EA3520

FISH HABITAT REHABILITATION DESIGNS FOR HEADQUARTERS CREEK WATERSHED, 2013

Submitted to

Tsolum River Restoration Society

October 2013

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Submitted to

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October 2013

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ACKNOWLEDGMENTS

Jack Minard of the Tsolum River Restoration Society provided contract management, project direction and guidance. Funding for the 2013 project was provided by the BC Habitat Conservation Trust Fund. Jack Minard and Lesley Taylor assisted with the field work in 2002, and David Morwood and Norm Wiens assisted in 2013. The assistance of all of these individuals is greatly appreciated.

1. INTRODUCTION

The Tsolum River Task Force (TRTF) identified Headquarters Creek, a tributary to the Tsolum River near Merville, as a candidate for protection and rehabilitation of salmon habitat (Campbell 1999). Headquarters Creek has a watershed area of about 27 km^2. Most of the land in the Headquarters watershed is owned by TimberWest Forest Corporation. The creek lies within the "forested upper slopes" zone of the Tsolum River basin, while the land immediately downstream of the proposed rehabilitation section would be classified "rural residential" (Campbell 1999). Wolf Lake in the upper reaches of Headquarters Creek is regulated to augment low summer discharges in the Tsolum River.

Coho and Pink Salmon, and Rainbow (Steelhead) and Cutthroat Trout are native to the Headquarters watershed (J. Minard, Tsolum River Restoration Society (TRRS) pers. comm.). The Tsolum River Restoration Society identified limitations to spawning and rearing habitat of native salmonids in a 300 m section of channel within lower Headquarters Creek. In particular, they identified a paucity of gravel substrate for pink salmon spawning and a lack of deep pools with cover for juvenile salmonids that rear in the creek (J. Minard, TRRS pers. comm.).

A preliminary rehabilitation design for Headquarters Creek was prepared in March 2002 (Gaboury 2002). The proposed rehabilitation site was re-visited in October 2013 to determine if any changes in channel morphology had occurred, and to revise and finalize the design. This report provides the detailed instream rehabilitation designs for the targeted 300 m section of Headquarters Creek (Figure 1). The target rehabilitation reach for this project begins about 800 m upstream of the Tsolum River Salmon Hatchery. The construction of LWD cover structures and riffles with spawning platforms are proposed. The rehabilitation designs target the spawning and rearing life stages of salmonids, in particular, Steelhead/Rainbow Trout, Pink and Coho Salmon, and Cutthroat Trout. Included are the construction drawings, access routes, materials summary, work plan, and schedule for the proposed projects.

2. ASSESSMENT METHODS

Field surveys for the siting and design of rehabilitation treatments were originally conducted on February 26 and March 21, 2002. Further surveys were conducted on October 11, 2013. Information collected at all sites included:

- locating each proposed rehabilitation site by thalweg chainage;
- estimating right and left bank heights above present water level;
- determining the availability of ballast rock on site;
- determining the type of bed and bank substrates; and
- identification of specific factors to restore local fish habitat.

In addition, detailed surveys included:

- level surveying the stream channel and floodplain at the rehabilitation sites to provide streambed and water surface profiles along the thalweg, floodplain and channel cross sections; and
- measuring bankfull width, bankfull height, and rehabilitation site length.

Photographs of the proposed riffle and LWD sites were also taken.

3. HYDROLOGY

Discharges in Headquarters Creek have been monitored for only a short time period by Water Survey of Canada and the Tsolum River Restoration Society. A short period of record prevents a reliable determination of flood frequencies for the creek. Therefore, the magnitude and recurrence interval for floods were estimated from selected Water Survey of Canada gauged streams on Vancouver Island. The estimates for the regional stations were computed from the annual peak discharges using the Log Pearson III distribution. Flood frequency values were based on the averages for four stations proximal to Headquarters Creek (Water Survey of Canada 1999). Due to the differences in drainage area between the four stations and Headquarters Creek and because smaller basins typically have higher unit discharges, the computed values for Headquarters Creek should be considered as underestimates. Flood estimates for 2 yr (bankfull) and 50 yr recurrence interval floods were needed to determine high water levels in Headquarters Creek and stable rock sizes for the proposed riffle structures. The unit flows for 2 yr and 50 yr recurrence interval floods for the gauged stations were calculated to be 357 and 824 $l/s/km^2$, respectively (Table 1). With a watershed area of 26.7 km^2 for Headquarters Creek, the 2 yr and 50 yr recurrence interval floods were estimated at 9.5 and 22.0 cms, respectively.

4. CHANNEL CHARACTERISTICS

Bankfull width in this section of Headquarters Creek was measured at approximately 11 m. Expected bankfull width for this creek was also estimated using relationships for channels that were determined from a large data set of streams throughout North America (Newbury et al. 1997). Bankfull width was estimated at 10 m using the formula:

$$W_{bf} = 4(Q_{bf})^{0.4}$$

where W_{bf} is bankfull width (m) and Q_{bf} is bankfull discharge (cms) (Kellerhals and Church 1989). Bankfull discharge for Headquarters Creek is estimated to be equal to the 2 yr recurrence interval flood of 9.5 cms (Table 1). This analysis suggests that the present channel width is stable and appropriate, relative to the channel maintenance discharge.

