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Volume 1 of 2

**FISH HABITAT RESTORATION DESIGNS
FOR FIVE EAST VANCOUVER ISLAND
WATERSHEDS**

**Ministry of Water, Land and Air Protection
Nanaimo, BC**

September 2002

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WATERSHEDS**

Submitted to:

BC Conservation Foundation

For:

**Ministry of Water, Land and Air Protection
Nanaimo, BC**

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ABSTRACT

Under the auspices of the BC Ministry of Water, Land and Air Protection, BC Conservation Foundation and LGL Limited identified potential restoration sites in five watersheds on east Vancouver Island including Chemainus, Nanaimo, Little Qualicum, Oyster, and Quinsam rivers. The report provides instream restoration designs in the mainstems of the five major watersheds, as well as Deadwood Creek, Haslam Creek, Little Oyster River, and Cold Creek. The restoration designs target all life stages of salmonids found within the proposed restoration sections of the five watersheds, but in particular the holding and rearing habitats for those species that spend an extended period of time as juveniles in fresh water. A total of about 41 km of stream and 371 structures were prescribed for instream restoration, with more than 4 km of off-channel habitat being identified for further surveys and design. Boulder-ballasted LWD structures, riffle enhancement, and spawning gravel placement were restoration treatments recommended. The estimated cost to implement restoration work at all 371 restoration sites was approximately \$1,007,800.

Flow release options for Fourth Lake were examined to determine if water temperatures could be increased to benefit trout rearing in the Nanaimo River downstream of the lake outlet pipe. From the analysis, it was estimated that flow releases of 2 m³/s from a fixed elevation invert at 8 m below Full Supply Level will provide, on average, temperatures of 14 to 16 °C in the Nanaimo River below Fourth Lake from 1 July to 30 September. Increasing summer temperatures from the existing range of 6.5-14 °C to an estimated range of 14-16 °C would affect at least 9 km of river or 180,000 m² of habitat. Increasing the outlet discharges to between 2.5 and 3.2 m³/s would require a lower elevation invert and would probably result in lower temperatures in the Nanaimo River. However, lower temperatures could be mitigated by the construction of an outlet structure that allows for water releases over a range of lake elevations rather than from a fixed elevation. The former structure would be more effective for steelhead / rainbow trout production. Temperature and volume values should be refined after a water balance for the reservoir has been completed.

1.0 INTRODUCTION

The BC Ministry of Water, Land and Air Protection (MWLAP), in cooperation with Fisheries and Oceans Canada (DFO), Habitat Restoration Unit, South Coast Division, have proposed to undertake fish habitat restoration work in five major watersheds on east Vancouver Island. These watersheds include: Chemainus River, Nanaimo River, Little Qualicum River, Oyster River, and Quinsam River (Figure 1). The BC Conservation Foundation and LGL Limited were contracted to identify potential restoration sites and prepare site-specific designs in these five watersheds.

To date there has been relatively few instream projects in the priority watersheds or projects that focused on preparing instream habitat restoration designs (Wightman et al. 1998; Appendix 4). DFO and MWLAP have investigated the enhancement potential of numerous off-channel sites in Oyster and Nanaimo Rivers (Griffith 1992). DFO have also constructed off-channel works in the Oyster River (four sites), Quinsam River (Cold Creek modifications) and Chemainus River (Westholme channel). DFO and/or MWLAP have improved fish passage in the mainstem or tributaries of Oyster River (Woodhus Creek) and Little Qualicum (Whisky Creek). In addition, there have been investigations of improving fish passage at Copper Canyon in the Chemainus River and at the Bore Hole and White Rapids in the Nanaimo River, but only limited work has been undertaken by DFO to improve spring chinook passage at the Bore Hole (Wightman et al. 1998).

