid water will limit the penetration of ultraviolet light into the water column and cold water temperatures will reduce the rate of production. Nutrient availability may ultimately determine the productivity of Lake Revelstoke tributaries, hence, this parameter deserves further study.

Discharge estimates indicate maximum flows occur from May to August, with the peak discharge occurring in June. High water events associated with snowmelt, glacial input, and heavy rainfall are amplified since there are few lakes to moderate

run-off in most of the streams entering Lake Revelstoke. Larger systems such as Downie Creek, Bigmouth Creek and the Goldstream River have broad valleys with numerous beaver dams and associated off channel habitat. Such habitat affords good refuge for fish during flood events, but many of the smaller streams are more confined and have little (if any) side channel habitat.

Sedimentation due to glacial input can increase mortality of incubating eggs. Given the incubation period for rainbow trout eggs, sedimentation may impact this species more severely than for kokanee and bull trout, which typically spawn in the fall when glacial input has become reduced. Few of the tributaries entering Lake Revelstoke are exempt from glacial input, and fewer still have lakes to buffer the effects of this input. It follows that few of the streams entering Lake Revelstoke provide ideal egg incubation conditions.

5.3 Enhancement Opportunities

The change in species composition within the Columbia River mainstem, now Lake Revelstoke, is supported by tributary surveys which indicate very few rearing whitefish or rainbow trout within streams accessible to lake resident fish. Rainbow trout were also more frequently encountered upstream of migrational barriers than below. Consequently, habitat accessible to adfluvial rainbow trout may be underutilized. Since recruitment of adults into Lake Revelstoke has been reduced by the presence of the Revelstoke Dam, the infrequency of this species' occurrence within accessible tributaries may reflect the inability of riverine stocks of rainbow to adapt to a lake environment. For this reason, enhancement opportuniites should focus upon those species which can exploit lake habitat.

Increase kokanee production within the reservoir is not a logical choice since the ability of the Lake Revelstoke to support a viable population of kokanee is questionable, considering the reservoir's ultra-oligotrophic nature and the rapid flush rate of water (Smith, 1990). Furthermore, repeated soundings for kokanee populations within the reservoir have not confirmed the presence of large juvenile or sub adult kokanee stocks (pers. comm. R. A. Lindsay). As such, creating spawning habitat for kokanee should not be considered until it is ascertained whether kokanee populations can be increased in Lake Revelstoke. The cost of creating additional habitat through side channel development or spawning channel

creation can not be justified without an adequate kokanee population to utilize such enhancement measures. A less expensive alternative to creating habitat is small barrier removal. Escapement of adult Kokanee into tributaries of Lake Revelstoke should be studied before creating artificial spawning habitat is considered.

A practical approach to increasing the recreational sports fishing potential in Lake Revelstoke Lake is to consider increasing recruitment of lake oriented species whose reproductive strategies effectively utilize available tributary habitat. These would include bull trout and pelagic oriented rainbow trout. Projects to complete this task should be multifaceted and address limiting criteria for each tributary in question. Enhancement should not be implemented until these criteria are determined.

Outplanting yearling bull and rainbow trout into streams (satelliting) entering Revelstoke Lake may be one means of increasing standing stocks, but barrier removal, rehabilitating habitat and management of the existing resource should complement such a hatchery program.

5.3.1 Hatchery Raised Fish and Outplanting

Tributaries to Lake Revelstoke which have been identified as being underutilized (following completion of further studies) would benefit from a satelliting program. Hatcheries are an established technique for increasing recruitment of salmonids into natal streams and have been utilized as a means of compensatory replacement of fish species in other reservoirs (Hirst 1991).

The Ministry of Environment has initiated a net pen program operated by Don Monk to raise Pennask Lake rainbow trout, a pelagic stock, for release into the reservoir. The success of releasing juvenile fish directly into Lake Revelstoke is unknown, however, juvenile fish are likely easy prey for larger lake dwelling predators such as squawfish, rainbow trout and bull trout, since the reservoir contains little littoral habitat to provide refuge for rearing juvenile trout. Ototlith analysis of of bull trout adults sampled from the Arrow lakes indicated that 15% of bull trout migrated directly into the lakes as 0^+ fry, yet the vast majority of bull trout fry migrating from Mackenzie Creek (tributary to Upper Arrow Lake) did so within their first year (McPhail and Murray, 1979. This indicated bull trout fry

migrating directly into the lake experienced higher mortality than experinced by 1^+ or 2^+ juveniles.

Satelliting hatchery raised yearling bull and rainbow trout into individual tributaries which either have a proven ability to support rearing juvenile populations, but are underutilized, or into tributaries which have good habitat but no existing fish stocks is likely more suited to increasing lake resident populations. Such fish may not only have a better chance at increased survival by utilizing tributary habitat for the first 2 to 4 years of their lives, but also may facilitate the return of adult fish to natal streams when spawning. Outplanting could supplement rearing populations in tributaries accessible to lake resident fish. This technique may also be emplyed to enhance stream resident stocks in those tributaries with good recreational fisheries potential. Such streams would include Nagel Creek (if the barrier is removed), as well as tributaries to larger streams such as the Goldstream River, Downie Creek, and Bigmouth Creek.