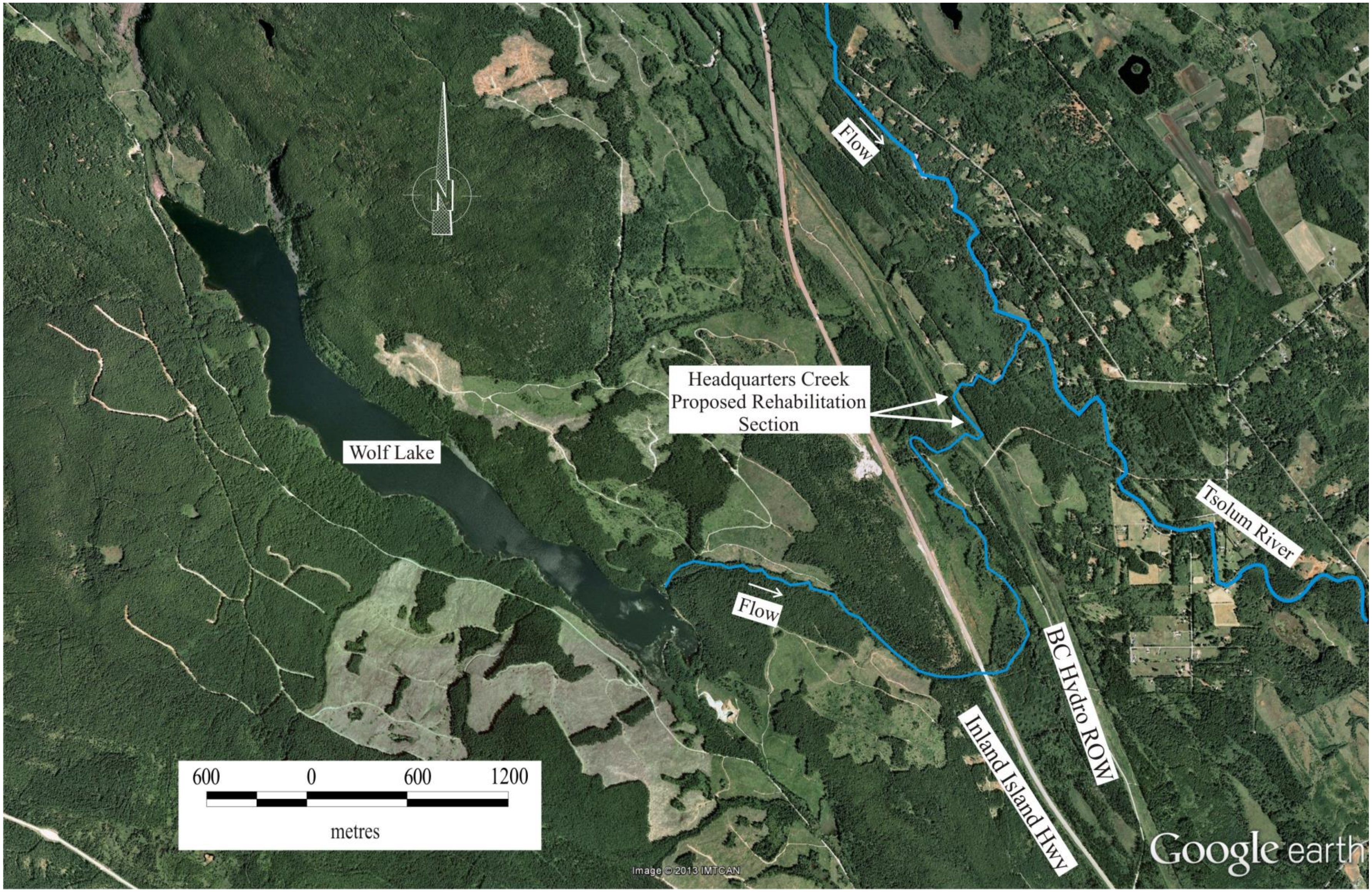


Figure 1. Orthophoto (1999) of lower Headquarters Creek showing proposed rehabilitation section.

Table 1. Summary of return period maximum daily discharges for selected East Vancouver Island streams.

Gauge	Station Name	Years	No. of Years	Area (km^2)	Unit Discharge ($l/s/km^2$) Mean Annual	2 yr	10 yr	25 yr	50 yr	Max	Average Monthly Discharge ($l/s/km^2$) January	February	March	April	May	June	July	August	September	October	November	December
08HB029	Little Qualicum River near Qualicum Beach	1960-1986	27	237	51	379	732	911	1043	1084	87	77	60	47	49	35	18	9	12	40	78	94
08HD011	Oyster River below Woodhus Creek	1973-1999	27	298	47	409	693	787	841	872	59	52	44	52	71	64	32	14	11	36	73	60
08HD005	Quinsam River near Campbell River	1956-1999	44	280	31	217	408	513	595	779	53	50	42	28	22	16	10	8	11	24	49	61
08HB011	Tsolum River near Courtenay	1914-1994	38	258	39	422	674	764	818	744	66	65	60	43	28	16	7	3	7	29	70	81
	Mean of All Gauges Above				42	357	627	744	824	870	66	61	52	43	43	33	17	9	10	32	67	74
Gauge	Station Name	Years	No. of Years	Area (km^2)	Discharge (m^3/s) Mean Annual	2 yr	10 yr	25 yr	50 yr	Max	Average Monthly Discharge (m^3/s) January	February	March	April	May	June	July	August	September	October	November	December
08HB029	Little Qualicum River near Qualicum Beach	1960-1986	27	237	12	90	174	216	247	257	20.6	18.2	14.3	11.2	11.7	8.4	4.3	2.1	2.9	9.4	18.4	22.2
08HD011	Oyster River below Woodhus Creek	1973-1999	27	298	14	122	207	235	251	260	17.5	15.4	13.2	15.4	21.1	19.0	9.6	4.3	3.4	10.6	21.8	17.8
08HD005	Quinsam River near Campbell River	1956-1999	44	280	9	61	114	144	167	218	14.8	14.0	11.7	7.8	6.1	4.4	2.8	2.3	3.2	6.6	13.6	17.0
08HB011	Tsolum River near Courtenay	1914-1994	38	258	10	109	174	197	211	192	17	16.8	15.4	11.2	7.3	4.1	1.8	0.9	1.7	7.4	18.0	21.0
	Estimate for Headquarters Creek (based on mean of all gauges)			26.7	1.1	9.5	16.7	19.9	22.0	23.2	1.8	1.6	1.4	1.1	1.1	0.9	0.4	0.2	0.3	0.9	1.8	2.0

With a gradient of 0.4%, the channel morphology for this section of Headquarters Creek under historic conditions would be considered as riffle-pool with predominantly gravel substrate (Anonymous 1996). Instream LWD would be very important in this channel type and would act to create some of the dominant channel characteristics. The lack of instream LWD in this section has undoubtedly reduced the frequency of pools as well as reducing the accumulation of spawning gravels at pool tail-outs or adjacent to natural log sills. This section of channel is somewhat confined by steep and high natural banks situated about 30 m apart. The channel over the proposed rehabilitation section (200 m) is comprised of riffle-run habitats with substrates of predominantly cobbles in the range of 60 to 150 mm.

5. REHABILITATION OBJECTIVES

In the proposed rehabilitation works, the objectives will be to:

- increase spawning habitat area for Steelhead/Rainbow Trout, Cutthroat Trout, and Pink and Coho Salmon;
- improve holding, overwintering and rearing habitat for endemic Steelhead/Rainbow Trout, Cutthroat Trout, and Coho salmon; and
- increase fish densities in LWD complexed mainstem sites to 0.9 Coho fry/m^2 and 0.3 trout fry/m^2.

The proposed rehabilitation activities to meet site-level objectives are to:

- increase the quantity and quality of spawning habitats by constructing two riffle structures and placing appropriately sized spawning gravel upstream of the riffle crest; and
- provide cover and promote pool scour by constructing LWD and riffle structures.

6. FISH HABITAT REHABILITATION DESIGNS

6.1 LWD Structures

LWD structures will be built at four specific sites in Headquarters Creek mainstem (Figure 2; Table 2 to Table 5; Photo 1to Photo 5). Each proposed LWD structure will be comprised of 5 logs (Figure 3). It is anticipated that the logs with rootwads will have an average dbh of 0.4-0.5 m and be approximately 10 to 12 m long. It is assumed in the materials summary tables that all structure materials (i.e., logs, ballast boulders) must be imported.

LWD cover structures will be positioned preferentially in a triangular manner or with members anchored to bank trees, stumps or ‘Manta’ anchors to ensure greater stability for the structure.