Biophysical assessments in the five watersheds have also been limited to date (Appendix 4). Lirette et al. (1987) completed biophysical inventories in Chemainus, Nanaimo and Little Qualicum Rivers. The primary objective of these inventories was to assess steelhead habitat capability. A summary of the habitat characteristics for Quinsam River were described in a comprehensive literature review by Burt (1999). BC Hydro also contracted a biophysical assessment on the Quinsam River in 1999. Other assessments have been completed under the Urban Salmon Habitat Program including: Haslam (Hanelt 2001) and Thatcher creeks in the Nanaimo River, and several tributaries of the Oyster River.

The bulk of the land within the watersheds is privately owned, with Weyerhaeuser and TimberWest being the largest land holders. For the most part, our restoration designs have focused on mainstem habitats. However, in the Nanaimo River only a short section of mainstem was proposed for spawning enhancement, and two tributaries, Deadwood and Haslam creeks, had instream habitat designs prepared. An assessment to determine storage release options and benefits of providing near-surface releases from Fourth Lake to the Nanaimo River was also completed. Restoration designs were also prepared for other tributaries, including Little Oyster River and Cold Creek (Quinsam River). Potential off-channel sites were identified in all five watersheds but level surveys and designs were not undertaken in this project.

This assessment and design project is a fundamental step in habitat restoration as it provides site-specific fish habitat restoration designs and construction procedures that will be implemented in an upcoming instream work window. The report provides instream restoration designs in the mainstems of the five major watersheds, as well as Deadwood Creek, Haslam Creek, Little Oyster River, and Cold Creek. A total of about 41 km of stream and 371 structures were prescribed for instream restoration, with more than 4 km of off-channel habitat being identified for further surveys and design. The restoration designs target all life stages of salmonids found within the proposed restoration sections of the five watersheds, but in particular the holding and rearing habitats for those species that spend an extended period of time as juveniles in fresh water. Therefore, the target species in this project include coho salmon, steelhead (rainbow), cutthroat and Dolly Varden. Included are the maps, construction drawings, materials summary, work plan, schedule and estimated costs for the proposed projects.

2.0 ASSESSMENT METHODS

Field reconnaissance for the siting and design of restoration treatments was conducted between 13 July and 3 October 2001. Field information was collected for all sites and included:

- locating each proposed restoration 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, ground photographs of the proposed instream restoration sites were taken.

Level surveys were completed at the proposed spawning enhancement site in the Nanaimo River immediately upstream of First Lake to provide:

- a streambed and water surface profile, and channel cross sections; and
- a measurement of gradient, bankfull width, bankfull height, and restoration site length.

3.0 DESCRIPTION OF STUDY AREA

Our investigations were limited to selected reaches within the anadromous sections of the five east Vancouver Island watersheds. These reaches were identified through discussions with C. Wightman (MWLAP) and J. Craig (BCCF). Prioritization for reach selection was based on:

- relative abundance of steelhead adults and juveniles being observed during snorkel surveys;
- high potential or observed utilization by coho juveniles for summer rearing and overwintering;
- potential to benefit other native resident and anadromous salmonids;
- relatively stable channels with a low to moderate likelihood that restoration works would be negatively impacted by current watershed processes and conditions; and
- vehicular access to restoration sites to facilitate equipment and material delivery during construction.

The study watersheds ranged widely in size, from about 4.4 to 820 km² in drainage area and with known accessible lengths between 9.5 and 93.7 km (Table 1). Bankfull channel widths at the restoration sites averaged between 6.5 and 44 m. All of the stream reaches where restoration designs were prepared had average gradients that were less than 1.7 %, with the majority averaging between 0.3 and 1% (Figures 2 to 9). Riffle-pool morphology dominated the channel reaches that were surveyed. In general, all the watersheds have had some riparian logging within the restoration sections but in most cases this occurred more than 30 years ago. All channels showed signs of impacts from historical riparian logging. We observed evidence of aggradation in the form of large gravel/cobble bars in some sections of all the streams in the project. Also, Large Woody Debris (LWD) was limited or absent from the channel in all streams, and when present, was oriented parallel with the banks indicating channel perturbation.