The proposal of increasing recruitment through hatchery production of sports fish should not be perceived as the long term means of increasing overall fish production in Revelstoke Lake. A recognized problem in hatchery fish populations is inbreeding, a concern which may be decreasing the genetic diversity of wild fish stocks and ultimately reducing the ability of fish to adapt to future environmental change (Simon, 1991). This concern counters one of the targets outlined by Lindsay (1991) in developing an enhancement plan for the Columbia River, specifically, maintaining wild fish stocks.

To maintain the genetic integrity of wild fish utilizing tributaries entering Lake Revelstoke, brood stock should be collected from streams which support healthy rainbow and bull trout populations. Tributaries entering Lake Revelstoke such as Mars, Nicholls, Kirbyville, Ruddock and La Forme Creeks may be able to supply necessary brood stock to initiate a hatchery program for adfluvial bull trout. Likewise, McCulloch, Brewster and Old Camp Creeks may be able to provide sufficient brood stock to increase resident cutthroat populations in the Goldstream River. Such a satelliting program could be of limited duration, with the numbers of fish outplanted slowly reduced each consecutive year, should the objective of increased rearing juveniles and increased adult spawner return be met. In this fashion, enhanced streams could revert to wild stocks of fish following stocking

programs. Such a program is presently being utilized by MOE at the Keogh River near Port Alberni, B.C. (Galesloot, 1990)

Existing provincial hatcheries could provide the necessary yearling trout if B. C. Hydro were to provide supplemental funding to pay for expansion and additional maintenance of facilities, the collection of broodstock and the care of rearing fish (H. Andrusak, Mang. Fish Culture Section, MOE pers comm. 1991.)

Hill Creek hatchery, an enhancement facility sponsored by B.C. Hydro, is producing approximately 100,000 bull trout and 80,000 rainbow trout annually for release into the Arrow Lakes (pers. comm R. Lindsay 1991). Hill Creek facilities would have to be expanded to accommodate outplanting of rainbow and bull trout into Revelstoke Lake tributaries.

Streamside incubation boxes may also be utilized to increase stocks within targeted streams, but the number of such incubation facilities and the requirement for constant monitoring makes a centralized hatchery rearing program more efficient.

Stocking kokanee into Lake Revelstoke is not recommend at this time. Kokanee eggs are in short supply, between 3 to 5 million eggs are requested for incubation programs each year, but the Fish Culture Section collects an average of 2 million eggs (H. Andrusak, Mang. Fish Culture Section, MOE pers comm. 1991). Kokanee brood stock may be collected from the base of Revelstoke Dam, as a B.C. Hydro initiative, during years kokanee accumulate at the dam, but a requirement of disease free eggs from the Fish Culture Section would prevent incubation of these eggs in provincial hatchery facilities. Incubation boxes or instream transplants of eggs collected from the dam site could be used to establish stocks in under utilized streams or to supplement existing runs of Kokanee in Carnes or Downie Creeks. Funds necessary for the collection of broodstock and operation of incubation boxes may be better spent providing alternate spawning habitat such as gravel placement near the base of the Mica dam or by removing the falls from Nagel Creek. Kokanee will readily use alternative habitat if made available, and will move considerable distances downstream to find this habitat if necessary (pers. comm. R. Lindsay 1991). Finally, the ability for Lake Revelstoke to support a viable kokanee stock should be addressed prior to initiating an enhancement program for this species.

5.3.2 Barrier Removal

Barrier removal is a valid method of increasing fish habitat in streams tributary to Lake Revelstoke only if the costs do not outweigh the biological advantages gained by carrying out such work. Conditions will obviously vary from stream to stream, but it is unlikely that falls with drops greater than 2.5 m can be removed merely by blasting, and fishways should be considered as alternatives when falls exceed 2.5 m in height (Jim Wild. DFO Eng. pers. comm. 1991).

Biologically, it is reasonable to seek means of rehabilitating or, making available natural habitat before creating artificial habitat. For this reason, removing the barriers at Nagel Creek, Downie Creek, and to a lesser extent, Hoskins and Park Creeks should be considered as valid enhancement opportunities. Nagel and Downie Creek have substantial amounts of low elevation, and comparatively good, mainstem habitat upstream of barriers. A barrier removal program would compliment an outplanting program since it would make more habitat available in enhanced streams, which could in turn, be exploited by adult fish returning to natal streams.

5.3.3 Rehabilitation and Creation of Habitat

Tributaries to larger streams such as Bigmouth and Downie Creeks were found to provide important spawning and rearing habitat for bull and rainbow trout, therefore, degradation of these small tributaries has probably impacted upon both lake and stream resident fish. Rehabilitating these small tributaries to Bigmouth and Downie Creeks could increase production of both lake resident and stream resident sports fish, therefore, these small stream represent excellent enhancement opportunities. Revitalization of riparian habitat (revegetation) combined with re-establishment of native fish species within these small tributaries (outplanting) should be considered.