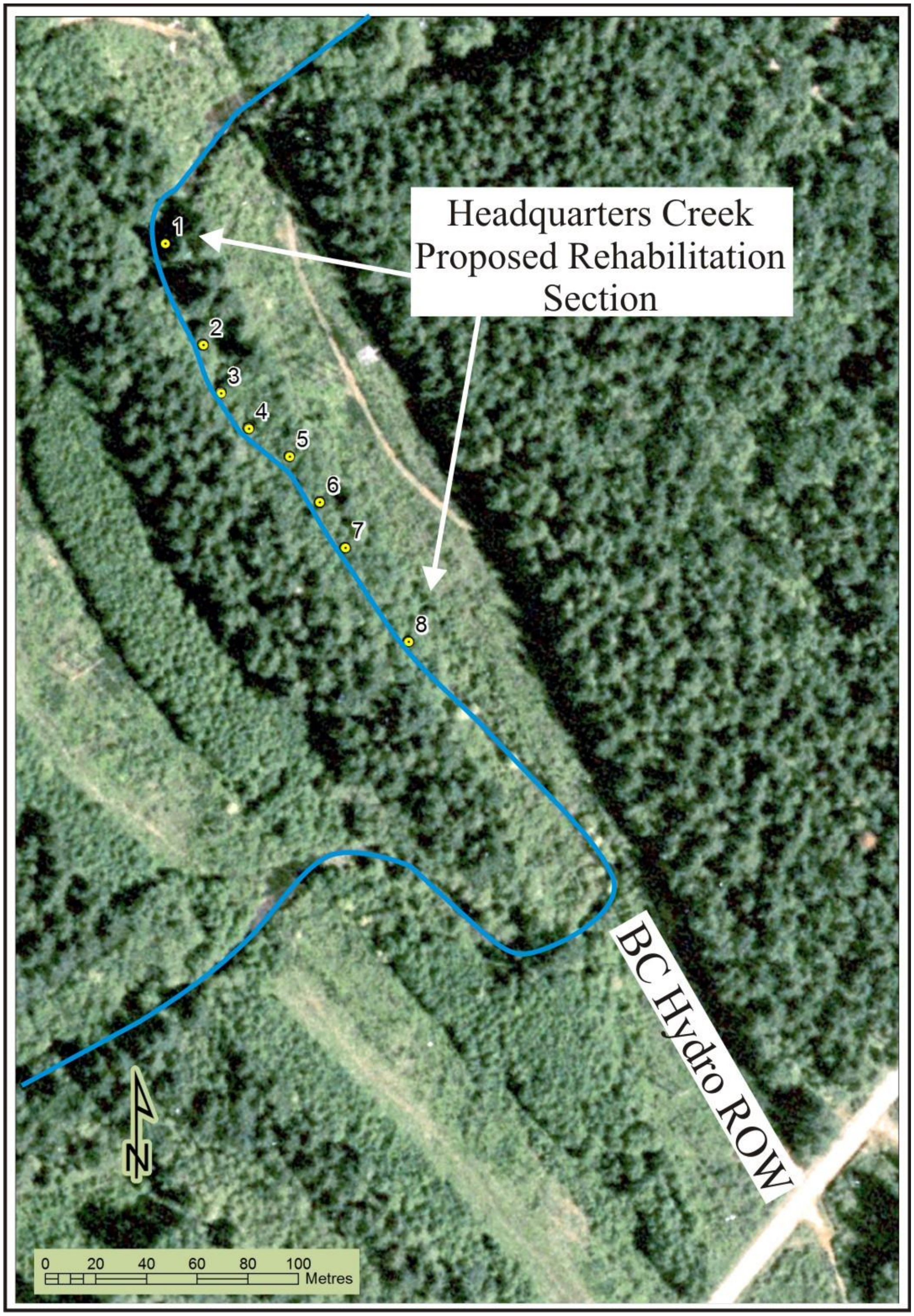


Figure 2. Location of eight proposed rehabilitation sites in Headquarters Creek.

Table 2. UTM coordinates of the eight rehabilitation sites in Headquarters Creek.

Site Number	UTM Coordinates
1	10 U 346960 5514511
2	10 U 346975 5514471
3	10 U 346982 5514452
4	10 U 346993 5514438
5	10 U 347009 5514427
6	10 U 347021 5514409
7	10 U 347031 5514391
8	10 U 347056 5514354

Ballast requirements for a DJ-5 LWD design have been determined using design charts that assume a triangular structure and a safety buoyancy factor of 1.5 (D'Aoust and Millar 1999; Slaney et al. 1997; Table 5). For a 0.5 m diameter log with attached rootwad, the total ballast required per metre of effective length would then be 130 kg/m, with safety factors of $\geq$1.5 for buoyancy and sliding (D'Aoust and Millar 1999). Effective length refers to the length of log projecting into the stream.

The ballast requirement for logs with rootwads attached requires conversion of the dimensions of the rootwad into an equivalent diameter and length of a log of equal mass. The total ballast requirement for the log with rootwad would be the sum of the individual ballast requirements determined for the bole and rootwad. For typical triangular log structures, we recommend anchors of 0.8 m in diameter, based on a typical log diameter of 0.5 m. Sufficient quantities of rock required to ballast the LWD structures are not available on site and would need to be brought to the proposed locations. The size or number of boulders can be reduced where a long stem lies on the stream bank, as its weight will prevent movement of the rootwad end that is in the stream.

LWD that are ballasted with boulders will be anchored by drilling 9/16-5/8" holes in the rock and using Epcon Ceramic 6 epoxy or equivalent and ½ inch galvanized cable (Figure 4). Two options for cabling of LWD to boulders are provided. The second option in Figure 4 provides a more natural appearance by minimizing exposure of the cable. When fastening cable around live trees, ensure that the cable is as close to the ground as possible or buried approximately 10 cm into the ground and wrapped around the base of a tree. Wrap cable in natural looking nylon or rubber material. As an alternative to cabling to live trees, deadman anchors can be placed in the ground on the bank.

At the time of construction, determining the best location for the LWD structures will require a visual examination of the thalweg profile. Typically, the LWD structure will be located at the deepest point in the thalweg profile. At all sites, LWD structures will:

- be situated in the thalweg and as close to the bank as possible;
- have a projection width above bankfull depth of less than 30% of the design bankfull width; or conversely
- have at least 70% of the design bankfull width unobstructed by LWD.

Table 3. Construction notes for specific rehabilitation sites in Headquarters Creek.