3.1 Hydrology

Discharges have been gauged by Water Survey of Canada (1999) on all of the major watersheds within the study area (Table 2). Monthly flows in these coastal watersheds begin to rise in October in response to rainfall, peak in December, and decline through Spring with the lowest discharges occurring typically in August or September. Based on the frequency analysis, unit flood discharges with a return period of 50 years ranged between 758 and 1921 l/s/km². Mean annual flows in the study streams ranged between 4 and 40 cms or 31 and 75 l/s/km².

The two year return period seven day low flow ranges from 0.11 to 8.84 l/s/km² (Table 3). Our observations and reports from members of the Oyster River Enhancement Society suggest that the Little Oyster River frequently has extremely low discharges during the summer. The flow analysis for the Water Survey of Canada data also indicates extremely low seven day minima but the period of record is short at only six years. Chemainus River and Haslam Creek also appear to have considerably lower unit minimum discharges than the other east Vancouver Island watersheds.

3.2 Fisheries Resources

All species of Pacific salmon have been observed in the five study watersheds over the past 40 years with sockeye generally having the lowest abundance (Table 4; Appendix 5). Based on current salmon escapement averages, coho in Chemainus River appear to be below their long term averages, while chinook, chum and pink appear to be at or above their long term averages in all the watersheds. This may be partly due to hatchery augmentation, fry outplanting or artificial spawning channels, which occurs for coho in Chemainus River, chinook and coho in the Nanaimo River, pink, coho and chinook in the Quinsam River, chinook and chum in the Little Qualicum River, and pink and coho in the Oyster River.

Winter steelhead are also found in the five watersheds but stock status is now considered as moderate to high risk due to their low numbers since the mid-1990's (Wightman et al. 1998; MWLAP unpubl. data; Appendix 6). The distribution of steelhead and the more abundant salmon species are shown on Maps 1 to 5. Other species such as cutthroat, rainbow and Dolly Varden are numerous in the watersheds but their distributions are not shown on the maps.

3.3 Habitat Limitations

In pristine watersheds, riparian vegetation, particularly large conifers, provides much of the future supplies of LWD for instream fish habitat. A climax riparian community also contributes to the creation and maintenance of overwintering areas such as overflow channels and off-channel ponds, and stabilizes the streambanks to prevent dramatic changes in channel morphology. Optimum rearing habitat for salmonids requires cover, and historically in these coastal streams LWD provided instream cover for fish rearing in deeper pools. LWD also provides a functional influence on channel morphology in streams with bankfull widths less than 38 m or gradients <8% (Anonymous 1996).

Forest practices and other land uses have accelerated the rate of occurrence of some types of disturbance (i.e., major floods, debris torrents, riparian and channel changes) (Cederholm et al. 2000). Levy et al. (1996) identified the negative impacts of past forest harvesting on fish habitat. He attributed the impacts to channel morphology changes, altered flood hydrographs, increased sediment delivery, and a reduction in LWD recruitment.

We observed evidence of channel morphology changes in the study watersheds, as indicated by channel widening, extensive gravel bars, pool-infilling, reduced pool frequency, and a lack of functional instream LWD. Historic logging practices in the study watersheds often removed most of the conifers from the riparian area of mainstem and tributary channels. The loss of large conifer recruitment

from the riparian areas to the stream channels has impacted both instream and off-channel summer and winter rearing habitat in these watersheds. This has particularly impacted juvenile salmon and trout that rear and overwinter in freshwater. In addition, it has affected adult fish that require suitable holding pools for migration and spawning.

Similar changes to channel morphology and watershed processes, and consequently fish habitat, can occur as a consequence of agricultural or residential developments. Within our project area, these impacts have occurred primarily in the lower reaches of Haslam Creek and Chemainus, Oyster and Quinsam rivers.

4.0 RESTORATION OBJECTIVES

The projects described below will mitigate habitat impacts that have occurred historically within the watersheds. In the proposed restoration works, the biological objectives include:

- improving overwintering and rearing habitat for native salmon, steelhead, trout and char;
- increasing juvenile fish access to overwintering habitats;
- increasing spawning area for resident and anadromous trout;
- increasing fry densities in LWD complexed sites to 0.9 coho fry/m² and 0.3 trout fry/m²; and
- increasing trout parr densities in LWD and boulder-complexed sites to 0.2 to 0.3 parr/m².