Healthy riparian habitat benefits salmonids by improving water quality, reducing water temperatures, increasing invertebrate food sources and providing valuable overhead cover. Vigorous riparian vegetation reduces bank erosion, thereby decreasing sedimentation, and also retains water, acting as an aquifer to maintaining water levels in small streams during dry periods and decreasing run-off during high

flow events (Triton Environmental Consultants Ltd., 1991). Revegetative bank stabilization is particularly effective for small streams, such as tributaries entering Downie and Bigmouth Creeks and the Goldstream River. Long term advantages of healthy riparian habitat include decreased sedimentation, stabilize channel form (thereby maintaining rearing and spawning habitat) and even increases in fish biomass/m^2.

Habitat complexes, side channel development or flow control may be effective in streams which support rearing populations of bull and/or rainbow trout. Construction of such facilities would require further studies, but this years works suggests high discharge events combined with alteration and degradation of existing habitat has impacted Brewster and McCulloch Creeks, tributaries to the Goldstream River. Stabilizing spawning habitat by stabilizing flows in these streams may benefit incubating cutthroat trout eggs and increase survival. Reach 2 and Reach 1 of Hoskins Creek of La Forme Creek may benefit from complexing directed at increasing cover and retaining gravel.

Finally, there is potential to develop lagoons and creek mouths to provide littoral habitat for both lake rearing salmonids and transitional habitat for sub-adults migrating from creeks into Lake Revelstoke. Creeks which offer potential for developing creek mouths or lagoon habitat include Kirbyville, Bigmouth, and possibly, Downie Creek.

5.3.4 Stream fertilization

Fertilization is becoming more prevalent as a method to increase primary productivity in streams and has been experimented with in numerous watersheds, including the Keogh, Nechako, and Salmon Rivers. Slaney et. al. (1986) observed a 77% increase in growth rates of steelhead salmon (*Oncorhynchus mykiss*) in the Keogh River (B.C.) following fertilization. He also noted that stream residence time for steelhead smolts was reduced, suggesting less competition for resources between age classes. Fertilization may be considered after further studies are conducted detailing water conditions and factors limiting productivity within tributaries to Lake Revelstoke.

5.3.5 Management of Existing Resources

Before enhancement projects are planned or applied to streams flowing into Revelstoke Lake, efforts should be made to ensure existing habitat is preserved. This is particularly true of streams that are accessible to fish or streams which present enhancement opportunities.

Minimizing damage to stream habitat from future logging is necessary to maintain available habitat and reduce impacts to sports fish species. Scrip, Ruddock, La forme, Carnes, and the upper reaches of Bigmouth and Downie Creeks have had minimal, if any, logging activity within their drainages. All these streams provide good enhancement opportunities and all are targeted in local area logging companies 5 year development plans.

Of particular concern is the condition of logging roads which access many of the tributaries entering Lake Revelstoke. Many of these tributaries are similar to each other since they have steep canyons or gorges near their outlets. Logging roads constructed into watersheds normally follow ridges along these canyons. The practice of side casting debris and slash during road construction was observed along logging roads following Lake Revelstoke tributaries. In many instances, such a procedure invariable resulted in to debris input into the streams adjacent to such roads.

Poorly placed, or missing culverts are also of concern. Culverts can act as migrational barriers, and also result in poor drainage along roads. Some roads, particularly those accessing Pat, Kirbyville, Sorcerer, and Scrip Creeks are experiencing erosion which is resulting in sediment and debris input into these streams. In some cases, particularly for Pat and Scrip Creeks, complete bank failure may occur. The consequences of such bank failures can only be hypothesized, however, since canyons are common near the mouth of Revelstoke Lake tributaries, it is not unreasonable to assume blockages to fish passage may result following mass wasting events.

Another concern related to logging practices occurring within drainages entering Lake Revelstoke is the use of cats and/or skidders to complete logging on steep slopes. In a high precipitation region such as the Revelstoke area, the resultant

drainage routes created by cat tracks facilitates sediment input into streams during run-off.

Other management concerns reflect sports fishing practices by unscrupulous individuals in the Revelstoke area. During a meeting with members of Revelstoke Rod and Gun Club members, concern was raised regarding the capture of gravid bull trout from creek mouths. While the timing of these particular captures did not coincide with bull trout spawning, the point is well taken.

Efforts to increase lake resident fish populations will only be successful if spawning adults are able to reproduce. Bull trout spawners, observed migrating into small streams such as Mars and Mica Creeks during low flow conditions, are particularly vulnerable to angling. Seasonal closures of creeks and creek mouths should be considered as a means of ensuring spawner escapement into streams. It should be noted that there is presently no permanently positioned Conservation Officers in Revelstoke, the nearest being located in Nelson. Without proper enforcement, closures will likely not be regarded.

5.4 Long Term Strategy

Prior to the actual initiation of enhancement projects, it is important that a thorough diagnosis of biological and physical parameters which may effect fish production within targeted streams is conducted (Adams and Whyte 1990). Bearing this in mind, a long term strategy should be devised to supplement the preliminary objectives identified in the introduction of this report. Hirst (1991) indicates the need for baseline biological data collected prior to and after hydroelectric developments to provide post development comparisons if proper compensatory programs and realistic future management objectives are to be achieved.