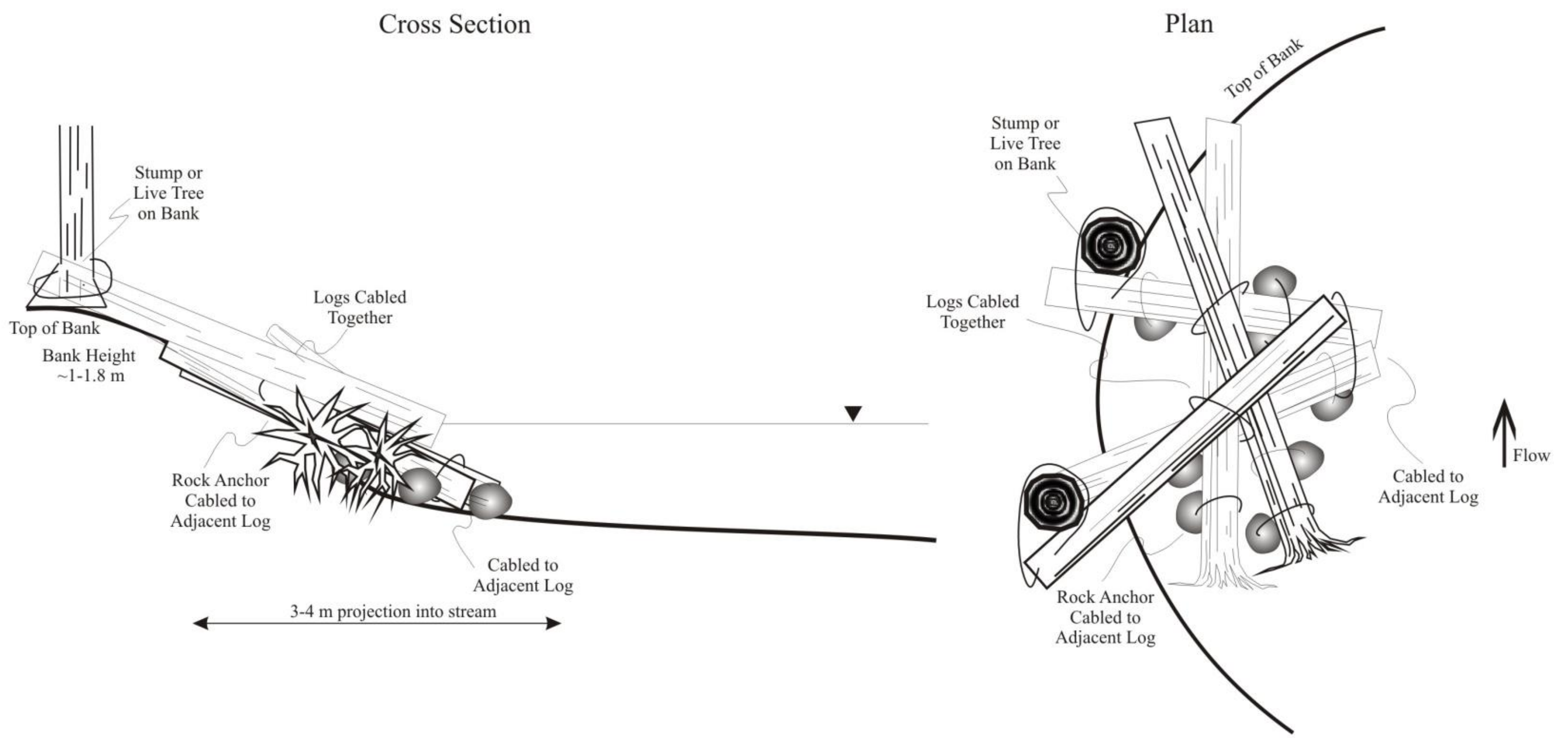
Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank		Rehabilitation Objectives and Construction Notes
0+000 m starting at left bank benchmark upstream of bedrock cascade in Headquarters Creek and progressing upstream					
0+012	1	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Locate structure in existing deep pool (>1 m); construct as sloping ramp structure with the LWD to facilitate the capture of floating LWD.
0+055	2	DJ-5	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate upstream end of structure at base of constructed riffle; excavate streambed to create a long narrow pool (2 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+082	3	Riffle	Fullspan	Rest. Obj.	To backwater and create suitable conditions for a spawning platform for trout and salmon; to diversify hydraulic habitat on the downstream face of the existing riffle; to increase the area of high quality summer rearing habitat for rainbow parr.
				1	Construct a new riffle with crest elevation ~0.7 m higher than existing streambed; rock diameters for crest and core should range between 0.25 and 0.7 m; place six 0.6-0.7 m diameter boulders on downstream face of riffle; raise low area of right bank floodplain to prevent erosion around edge of riffle.
				2	Follow construction guidelines in rehabilitation design drawing and schematic riffle construction sketch.
0+102	4	Spawning Platform	Fullspan	Rest. Obj.	To increase salmonid spawning habitat area and create conditions to accumulate spawning gravels.
				1	Place approximately 132 m^3 of 1-10 cm sized spawning gravel in a rectangular shape of 11 m wide by 20 m long upstream of the riffle crest.
				2	Top of the gravel should be at an elevation of 0.1 m less than the riffle crest elevation to ensure a minimum water depth of 0.1 m is maintained over the spawning area.
0+109	5	DJ-5	Right	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Locate upstream end of structure at base of constructed riffle; excavate streambed to create a long narrow pool (2 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+132	6	Riffle	Fullspan	Rest. Obj.	To backwater and create suitable conditions for a spawning platform for trout and salmon; to diversify hydraulic habitat on the downstream face of the existing riffle; to increase the area of high quality summer rearing habitat for rainbow parr.
				1	Construct a new riffle with crest elevation ~0.7 m higher than existing streambed; rock diameters for crest and core should range between 0.25 and 0.7 m; place six 0.6-0.7 m diameter boulders on downstream face of riffle; raise low area of right bank floodplain to prevent erosion around edge of riffle.
				2	Follow construction guidelines in rehabilitation design drawing and schematic riffle construction drawing.
0+152	7	Spawning Platform	Fullspan	Rest. Obj.	To increase salmonid spawning habitat area and create conditions to accumulate spawning gravels.
				1	Place approximately 132 m^3 of 1-10 cm sized spawning gravel in a rectangular shape of 11 m wide by 20 m long upstream of the riffle crest.
				2	Top of the gravel should be at an elevation of 0.1 m less than the riffle crest elevation to ensure a minimum water depth of 0.1 m is maintained over the spawning area.
0+190	8	DJ-5	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Locate upstream end of structure at base of existing riffle; excavate streambed to create a long narrow pool (2.5 m wide x 15 m long) with residual water depth of 0.6 m prior to constructing LWD structure.

Table 4. Summary of materials required for LWD structures and riffles with spawning platforms in Headquarters Creek.

						LWD Ballast		Rock Placements		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Volume (m^3)	Comments
0+000 m - starting at left bank benchmark upstream of bedrock cascade in Headquarters Creek and progressing upstream										
1	0+012	DJ-5	Left	5	0.5 x 10-12	8	0.8			Two logs with rootwads, three without
2	0+055	DJ-5	Right	5	0.5 x 10-12	8	0.8			Two logs with rootwads, three without
3	0+082	Riffle	Fullspan	0		0		0.25-0.7	105	
4	0+102	Spawning Platform	Fullspan	0		0		0.01-0.10	132	
5	0+109	DJ-5	Right	5	0.5 x 10-12	8	0.8			Two logs with rootwads, three without
6	0+132	Riffle	Fullspan	0		0		0.25-0.7	108	
7	0+152	Spawning Platform	Fullspan	0		0		0.01-0.10	132	
8	0+190	DJ-5	Right	5	0.5 x 10-12	8	0.8			Two logs with rootwads, three without
Total				20		32			477	

Table 5. Ballast requirements and boulder size options for the LWD structures in Headquarters Creek.

					Log		Rootwad		Alternative Quantities for Each Boulder Diameter (m)							
Site	Chainage (m)	Structure Type	No. of Logs	Average Submerged Length of Each Log (m)	0.5 @ 150 kg/m	0.7 @ 330kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (kg)	0.3 @ 35 kg	0.4 @ 90 kg	0.5 @ 190 kg	0.6 @ 300 kg	0.7 @ 480 kg	0.8 @ 700 kg	0.9 @ 1000 kg	1 @ 1400 kg
0+000 m - starting at left bank benchmark upstream of bedrock cascade in Headquarters Creek and progressing upstream																
1	0+012	DJ-5	5	6	4500	0	1320	5820	166	65	31	19	12	8	6	4
2	0+055	DJ-5	5	6	4500	0	1320	5820	166	65	31	19	12	8	6	4
3	0+082	Riffle	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0+102	Spawning Platform	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0+109	DJ-5	5	6	4500	0	1320	5820	166	65	31	19	12	8	6	4
6	0+132	Riffle	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0+152	Spawning Platform	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0+190	DJ-5	5	6	4500	0	1320	5820	166	65	31	19	12	8	6	4



Construction Notes:

1) LWD pieces may be between 10-12 m long x 0.4-0.5 m diameter.
2) Number and size of rock anchors depends on predicted maximum flow, maximum flow velocity and number and size of LWD used.
3) Ensure cables are tight to the LWD to reduce excessive flexing of the wire.
4) If using deadman anchors instead of stumps or live trees on the bank, care should be given to the positioning of the anchors to not allow the spur to shift downstream.

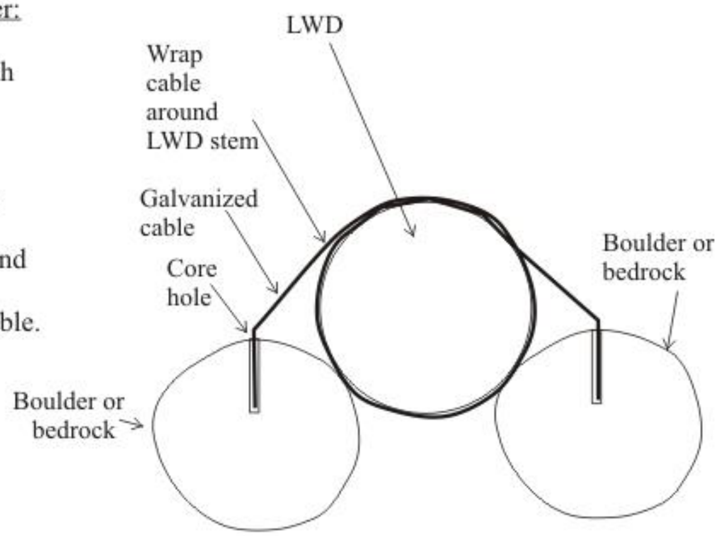
	LWD Design: DJ-5
	Typical LWD Jam Plan and Cross Section
LGL Limited	Scale: Not to Scale

Figure 3. Typical drawing for large woody debris (LWD) structure, DJ-5.