The proposed restoration activities to meet site-level objectives include:

- constructing LWD structures in mainstem and tributary sites to provide cover and promote pool scour;
- placing large diameter boulders in runs and on the downstream face and scour pools of existing riffles to diversify hydraulic habitats for juvenile fish; and
- placing spawning gravel in selected locations to increase preferred spawning area.

5.0 FISH HABITAT REHABILITATION

5.1 LWD Structures

LWD structures will be built at specific sites in the five watersheds (Maps 6 to 11; Tables 5 to 28; Photos 1 to 343). Each proposed LWD structure will be comprised of 1 to 6 logs (Figures 10 to 22). It is anticipated that the logs with rootwads will have an average dbh of 0.5 to 0.7 m and be approximately 4 to 15 m long. Although some LWD is available currently at the proposed sites, it is assumed in the materials summary tables that all structure materials will 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 structures. Alternatively, the tops of the LWD will be buried in the streambank (e.g., Figure 15).

Ballast requirements for LWD designs, e.g., LT-3, LT-6, and DJ-5, 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). As an example, 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 ≥ 1.5 for buoyancy and sliding (D'Aoust and Millar 1999). Effective length refers to the length of log projecting into the stream.

In situations where the LWD structure is not constructed in a triangular manner, ballast requirements should be determined assuming that each log is a 'single-log lateral jam' (e.g., LO-3 structure) (D'Aoust and Millar 1999; Slaney et al. 1997). In order to determine the ballast requirements for this type of structure, a design velocity estimate using the formula $V=20(HS)^{1/2}$ is required. Channel gradient (S) is $\leq 1\%$ at the locations where these structures are proposed. An average floodplain height (H) of about 2 m was assumed in the calculations. The design velocities were calculated as 2.8 m/sec. For 0.5 m diameter logs, the minimum ballast required per metre of effective length would then be 280 kg/m, with a safety factor against sliding of 2 (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 would require 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. Except where noted, 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. Similarly, fewer boulders would be required if the tops of the LWD are buried into the streambank about 2 to 3 m horizontally and 1 m vertically (Figure 15). We recommend that boulder ballasting be concentrated away from the channel thalweg and preferably on the streambanks. Cedar log piles should be considered as another alternative to boulder ballasting. The piles should be 0.5 m in diameter and buried 2.5 to 3 m below the existing thalweg elevation.

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 23). Two options for cabling of LWD to boulders are provided. The second option in Figure 23 provides a more natural appearance by minimizing exposure of the cable.

When fastening cable around live trees, the cable will be as close to the ground as possible or buried approximately 10 cm into the ground and wrapped around the base of a tree. Also, the cable will be wrapped in natural looking nylon or rubber material to protect the living tree. As an alternative to cabling to live trees, duckbill anchors or deadman anchors may 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 and plan view of the channel. Typically, the LWD structure will be located at the deepest point in the thalweg profile and upstream of a riffle or shallowest point on the thalweg profile (Figure 24). 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.

5.2 Boulder Placements

Boulder placements to increase hydraulic diversity in runs and on the downstream face and scour pools of riffles are proposed for four watercourses, including Chemainus River, Haslam Creek, Little Qualicum River and Oyster River (Tables 5, 8, 14 and 17). Boulders will be configured into a cluster when placed in scour pools of riffles or in run habitats. Construction of boulder clusters follows a typical design template (Figure 25). Larger diameter boulders should be randomly spaced on the downstream face of the riffles approximately 50 to 70 cm apart to provide greater hydraulic and habitat diversity.

The boulders are selected to be stable at flood stage. An approximation of the maximum size required may be obtained by analyzing the tractive force on the face of the riffle or for the run habitat, and applying guidelines for selecting riprap materials (Newbury and Gaboury 1994). The tractive force T (kg/m^2) may be estimated as $T = 1000 \times \text{Flow Depth (D in meters)} \times \text{Slope of the Downstream Face of the Riffle or Run (S in m/m)}$ or:

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

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 $T \text{ (kg/m}^2\text{)} = \text{diameter (}\phi \text{ cm)}$. A safety factor of $1.5 \times \phi \text{ cm}$ is recommended for selecting stable rock diameters (U.S. Federal Highway Administration 1988).