As earlier indicated, some pre-impoundment baseline biological data does exist for Revelstoke Lake tributaries, however, this information is limited. Long term strategies should not only include enhancement of existing fish populations, but coincidentally involve detailed studies of targeted streams, identifying the biological parameters and other factors which have potential to affect enhancement objectives. This includes:

1) **Establishment of an integrated Forestry - Fisheries management plan.**

Guidelines concerning Forestry-Fisheries interactions, currently in use on coastal systems, have been developed through a co-operative venture by the Dept. of Fisheries and Oceans, the Ministry of Environment, the B.C. Forest Service and the Council of Forest Industries (Forestry-Fisheries Guidelines, 1988). Similar guidelines are being developed for interior regions, but will not be available until 1992 (pers. comm. Jim Blake, BCFS Forestry Officer, 1991). The results of this project will hopefully facilitate an integrated management plan by identifying to all parties involved, streams which are sensitive to logging activities and which areas of these streams afford good or potentially good fish habitat.

2) **Further studies to collect baseline data and determine standing stocks of the more important streams entering the reservoir.**

This year's work has developed a short list of streams which present enhancement opportunities given more information is gathered to determine criteria which limit fish production.

The development of baseline data is critical to determine the effectiveness of enhancement activities by comparing pre and post enhancement data. Monitoring the success of particular enhancement programs will aid the development of enhancement programs for tributaries to Lake Revelstoke as well as determine if changes in strategies are required.

Future studies initiated to collect baseline data should include:

(i) Collection of biophysical data specifically from the 9 primary (category "A") streams. Water sampling, temperature profiles and invertebrate sampling will aid in the determination of primary productivity and carrying capacity within individual streams. The frequency of such sampling would depend upon the degree of resolution desired. It is suggested that water sampling occur on a bi-monthly basis through the growing season (May to October) of one calendar year. Continuous temperature data should be recorded for, at least, the duration of the growth period. Replicated samples of invertebrates

within substrata, and, sampling insect drift, should occur during maximum and minimum production periods (summer and winter).

(ii) Determine seasonal variations in utilization by resident and/or adfluvial species in targeted streams. This could include downstream and/or upstream trapping programs and return visits to particular sample sites to determine changes in species composition or numbers.

(iii) Explore habitat and areas of streams not surveyed during this years' project with the intent of determining population densities. Examples would be to determine the importance of beaver pond and marsh habitat common to many of nine primary tributaries, and to conduct more extensive surveys of smaller tributaries to large streams. Sampling at most of these small tributaries was limited to one site during this project.

(iv) Monitor enhanced streams, (such as Birch Creek) to:

a) determine the effectiveness of barrier removal and conduct maintenance as required.

b) create a database cataloging changes in fish densities and diversity within enhanced streams prior to and at after enhancement programs.

3) **Initiate a pilot enhancement program, encompassing the goals outlined in (1) and (2).**

The first phase of such a pilot project would involve initiating a awareness program identifying important tributaries and proposed enhancement plans for these tributaries to recreational and commercial resource user groups. This would be followed by the collection of baseline biological data. Two streams, one on either side of the reservoir, selected as representative drainages, could be the focus of trapping and habitat assessment studies. Fence traps would be constructed to intercept lake resident sports fish migrating to spawning grounds. A mark recovery program would allow a population estimate of the adult escapement. Construction of semi-permanent two way enumeration fences would be a valuable contribution to initiating such a program since estimating the adult and juvenile migrations of

rainbow and bull trout is hampered by the practical difficulties in erecting and maintain temporary enumeration fences on Lake Revelstoke tributaries during periods of highwater. Otherwise, only the smaller tributaries entering the reservoir could have fences installed on them. La Forme, Ruddock, Scrip and Kirbyville and possibly Carnes Creek are potential candidates for this work. La Forme Creek is highly recommended since preimpoundment data is available for this stream, and this study has indicated La Forme Creek is probably an important bull trout producing stream.

The second phase of the program would see the initiation of specific enhancement projects such as outplanting, habitat improvement, barrier removal etc. If outplanting is determined to be a viable alternative, all hatchery raised fish should be tagged and fin clipped so creel surveys occurring on Lake Revelstoke and proposed enumeration fences can include a recovery program to better determine migration patterns and outplanting success.

5.5 Estimated Costs

5.5.1 Barrier Removal

The costs for barrier removal will vary depending upon the type of barrier and the access to the barrier. The cost to remove small barriers which require little engineering or capital expenditures may be as low as $2,400 (Table 55) to $5,000 (Table 56). The Dept. of Fisheries and Oceans estimates the cost of formal structures to bypass falls to be between $22,650 and $119,290 per vertical m of height (Table 56). The mean cost of barrier removal and fishway projects completed through expenditures from the Habitat Conservation Fund is only $18,700 (Table 57). Costs summarized for various enhancement techniques presented in Table 56 can generally be assumed to be more capital intensive and involve considerable engineering. Comparatively, the costs presented in Table 57 are more labour intensive and generally smaller in size. Recently, a vertical slot fishway was constructed as a joint project between MOE and DFO to bypass a 7 m falls on the Bonneparte River. The total cost of this structure was $300,000, or approximately $43,000 per vertical m (Pers. Comm. Ian McGregor, Senior biologist, MOE, Kamloops B.C.). This figure is considerably less than that shown in Table 56.