Two Cabling Options

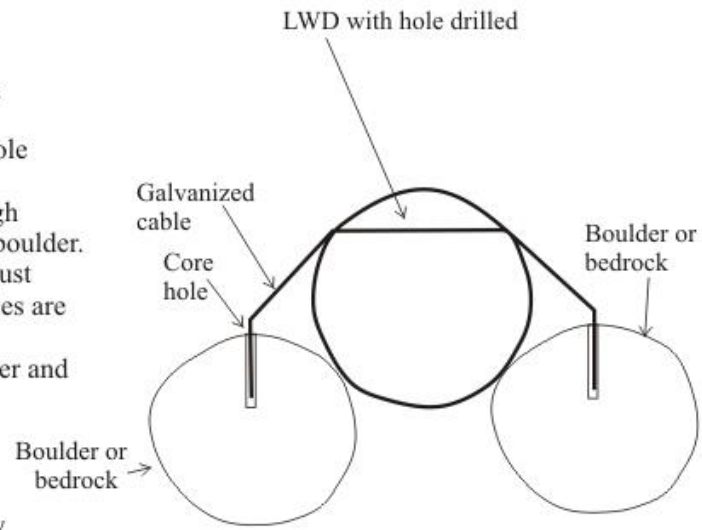
Attach cable to rock in following manner:

1- drill hole in rock 0.2-0.25 m deep with bit 1/16" larger in diameter than cable diameter (9/16" hole recommended).
2- clean holes thoroughly of dust using wire brush and water. Ensure holes are completely clean.
3- wrap cable (1/2" recommended) around LWD, and tighten.
4- squeeze epoxy into hole and insert cable.



Attach cable to rock in following manner:

1- drill a hole through the LWD using a hole diameter slightly larger than cable.
2- Pass the cable from one boulder, through the hole, and back down to the second boulder.
3- clean holes in boulders thoroughly of dust using wire brush and water. Ensure holes are completely clean.
4- squeeze epoxy into holes in each boulder and insert cable.



For additional information, refer to Slaney and Zaldokas (1997) WRP technical circular number 9, chapter 8, page 26.

Use Epcon Ceramic 6 epoxy or equivalent.

	Detail for Attaching Boulders to LWD.
LGL Limited	Scale: Not to scale

Figure 4. Detail for attaching boulders to large woody debris.

6.2 Riffle and Spawning Platform Construction

The uniform channel characteristics of this section of Headquarters Creek prevent the accumulation of suitably-sized spawning gravels. The channel presently lacks deep pools and large in-channel obstructions such as large boulders or LWD that would alter the hydraulics or gradient locally and cause smaller gravels to aggrade (Figure 5). In order to increase spawning habitat for trout and salmon, two riffles with spawning platforms are proposed for construction (Figure 6; Table 3 and Table 4). During floods, the riffle structures will widen the cross section locally and backwater the spawning gravels which will decrease the tractive force and increase the likelihood that the gravels will not be scoured downstream. In addition, pools will be excavated during riffle construction on the downstream side of the riffle and LWD will be added to provide cover for rearing salmonids. The pools will be excavated to create a residual depth of about 0.6 to 0.8 m.

All riffle structures should have a 20 to 1 downstream face, and should be constructed following the guidelines in the schematic riffle construction drawing (Figure 7). The riffles should be built with a range of rock sizes. The largest rocks are selected to be stable at the 1 in 50 yr flood stage. The larger rocks placed on the surface of the riffle create chutes and small drops that provide diverse rearing habitat for Steelhead/Rainbow Trout parr and assist fish passage at low flows. These rocks are the most vulnerable to movement and represent the upper range of rock size required for the riffle. An approximation of the maximum size required may be obtained by analyzing the tractive force on the face of the riffle and applying guidelines for selecting riprap materials (Newbury and Gaboury 1994). The tractive force T (kg/m^2) may be estimated as T = 1000 x Flow Depth (D in meters) x Slope of the Downstream Face of the Riffle (S in m/m) or:

$$T = 1000 \times D \times S \qquad \text{(Chow 1959)}$$

Although the gradient in the rehabilitation section of Headquarters Creek is approximately 0.4%, the stability of the riffle materials under the design flow condition can be tested where critical flow is assumed to occur on the downstream riffle face which has a 20 to 1 (5%) slope. The design discharge for Headquarters Creek would be about 22 cms (Table 1). This is the estimated maximum annual flow with a 50 yr recurrence interval and it is based on a unit value of 824 $l/sec/km^2$.

In this case, the critical depth in the channel at the design discharge (1 in 50 yr flood) would be solved using the continuity equation and mean channel width. The channel width for Headquarters Creek at the design discharge was estimated at about 11 m. Using this mean width, a stable rock size for the riffle structures was determined from the following formulae:

$$\text{Discharge (Q)} = \text{velocity} \times \text{depth (d)} \times \text{width}$$

$$\text{with } v_c = (g \times d)^{1/2} \text{ substituted for velocity}$$

$$22 = (9.8 \times d)^{1/2} \times d \times 11$$

$$d = 0.74 \text{ m}$$

$$\text{Tractive Force (T)} = 1000 \times \text{depth (m)} \times \text{slope (m/m)}$$
$$T = 1000 \times 0.74 \times 0.05$$
$$T = 37 \text{ kg/m}^2$$

Studies of stable channels, summarized by Lane (1955), indicate that the relationship between the tractive force and bed material diameter at incipient motion for pebble-size and larger materials is T (kg/m^2) = diameter (ϕ cm). A safety factor of 1.5 is recommended (U.S. Federal Highway Administration 1988). Stable rock size is then determined by:

Stable Rock Size: ϕ_s (cm) = 1500 x depth x slope or 1.5 times the tractive force.

$$\phi_s \text{ (cm)} = 1.5 \times 37$$
$$\phi_s \text{ (cm)} = 56 \text{ cm}$$

A minimum rock diameter of 0.6 m should be used for riffle construction. It is recommended that stones larger than the minimum stable diameter quoted above be used for the crest and downstream surface of the riffle. Smaller diameter rocks (0.25-0.4 m diameter) can be used in the core of the structure. Larger diameter boulders (>0.6 m) should be randomly spaced on the downstream face of the riffles approximately 20 to 30 cm apart to provide greater hydraulic and habitat diversity. The gradation for the rock should be: 80% larger than 0.25 m; 50% larger than 0.6 m, and 20% larger than 0.7 m. The volume of rock required for the two riffles is about 213 m^3 (Table 4).

Construction of spawning platforms is proposed on the upstream side of the two riffles (Table 3; Figure 6). The platforms will be approximately 11 m wide by 20 m long and have a surface elevation about 0.1 m lower than the riffle crest. Gravel size should range between 1 and 10 cm for Steelhead/Rainbow Trout, Cutthroat Trout and Pink and Coho Salmon (Whyte et al. 1997). The volume of gravel required for the two spawning platforms is about 264 m^3 (Table 4).