A conservative depth of flow of 2 m and a riffle slope of 2.5% was selected in the tractive force calculations where boulders are placed on the downstream face of the riffle. Average channel gradients obtained from the long profiles (Figures 2 to 9) were used in the calculations for determining stable rock sizes for boulder clusters. Stable rock sizes based on the tractive force equation were 0.2 to 0.3 m for boulder clusters, and 0.8 m for riffles (Table 29). However, the minimum sizes we recommend for boulder clusters range from 0.5 to 0.7 m, while the minimum for riffle enhancement is 0.8 m. The recommended rock sizes will maximize hydraulic diversity and provide optimal habitat conditions for steelhead and rainbow parr in particular.

5.3 Spawning Enhancement

An opportunity exists to improve spawning habitat for rainbow trout in the Nanaimo River immediately upstream of First Lake (Map 8). Level surveys of the site found that the water surface gradient from the lake upstream to the bridge was 0.4%, with a localized gradient over the proposed spawning area of 0.1%. The average velocity at the time of the survey (3 October 2001) was 0.3 m/s near the right bank and 0.4 m/s mid-stream. The proposed site had a water depth of less than 1.4 m at 3 October 2001 flows (Figure 26). The proposed site extends over a distance of 20 m and a width of 7 m for a potential spawning area of about 140 m². The gravel should be placed along the right bank, extending out from the water's edge about 7 m at a 2 to 1 or 0.4% slope. The stream-side edge of the gravel placement will have a 2 to 1 or 50% slope and larger diameter boulders (0.5-0.6 m) should be placed at the base of the slope to reduce sloughing. A gravel size between 6 and 80 mm is recommended to provide opportunities for both steelhead and rainbow trout at the spawning site. The gravel gradation should be: 20% from 6 to 20 mm, 20% from 20 to 40 mm, 40% from 40 to 60 mm and 20% from 60 to 80 mm. It is estimated that about 70 m³ of gravel and 40 m³ of 0.5-0.6 m diameter boulders will be required.

The tractive force at the spawning site ranges between 2.5 and 4.0 kg/m², assuming a depth of flow of 2 to 2.5 m and a slope of 0.1 to 0.2%. As discussed above, the relationship between the tractive force and bed material diameter at incipient motion for pebble-size and larger materials is $T \text{ (kg/m}^2\text{)} = \text{diameter (}\phi \text{ cm)}$ (Lane 1955). Therefore, some displacement of the spawning gravel less than 40 mm in size will occur over time. Monitoring of the stability of the spawning gravel should be undertaken annually to determine the possible need for replenishment.

5.4 Flow Release Options for Fourth Lake

The Fourth Lake reservoir was constructed in the early 1950's by H.R. MacMillan Export Co. Ltd., Pulp Division, Nanaimo. It is currently owned and operated by Pope and Talbot Ltd., Harmac Pulp Operations, Nanaimo. The reservoir has a live storage capacity of 38.6 million cubic metres (Anonymous 1993; Figure 27). Flow releases from the reservoir compensate for withdrawals made downstream near TCH 1 for use at Harmac Pulp Operations and to maintain minimum flows for fish. Migration of fall spawning chinook is particularly difficult if flows are less than 1.4 m³/s within the reach downstream of the Harmac intakes (Anonymous 1993). Following established rule curves and operational guidelines, coordinated flow releases between the Greater Nanaimo Water District that operates Jump Lake reservoir and Harmac Pulp Operations ensures a minimum 1.4 m³/s residual flow is maintained below the Harmac intake. Actual flow releases from Fourth Lake between 1996 and 2001 have typically averaged less than 2 m³/s in July and August, ranging between 0.57 and 3.4 m³/s on a daily basis (Figure 28; Appendix 7). A pulse flow release of about 14 m³/s has occurred regularly in late September or early October to stimulate the chinook spawning migration. With recent plant upgrading that now incorporates water recycling and effluent treatment, Harmac has, since 1994/95, reduced the amount of water it requires. Therefore, the average daily discharge released from Fourth Lake is less now than prior to 1994 (D. Groeneveld, Pope and Talbot Ltd., Harmac Pulp Operations, pers. comm.).