Table 55: Cost estimate for the removal of Nagel Creek Waterfall.

Category	Description	Quantity	Unit	Cost/Unit	Total Cost
Equipment	Jackleg Drill	3	day	$70	$210
Labour	Drill operator and assistant	48	hours	$22	$1,056
	Blaster operator& assistant	32	hours	$22	$704
Materials	Explosives 40 kg and Accessories				$300
	Fuel				$150
Total Cost					$2,420

Table 56: Standard Costs and Life Expectencies for Enhancment Facilities
(Adapted to 1991 dollars from Lill et al. 1982)

Description	Captital Cost	Annual Operating Cost	Duration of Operation (yrs)
Spawning Ch. (controlled)	$1,510,000 $137/ m^2 area	$45,300 $4/ m^2 area	40
Side Ch. (uncontrolled) Inlet & outlet works + gravel addition	$77/m^2 area	$2.3/m^2 (3% cap)	20
Vertical Slot Fishway	$119,290/ vertical m	$3,580 (3%cap)	40
Steep Pass	$31,710/ vertical m	$951 (3% cap)	10
Rock Fishway (falls removal)	$22,650/ vertical m	$680 (3% cap)	20
Minor Storage/Flow control	$75,500/ each	$2,265 (3% cap)	20
Incubation Box	$30,200/ each	$15,100	10
Log Jam Removal	$7,550/ each	n/a	5
Hatchery (Japenese Style)			
under 1000 kg	$95/ Kg of output	$81,540 plus $143/ kg output	10
1000 to < 3000 kg	$227/ Kg of output	$81,540 plus $143/ kg output	10
3000 to <5000 kg	$227/ Kg of output	$460,550 plus $9.2/kg output	40
> 5000 kg	$174/ Kg of output plus $3,000,000	$460,550 plus $9.2/kg output	40
Satelliting from hatchery	$45,300/ each	$151,000	
Juv. Stocking (Colonization)	$36,240/ each	$45,300	
Transplanting	Incubation Box + Satellite or Colonization Costs		
Adult Transplant (trapping and trucking)	$45,300	$86,070	

Table 57: Expenditures from the Habitat Conservation Fund from 1981 to 1991. Costs are expressed as an average amount spent per enhancement technique . (Note, some projects needed more than one year to complete but are listed as individual projects each year.)

Enhancement Technique	No. of Projects	Range	Average Cost/Technique
Brood Stock Collection	2	$34,751 - $43, 694	$39,223
Stream Clearance	35	$968 - $59,989	$17,769
Water Storage Dam (Constuction & Maintenance)	9	$2,545 - $51,112	$19,267
Fishway and Barrier Removal	20	$19 - $117,334*	$18,691
Gravel Placement **	48	$971 - $68,246	$12,357
Spawning Ch. Construction	20	$4,553 - $109,928	$32,167
Transplanting	11	$2,348 - $23,453	$10,647

* Includes Construction of Boneparte Fishway (separated into 2 years)
** Includes replacement maintenance of spawning channel gravels.

Local volunteers should be encouraged and sponsored to engage in small enhancement projects such as removing barriers like the debris jam on Park Creek or the old dam on La Forme Creek. Revelstoke Rod and Gun Club members have proven their willingness and competence in removing barriers, such as the log jam on the Illecilewaet River. More detailed planning and an engineer on site is recommended for removal of barriers such as the ones on Downie Creek and possibly Nagel Creek, but this should not preclude local involvement.

Fluctuations in water level are minimal in Lake Revelstoke compared to Kinbasket and Upper Arrow Lakes, and annual variations in lake levels have been reduced since the creation of the Revelstoke reservoir, however, fishway or barrier removal plans for the mouths of creeks must include contingencies for varying water levels.

5.5.2 Collection of Baseline Biological Data

Beyond barrier removal and habitat rehabilitation, it is not recommended that specific enhancement activities occur until background data is collected to determine the standing stocks of targeted streams and carrying capacities of these streams. The cost outlined for conducting further study programs are rough estimates only, and could vary dependant upon the resolution desired during collection of background data.

The approximate cost for a fence trapping program on 2 streams is $67,000 (Table 58). This cost does not include the construction of a semi-permanent enumeration fence. Spring freshets may preclude the use of a temporary enumeration fence on most of the tributaries to Lake Revelstoke. The exact number of mandays required for enumeration will vary depending on the duration of rainbow and bull trout migrations.

The cost of a spring trapping program would be similar to that of a fall program if a fence were used, however, Inclined Plane Traps (IPT's) or Rotary traps may be used for a downstream program if fences are not employed (semi permanent structures or otherwise). IPT's are inexpensive but they are not reliable smolt catchers, whereas Rotary traps are efficient, but expensive and in short supply. The estimated cost to operate 2 IPT's is $63,990 (Table 59).

Table 58: Estimated cost to build and monitor 2 adult trapping fences.