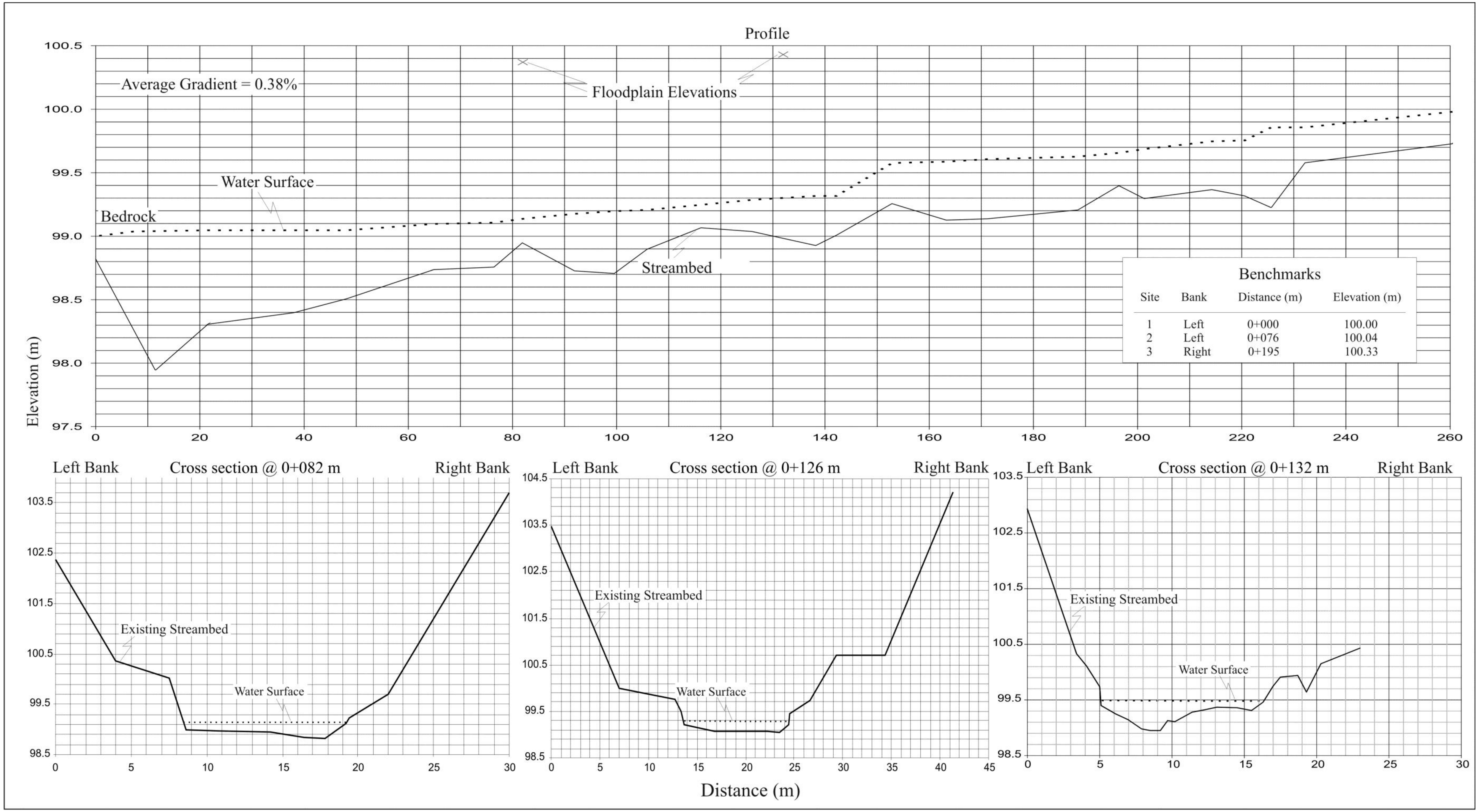


Figure 5. Existing profile and cross sections of Headquarters Creek.

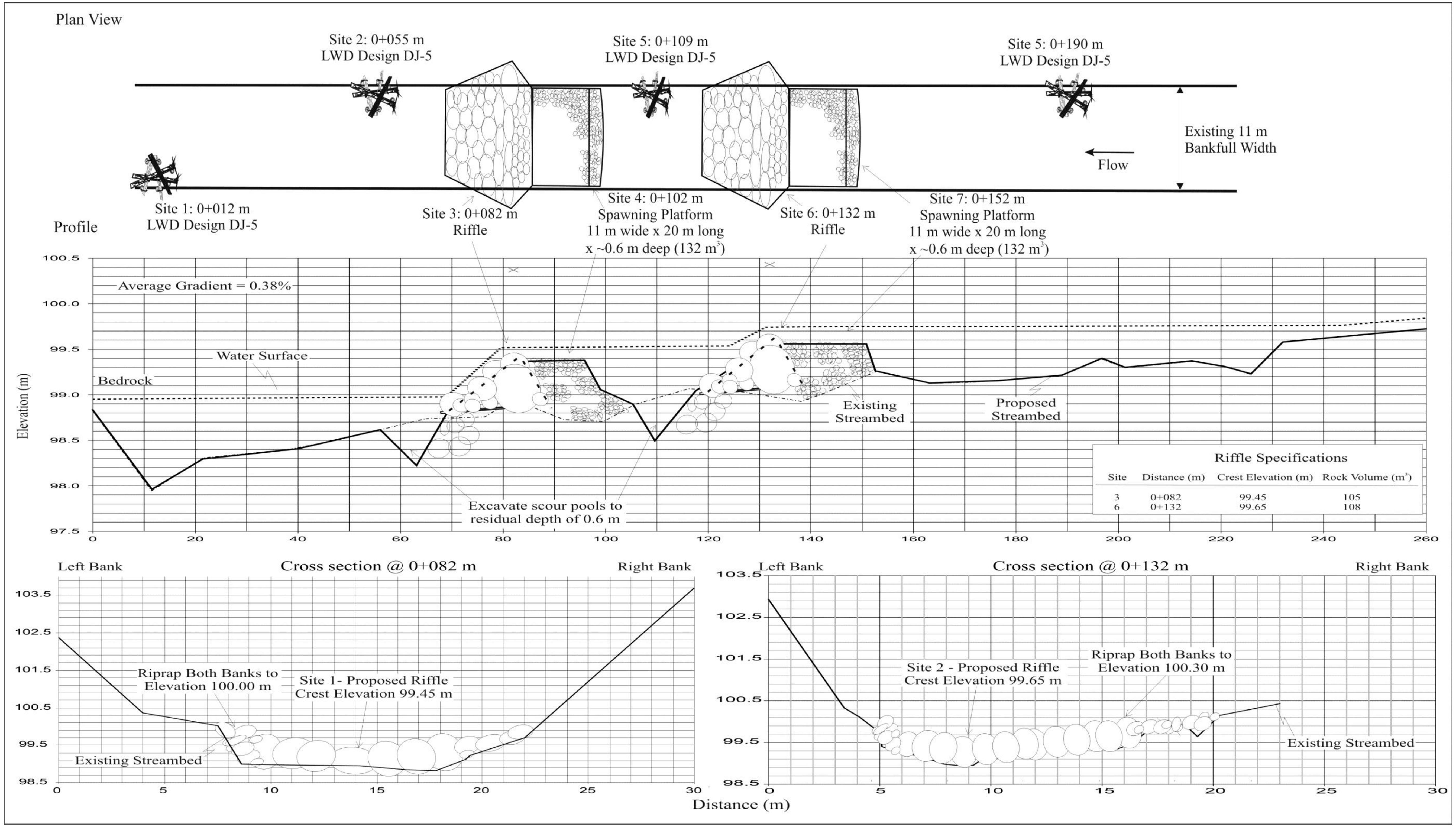
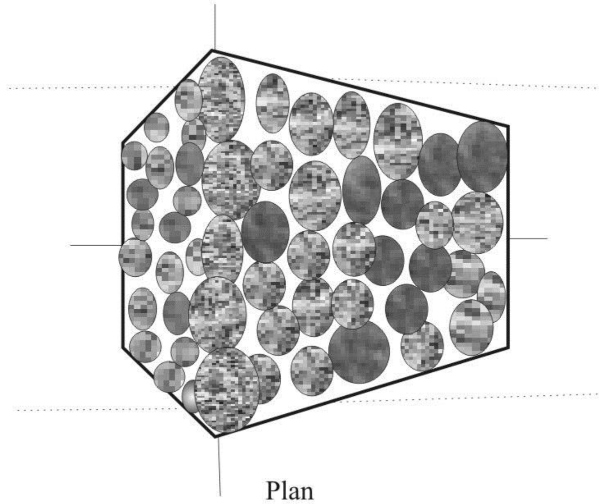


Figure 6. Plan, profile and cross sections of proposed rehabilitation measures in Headquarters Creek.

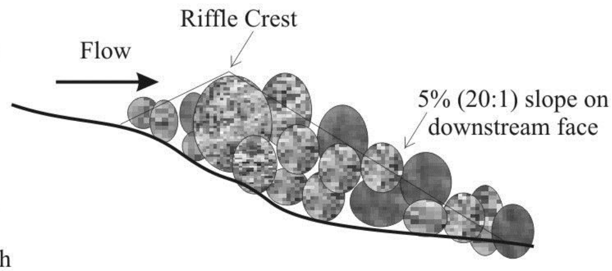
1. PLAN: build riffle crest across the stream with large diameter boulders; back up with next largest stone downstream



Plan

2. PROFILE: construct downstream face of riffle at a shallow re-entry slope that mimics local natural riffles

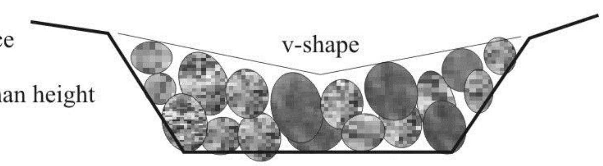
3. SURFACE: place large rocks randomly on the downstream face, 20 to 30 cm apart to dissipate energy and create low flow fish passage channels and back eddies



Profile

4. CROSS SECTION: V-shape the crest and face downwards to the centre of the riffle. Centre should be 0.3 to 0.6 m lower than height at the banks

5. BANKS: rip-rap both banks with embedded boulders and cobbles to the floodplain level



Cross Section

This drawing may be augmented for machine operators or hand labour crews with notes on the placement of construction stakes and photographs of natural and well-constructed riffles (after Newbury et al. 1997).

	Schematic Riffle Construction Drawing
LGL Limited	Scale: Not to scale

Figure 7. Schematic riffle construction drawing.

6.3 Access, Logistics, Materials and Labour

Access for delivery of materials to the proposed rehabilitation sites is good. Trails adjacent to the hydro right-of-way on the right bank pass within 100 m of the rehabilitation sites (Figure 1). Some minimal improvements would need to be made to the trails to allow truck access. It is recommended that a self-loading logging truck move the LWD to staging locations on the trail adjacent to the LWD and riffle sites. Similarly, a dump truck should bring the boulders to these locations. A small track excavator should then move materials from these drop-off locations to each rehabilitation site.

An excavator should be used to construct the LWD and riffle structures. Drilling, cabling and gluing of the boulders to the LWD should be done by the labour crew. The required crew and machinery will be a crew supervisor, an excavator operator, several swampers, and an environmental monitor. Continued professional input from a biologist/hydrologist that is familiar with LWD structure construction is recommended.

The materials required to construct the prescriptions as outlined include:

- Large logs with and without rootwads: 10 to 12 m long by 0.5 m average diameter;
- Boulders (0.8 m diameter) for ballasting the LWD;
- Boulders (0.25-0.7 m diameter) for riffle structures;
- Gravel (0.01-0.10 m diameter) for spawning platforms;
- Galvanized cable, ½” or larger; and
- Galvanized wood staples and cable clamps.

Special equipment required:

- Excavator(s) (track excavator);
- Dump and self-loading logging trucks;
- Rock and wood drills, and epoxy for fastening cable in rock; and
- Chainsaw winches to pull LWD into place (optional).

Labour required:

- Ground crew;
- Excavator operator;
- Crew supervisor; and
- Technical support.

The estimated cost for implementing the proposed works is summarized in Table 6. The estimate (2013$) is based on the work being done as a single project. Also, the estimate is conservative as it assumes boulder ballasting rather than embedding the tops of the LWD in the streambank.

Table 6. Cost estimate for rehabilitation project in Headquarters Creek.

	Description	Unit	Approx. Quantity	Unit Cost	Cost
Major Equipment:					
1	Excavator (15 ton), all found	hour	50	$125.00	$6,250.00
2	Excavator mob/demob.	km	80	$2.50	$200.00
3	Excavator (trails+transfer)	hour	40	$125.00	$5,000.00
4	Dump Truck, all found	hour	40	$120.00	$4,800.00
5	Self-loading Logging Truck, all found	hour	20	$140.00	$2,800.00
Sub-total major equipment					**$19,050.00**
Manpower:					
1	Project Coordinator (1)	day	20	$350.00	$7,000.00
2	Restoration Biologist (1)	day	1	$1,100.00	$1,100.00
2	Semi-skilled Labour (2)	day	10	$250.00	$2,500.00
Sub-total manpower					**$10,600.00**
Light Equipment:					
1	Drilling Equipment Rental	week	1	$500.00	$500.00
Sub-total light equipment					**$500.00**
Materials:					
1	LWD With and Without Rootwads	log	20	$100.00	$2,000.00
*2	Ballast Rock (0.8 m) for LWD Structures	m^3	30	$25.00	$750.00
3	Rock for Riffles	m^3	213	$25.00	$5,325.00
4	Spawning gravel	m^3	264	$27.50	$7,260.00
5	Miscellaneous (epoxy, clamps, cable,etc)		2	$1,000.00	$2,000.00
Sub-total materials					**$17,335.00**
Total Cost					**$47,485.00**

6.4 Fish Habitat Construction Timing Windows

The following table summarizes recommended timing windows for instream construction in Region 1 from the BC Ministry of Environment (2007) (http://www.env.gov.bc.ca/wsd/regions/vir/wateract/terms_conditions_vir.pdf).

Species	Construction Window
Coho salmon	15 Jun - 15 Sept
Pink salmon	1 May - 15 Aug
Steelhead	15 June - 15 Sept
Rainbow trout (resident)	15 Aug - 15 Sept
Cutthroat trout (resident)	15 Aug - 15 Sept
Available Window (pinks present)	15 Aug - 15 Aug

These dates refer to the period when there are no fish eggs or alevins present in the substrates of the river or creek. Please note that specific species timings will vary from year to year with variations in spawner run timings and other environmental conditions. The presence of Pink salmon and Steelhead/Rainbow Trout in Headquarters Creek will necessitate that the permissible windows be determined by both federal and provincial regional staff. In cases where construction activities will be conducted entirely "in-the-dry", extensions to these construction windows may be granted by agency staff.

6.5 Timing of Works, Priorities and Scheduling

Construction of the proposed rehabilitation works could proceed during the fisheries work window in one season, if adequate funding is available. Depending on the emergence of trout fry and Pink salmon spawning in Headquarters Creek, construction is recommended during the first two weeks of August. Construction should progress from the upstream to downstream LWD and riffle sites in order to reduce the backwatering effect of the riffle structures during streambed excavation and gravel placement.

6.6 Environmental Controls

A qualified environmental monitor must be on site at all times during construction to ensure that all potential impacts to fish habitat are mitigated. This person will be responsible for ensuring that sediment control procedures are followed as per the DFO Land Development Guidelines (Chilibeck 1992) and that fish salvage operations are conducted as necessary. Appendices A and B contain excerpts from the DFO Land Development Guidelines on a variety of issues related to work in and around streams. All construction personnel should be familiar with these guidelines prior to commencing work on the site. Four guiding principles are worthy of note here:

- the natural riparian vegetation and stream banks should be protected and/or rehabilitated during and after construction;
- prevent the introduction of pollutants and deleterious substances by controlling construction activities and site conditions;
- prevent the generation of sediment by utilizing proper instream construction controls and supervision; and
- conduct fish salvage as required to remove fish from the area of impact (using minnow traps, beach seines, or lastly, electrofishing).

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APPENDICES

Appendix A. Guidelines for Instream Work (Chilibeck 1992).