Mandays and Professional Fees

Personnel	Installation	Monitoring	Data Analysis & Reporting	Total Days	Per Diem Rate	Total Cost
Biologist	6	60	20	86	$310	$26,660
Technician	6	60	10	76	$300	$22,800
Volunteer	6			6		
Total	**18**	**120**	**30**	**168**		**$49,460**

Disbursements

Description	No. Units Required	Cost per unit	Total
Transportation			
Truck	65	$50	$3,250
Gas	65	$40	$2,600
Accomodation			
Cabin Rental	60	$10	$600
Food	60	$40	$2,400
Field Equipment			
Boat	60	$10	$600
Motor	60	$10	$600
Tagging Equip.			$300
Dip Nets	8	$10	$80
Scale	60	$10	$600
Misc. Equip	60	$10	$600
Fence Construction			
Materials (Lumber, Sandbags rebar etc.)			$3,500
Tools (power and hand)	60	$10	$600
Generator	60	$8	$480
Misc. Expenses			$500
Total Field			**$16,710**

Office

Description	
Communication	$500
Report Prod.	$750
Misc	$250
Total:	**$1,500**

Estimate of Total Costs to run a trapping program on two creeks $67,670

Table 59 : Estimated cost for a juvenile out migration program.

Mandays and Professional Fees

Personnel	Installation	Monitoring	Data Analysis & Reporting	Total Days	Per Diem Rate	Total Cost
Biologist	6	60	20	86	$310	$26,660
Technician	6	60	10	76	$300	$22,800
Volunteer	6			6		
Total	18	120	30	168		$49,460

Disbursements

Description	No. Units Required	Cost per unit	Total
Transportation			
Truck	65	$50	$3,250
Gas	65	$40	$2,600
Accomodation			
Cabin Rental	60	$10	$600
Food	60	$40	$2,400
Field Equipment			
Boat	60	$10	$600
Motor	60	$10	$600
Dip Nets	8	$10	$80
Balence	60	$10	$600
Misc. Equip	60	$10	$600
IPT (x2)	60	$20	$1,200
Misc. Expenses			$500
Total Field			**$13,030**

Office

Description	
Communication	$500
Report Prod.	$750
Misc	$250
Total:	**$1,500**

Estimate of Total Costs to run a trapping program on two creeks $63,990

Detailed (intensive) stream surveys of two specific streams would involve field trips to conduct water sampling, calculate population estimates of juvenile standing stocks, and perform multiple habitat assessments for each reach within study streams. Three water sampling field trips coinciding with periods of maximum fish growth could occur on a bi-monthly basis beginning in May and continuing through to November. Replicates at each water sampling site should also be taken. Detailed population estimates could be made once during the periods of maximum and minimum growth such as during summer (mid to high water) and again during winter (low flow). This would aid determining seasonal variations in population densities and associated stream conditions.

Analysis of 6 water samples, assuming 2 replicates are taken at one site 3 times over a 6 month period, would range in cost from $408 to $780 each, depending on the type of analysis (Table 60). Assuming 1 week were spent for each field trip, and 2 field trips were made, detailed habitat surveys would cost an estimated $24,650 per stream (Table 61).

Most of the cost for a water sampling program would be incurred as professional fees and disbursements due the time and expenses necessary to travel to Revelstoke Lake. These costs could be reduced by employing personnel from the Revelstoke area. Also, the estimated costs of trapping, water sampling and detailed habitat assessment studies have been presented separate of each other, but efficiencies could be realized by combining all programs into one project, significantly reducing the overall expenditures. For example, the additional field time required to conduct water sampling at more than one stream would be minimal. Likewise, habitat assessments and water sampling may occur, in part, during trapping programs, reducing both professional fees and disbursements. Finally, volunteers should be encouraged to participate in various stages of each program. The use of volunteers will reduce expenditures and also aid management of local streams by increasing local interest, knowledge, and expertise of fish resources in the Revelstoke Lake area.

5.5.3 Hatcheries and Outplanting

A hatchery program to increase fish populations within Revelstoke Lake will require either expansion of existing facilities at Hill Creek or construction of new

Table 60: Cost of monthly water samples for one year at one site.

Mandays and Professional Fees

Personnel	Field	Data Analysis & Reproting	Total Days	Per Diem Rate	Total Cost
Biologist	36	5	41	$310	$12,710
Technician	36	2	38	$300	$11,400
Total	72	7	79		$24,110

Disbursements

Description	Cost per Unit	Number of Units	Total
Transportation			
Truck	$150	36	$5,400
Gas	$40	36	$1,440
Accomodation			
Hotel	$50	36	$1,800
Food	$80	36	$2,880
Field Equip.			
Thermograph	$3	360	$1,080
Boat	$25	36	$900
Motor	$25	36	$900
Misc. Equip	$10	36	$360
Water Samples			
Nutrients	$68	12	$816
Metals	$45	12	$540
Mercury	$17	12	$204
All water samples combined:	$130	12	$1,560
Total Disbursements			
Only nutrient analysis			**$15,576**
Nutrient and Metal analysis			**$16,116**
Nutrient , metal and mercury analysis			**$16,320**

Estimated total cost for water sampling 1 stream. $39,686 to $40,430

Table 61: Estimated costs to complete intensive habitat inventories during low and high water flow regimes.