SECTION 5 INSTREAM WORK

Objective

It is recognized that at times it may be necessary to perform instream work as part of the process of developing land. The objective of the instream work guidelines is to promote careful planning and construction practices to limit the potential for impacts on the aquatic environment. Instream work is any work performed below the high water mark, either within or above the wetted perimeter, of any feature within the Fisheries Sensitive Zone (FSZ). Prior to commencement of any instream work and with sufficient lead time, proponents should consult with DFO/MOELP for information regarding FSZ species timing windows and construction methods. Because instream work has the potential to be extremely destructive to fish habitat, methods and procedures to minimize instream activities should be considered during the planning and design stages of a project. The procedures should be specifically designed to achieve the following objectives throughout the project.

- Protect the natural stream conditions and structure to promote stability of bank and bed structures, and retain riparian vegetation.
- Provide the instream conditions required for unhindered fish passage upstream and downstream.
- Prevent introduction of pollutants and deleterious substances by controlling construction activities and site conditions.
- Prevent generation of sediment, impacting fish and aquatic habitat, by utilizing the proper instream construction technique and supervision.

Guidelines for Instream Work

General guidelines for instream work include:

- Consult with local DFO/MOELP staff regarding presence, distribution and timing of migrations of fish species in the stream or watercourse, and FSZ window (Appendices 2 and 3).
- Plan instream work for periods within the confirmed FSZ window that will minimize disturbance and impact on fish and fish habitat.
- Plan instream work for periods of suitable stream and environmental conditions, determined in consultation with DFO/MOELP.
- Minimize the duration of the instream activities.
- All material placed within the wetted perimeter must be coarse, non-erodible, and non-toxic to fish. Do not remove gravels, rock or debris from any stream without the approval of DFO/MOELP.
- Minimize disturbance to stream banks where equipment enters and leaves the watercourse.
- Reconstruct and revegetate stream banks to their original condition as soon as activity has finished (see Section 2 in Chilibeck 1992).

- Use the proper equipment for the proposed construction activity. Avoid damage caused by stuck equipment or delays because of insufficient capacity for proposed work.
- Ensure that all construction equipment is mechanically sound to avoid leaks of oil, gasoline, hydraulic fluids and grease. Consider steam cleaning and check-up of construction equipment prior to use instream.
- Require the use of biodegradable hydraulic fluids for machinery used for instream work.

Timing of Instream Work

It must always be assumed that fish are present in a watercourse since the utilization and residency times for different species vary widely in accordance with their spawning and rearing cycle requirements. The windows of allowable times when instream work can be tolerated are often based on the reduced sensitivity of the fish to disturbances rather than the absence of fish during these times. The work should be coordinated and timed so that conflict with the fish populations is minimized. The utilization of various habitats (freshwater lakes, rivers, estuarine and marine environments) by both resident and anadromous fish populations place restrictions on instream work. **Timing windows of allowable instream work should always be confirmed with DFO/MOELP personnel responsible for the local area in which the proposed development is located**. Site specific differences exist and DFO/MOELP staff should be consulted early as possible in the planning process.

Sediment and Erosion Control during Instream Work

Sediment Control

The temporary containment and removal of sediment-laden water will probably be necessary during instream work, even when isolation techniques are used. Contaminated water within the work site must be pumped onto a land site where it will not re-enter the creek, or will do so only after filtration and settling has taken place.

Instream Machine Crossings

Where no alternate access to the opposite side of a watercourse exists, where it is impossible to do certain instream work from the banks, or where it is not feasible to isolate a worksite during construction, it may be necessary to take machinery and/or equipment into or through a flowing stream. In such situations, the local fisheries agencies must be consulted beforehand. Access should be arranged for the period of flow with the least impact to fish and fish habitat. All vehicles and equipment must be clean and in good repair to avoid leakage of petroleum products. Access by fording should be restricted to one crossing location, and traffic should be limited. Instream control measures and engineered roads using clean fill materials may be necessary. The access site must be chosen with care, where banks are low, the stream substrate is suitable, and the water shallow. Upon completion, the banks should be restored, restabilized and revegetated to prevent erosion.

Erosion Control and Streambank Rehabilitation

Any time a bank or the channel bottom is disturbed, restorative action should be taken to prevent erosion, siltation and to replace lost fish habitat. If adequate site selection and careful construction techniques are implemented, minimal disturbance and rehabilitation should be required to the riparian zone and the stream. Each site needs to be assessed individually at the planning stage to determine what rehabilitation will be needed. Erosion control materials should not encroach into the stream's cross-sectional width. Encroachment can create backwatering (flooding) and increase stream velocities that may cause scouring and erosion. It may be possible to reuse excavated materials. In some cases, however, they may have to be totally replaced with materials more suitable for fish habitat (i.e. using washed, silt-free gravel as backfill). Acceptable bank erosion control methods include hand seeding, hydroseeding, silt blankets, rock riprap and revegetation using plantings. Scalping existing instream material, like gravel bars or large rocks, will not be permitted. The top of banks and the riparian zone may also need to be stabilized, commonly by planting trees, shrubs, and various bushy types of vegetation. Native species should be used for all revegetation projects.

Maintenance of Instream Structures

Well designed and constructed instream structures should require minimum maintenance. Frequent inspections, particularly during high runoff periods, are very important. Improper functioning of a structure during or after a major storm event may indicate the need for minor repairs or modifications. It is advisable to perform such minor repairs immediately in order to prevent the need for major repairs later, and to ensure safety and reduce the environmental impact. General maintenance should be carried out according to an agreed schedule of works and agency contact procedure. If emergency measures are required, only justifiable essential preventative actions should be taken to protect life and major losses of property. If time allows, contact the fisheries agencies before carrying out emergency repairs.

Appendix B. Guidelines for Construction Practices within the Fisheries Sensitive Zone (Chilibeck 1992).

The following provisions are steps intended to protect leave strips and maintain a healthy functional riparian zone.

Planning and Minimizing Impacted Area

- Streambank characteristics and vegetation should be taken into account when planning development activities in and around rivers and streams.
- During development of the land, there should be no unauthorized work or disturbance into the FSZ.
- Where encroachment into a leave strip is required, specific plans must be prepared and approved by DFO/MOELP in advance.
- Requests for permission to encroach will only be considered for major vehicle or footbridge crossings, utility crossings, and stormwater discharge outfalls.
- The plans for such encroachments should include details including the extent of work areas; plans for the control of water discharged from the work area; the timing of work; and the details for restoration after construction.
- Carefully select access points to streambank through the riparian zone, minimize the size and duration of disturbance, and preserve streamside vegetation and undergrowth wherever possible.
- Limit machinery and equipment access and direct disturbance to streambank areas.

Stabilizing Impacted Area

- Physical stabilization of eroding or eroded banks may be required to promote bank stability and regeneration of riparian vegetation.
- Design and construction of stabilization works should prevent their subsequent erosion.
- Remove disturbed, unstable debris from the riparian zone to prevent it from being swept away during high water.
- Retain stable large organic debris (LOD) which does not impede flows and fish migration, or promote bank erosion.

Revegetating Impacted Area

- Revegetate disturbed areas immediately following completion of work in riparian zones.
- Establish ground cover to prevent surface erosion and deeper rooted plants and shrubs to prevent streambank erosion.
- Cedar, vine maple, alder, cottonwood, willow, salmonberry and red osier dogwood are common native plants used to augment brush and large plant formation.
- Large tree species will provide long-term sources of LOD.

PHOTO PLATES

Photo 1. Looking downstream at Site 0+055 m on the right bank of Headquarters Creek.

Photo 2. Looking downstream at proposed riffle and spawning platform (Sites 0+082 and 0+102 m) in Headquarters Creek.

Photo 3. Looking downstream at Site 0+109 m on the right bank of Headquarters Creek.

Photo 4. Looking upstream at proposed riffle and spawning platform (Sites 0+132 and 0+152 m) in Headquarters Creek (site is immediately upstream of yellow tripod).

Photo 5. Looking upstream at Site 0+190 m on the right bank of Headquarters Creek.