Mandays and Professional Fees

Personnel	Field	Reporting & Data Analysis	Total Days	Per Diem Rates	Total Cost
Biologist	15	10	25	$310	$7,750
Technician	15	7	22	$300	$6,600
Total	30	17	47		$14,350

Disbursements

Description	No. Units Required (days)	Cost per Unit	Total
Transportation			
Truck	15	$150	$2,250
Gas	15	$40	$600
Helicopter (hrs)	4	$750	$3,000
Accomodation			
Cabin	15	$25	$375
Food	15	$40	$600
Field Equipment			
Boat	15	$25	$375
Motor	15	$25	$375
Electroshocker	15	$60	$900
Balence			
Film & Developir	6	$22	$132
Misc. Equip.	15	$10	$150
Misc. Expenses			$500
Total Field Disbursements			**$9,257**
Office			
Communications			$300
Report Production			$250
Miscelaneous			$500
Total Office Disbursements			**$1,050**
Total Disbursements			$10,307

Estimated total cost for habitat inventories of one stream: $24,657

facilities in the Revelstoke Lake Area. Constructing new facilities will be more expensive than expanding rearing capabilities at the Hill Creek hatchery, but it would offer local employment to the Revelstoke area, and the reduce costs incurred for transportation, collection of brood stock and, release of fry. Also, mortality as a result of excessive travel time may be reduced by having a hatchery centered on Revelstoke Lake, however, considerable engineering and planning will be necessary prior to construction of a new facility. For these reasons, expansion of the Hill Creek hatchery is recommended since:

(1) The applicability of outplanting fish into primary streams has yet to be determined.

(2) A pilot program would be the initially step towards outplanting

(3) Continued enhancement through production of hatchery raised fish is not the goal of the proposed program.

Satelliting costs summarized by DFO (Table 56) include capital and engineering expenses required to construct and expand major facilities, whereas Table 57 provides average costs for programs sponsored by MOE's Habitat Conservation Fund. Hill Creek hatchery presently produces about 180,000 rainbow and bull trout each year, for a total operating cost of $100,000. Mr. H. Andrusak (MOE's Fish Culture Section) estimates the average cost per rainbow trout yearling for the entire provincial hatchery system is approximately $0.37 per fish.

6.0 CONCLUSIONS

This years' survey of tributaries to Lake Revelstoke has identified 9, of 23 streams assessed, which have good enhancement potential. Eight of these streams, including Nagel, Ruddock, Scrip, Kirbyville, La Forme, Bigmouth, Carnes and Downie Creeks, were determined to possess good potential for enhancement of adfluvial (lake resident) sports fish species. These streams are accessible to lake resident fish or, in the case of Nagel Creek, could easily be made accessible by the removal of a barrier. The Goldstream River is isolated from Lake Revelstoke by a large falls at its mouth but offers good possibilities for enhancement of resident cutthroat trout.

The carrying capacities of these tributaries is unknown but a lack of returning adults, insufficient quality rearing and/or spawning habitat, water quality, water temperatures, and habitat degradation are all factors which may limit production of sports fish species in one or more of these tributaries. Sparse numbers of fish may also indicate habitat which is available to rearing fish is be under-utilized, probably because of lowered escapement of spawners into these streams following decreases in lake stocks of rainbow and bull trout from pre-impoundment levels and continued recreational fishing pressure. Further studies should be initiated to determine the elements which limit production in the 9 primary streams, so specific enhancement programs can be designed for each stream.

Enhancement techniques for these streams should involve a multifaceted approach with technique complementing each other to meet the objective of increasing fish stocks. Options include:

(1) Outplanting of hatchery reared fish,

(2) Habitat rehabilitation, and development,

(3) Barrier removal,

(4) Stream fertilization,

(5) Management of existing resources.

Hirst (1991) reports increasing stock densities can only be accomplished by sustained stocking programs, but warns that run of the river reservoirs have, so far, responded poorly to such long term programs.

The proposed program to increase existing fish populations within the Lake Revelstoke watershed is a long term project. This program may be sped up by infusions of yearling rainbow and bull trout into selected streams entering Lake Revelstoke, opening or creating new habitat, and stream fertilization but, the key to ensuring the overall success of increasing fish stocks within Lake Revelstoke hinges upon conservation and management of existing resources. This in turn relies upon the collection of sustained, accurate baseline data which can be applied to enhancement and conservation efforts. Of particular concern is degradation of available fish habitat due to continuing logging and mining activities in watersheds of the nine important streams and the loss of wild stocks due to recreational fishing pressures.

The goal of increasing wild fish populations within Lake Revelstoke to a self sustainable level should begin with the implementation of a pilot project on two representative tributaries, selected from the identified priority streams. This work would begin with detailed biological studies to determine standing stocks of rearing juvenile fish, adult escapement and identify specific factors limiting fish production. Following this, specific enhancement programs could be initiated for these 2 streams. Collection of baseline data and monitoring of enhancement activities would continue throughout the period of enhancement so judgments on enhancement success and or changes in enhancement strategies can be made as required. Expanding enhancement of the remaining primary tributaries would follow pending evaluation of the success of the pilot project. Projects such as barrier removal and stream rehabilitation will increase tributary habitat available to lake resident fish and, could occur concurrent with, and in some cases, preceding, the collection of baseline data and outplanting of juvenile fish. Participation of local Rod and Gun Club members to complete enhancement projects, particularly barrier removal and revegetation programs should be encouraged and supported.

On-going aquatic monitoring programs have shown Revelstoke lake to be an ultra-oligotrophic lake. The practicality of maintaining a viable recreational sports fishery is limited by Lake Revelstoke's productivity as well as the tributary habitat available to spawning and rearing sports fish species. Increasing fish stocks in Lake Revelstoke so a sustainable population of wild fish will provide recreational fishing opportunities requires a long term strategy. This strategy must encompass the

concerns of numerous resource users groups. A project of this magnitude will be expensive to maintain and therefore, the overall benefits must be weighed against the costs.

7.0 REFERENCES

Adams, M. A. and I. W. Whyte, 1990. Fish habitat enhancement, a manual for freshwater, estuarine and marine habitats. Prepared for the Dept. of Fisheries and Oceans, Canada. DFO 4474. 330p.

Carl, L. 1985. Proceedings of the Flathead River basin bull trout and population dynamics modeling information exchange. Fisheries Br. B.C. Min. of Environ. Edited by D.D. MacDonald. 9pp.

Environmental Research Consultants, 1976. Revelstoke project: environmental II studies. Produced for B.C. Hydro and Power Authority, By E.R.C. Vancouver, B.C. 59 p.

Fleming, J.O. and H. A. Smith 1986. Revelstoke Project: Revelstoke reservoir aquatic monitoring program. B.C. Hydro and Power Authority. Report No. ER 88-03, 66 p.

Fleming, J.O. and H. A. Smith, and S. MacAdam. in prep. Revelstoke Project: 1987 Revelstoke reservoir aquatic monitoring program. B.C. Hydro and Power Authority. Report No. ES 88-05.

Ford, B.S., P.S. Higgins, A.F. Lewis, K.L. Cooper, T.A. Watson, G.L. Ennis and R.L. Sweeting. 1992. Literature reviews of life history, habitat requirements and mitigation/compensation strategies for 13 species of sport fish in the Peace and Columbia drainages of British Columbia. Can. MS. Rep. Fish. Aquat. Sci. XXXX: 329pp.

Galesloot, M. M. 1989. The steelhead trout of the Keogh River in the spring of 1989: Adult population estimates and smolt enumeration. Rec. Fish. Div., B.C. Min. of Environ. , contract No. CFB9053.

Hirst, S.M. 1991. Impacts of the operation of existing hydroelectric developments on fishery resources in British Columbia. Vol. II. Inland fisheries. Can. Manuscr. Rep. Fish Aquat. Sci. 2093: 200 p.

REFERENCES (continued)

Lindsay, R.A. 1991. Lake Revelstoke Fisheries Management Plan. Ministry of Environment, Fisheries Branch, British Columbia B.C. 11 p.

Lindsay, R.A. 1977. Investigations on fish populations that will be affected by the Revelstoke 1880 Dam. Produced for the Fish and Wildlife Branch and B.C. Hydro and Power authority.

Martin, A. D., 1975. Dolly Varden and rainbow trout tagging operations on the Columbia River. Fall 1975. Fish and Wildlife Branch, British Columbia.

Mason, B. C. 1985. Revelstoke Project: Aquatic biology program interim report. B.C. Hydro and Power Authority.

Newton, M. K. M. Howard, B. R. Kelpaas, R. Danhous, C.M. Lottman, S. Dubelman, 1984. Fate of glyophosphate in an Oregon forest ecosystem. J. Agricultural and Food Chem. 8 pp.

McPhail, J. D. and C. B. Murray 1979. The early life history and ecology of Dolly Varden (*Salvelinus malma*) in the Upper Arrow Lakes. Prepared for B.C. Hydro and the Kootney Region Fish and Wildlife Branch by the University of British Columbia. 112 pp.

Pratt, K. 1985. Proceedings of the Flathead River basin bull trout and population dynamics modeling information exchange. Fisheries Br. B.C. Min. of Environ. Edited by D.D. MacDonald. 2pp.

Simon. R. C. 1991. Management techniques to minimize the loss of genetic variability in hatchery fish populations. American Fisheries Society Symposium 10: 487-494.

Slaney, P. A., C. J. Perrin, B. R. Ward, 1986> Nutrient concentration as a limitation to steelhead smolt production in the Keogh River. Paper presented at: Western Div. of the A.F.S. Portland, Oregon, U.S.A. 13pp.

Smith, H. A. 1990. Revelstoke reservoir (Columbia River system): biophysical to 1987. Collection Environment et Geologie, 9: 297-325.

Terzi, R.A. 1981. Hydrometric field manual - measurement of streamflow. Environment Canada, Inland Waters Directorate, Water Resources Branch, Ottawa, Canada. 37 pp.

Triton Environmental Consultants Ltd. 1990. A review of riparian revegetation techniques for control of bank erosion and sediment input and their potential for application to the Nechako River. Nechako Fisheries Conservation Prog. Rep No. RM 90-3.1. 55 pp.

Wan, M. 1984. Glyophosphate monitoring results in B. C. - an updae. Dept. of Evirion. E.P.S., Pacific and Yukon region. 4 pp.