Since 1985, there have been documented concerns within the BC Ministry of Water, Land and Air Protection that cold water releases from Fourth Lake were having a negative impact on trout growth and production in the Nanaimo River for some distance downstream of the outlet pipe (BC MWLAP library, Nanaimo unpubl. information). The tunnel invert is located at the bottom of the lake at 285.3 m, so water temperature of the release flows are usually between 6 and 9 °C (Figures 27, 29 and 30). The Ministry undertook a brief study in 1986 to determine if a significant problem exists as a result of cold water releases from Fourth Lake (BC MWLAP library, Nanaimo 1986 unpubl. report). The study found that cold water releases affected water temperatures as far downstream as Second Lake, potentially causing a 38% loss in steelhead fry usable habitat within the first 6 km downstream of the outlet pipe. Water temperatures were measured in the Nanaimo River, above and below the Fourth Lake outlet pipe in July, August and September, 1986 (Figure 29). Water temperatures in the Nanaimo River above the outlet pipe averaged 17.4 °C during this period whereas outlet releases averaged 7 °C.

Flow release options for Fourth Lake were examined to determine if water temperatures could be increased to benefit trout rearing in the Nanaimo River downstream of the lake outlet pipe. Various scenarios were undertaken to examine the resultant discharges and water temperatures under various flow release options (Table 30). In this analysis, temperature of releases from Fourth Lake from

various fixed elevation pipes is based on a 1979 lake survey by MWLAP (Nanaimo library, unpubl. data) (Figure 30). An estimate of Nanaimo River flows at Rockyrun Creek were used to approximate natural river flows upstream of the outlet pipe (Table 2). The water volume available at various invert depths (i.e., 4 to 14 m) and time period of discharge determines the Fourth Lake outlet releases. Water temperatures are estimated from the relative volume contributions from the two sources. Evaporation or natural inputs to the reservoir have not been considered in this analysis, nor has a water balance been calculated to determine the annual reservoir recharge. Also, the analysis does not consider the potential increase in outlet flow temperature from a fixed elevation invert with reservoir drawdown through the summer. As historical records have shown, it was assumed in this analysis that the reservoir was at Full Supply Level (FSL) of 319.7 m at the beginning of the discharges (Figure 27; Appendix 7). Since 1996, except for pulse flows, discharges released from the Fourth Lake outlet have been between 0.57 and 3.4 m³/s (Pope and Talbot Ltd., Harmac Pulp Operations unpubl. data; Figure 28; Appendix 7). Consequently, the release options examined scenarios between 2 and 3.2 m³/s that provided a range of discharges similar to current operations. However, additional scenarios with Fourth Lake discharges of less than 2 m³/s were calculated solely to demonstrate temperature effects of a higher invert elevation.

The precision of this analysis was evaluated using measured water temperatures and discharges from 1986 (Table 30). The water temperatures shown for the Nanaimo River were recorded 1.5 km downstream of the Fourth Lake outlet and discharges from the outlet pipe were measured by Harmac Pulp Operations. Unfortunately, average upper Nanaimo River discharges in Table 30 are based on estimates (Table 2). In this evaluation, stream temperature in the Nanaimo River was overestimated, probably as a consequence of the annual variability in upper Nanaimo River discharges. Nevertheless, the analysis does provide an indication of the temperature increases from a surface invert under average upper Nanaimo River discharges.

From the analysis, it is estimated that flow releases of 2 m³/s from a fixed elevation invert at 8 m below FSL will provide, on average, temperatures of 14 to 16 °C in the Nanaimo River below Fourth Lake from 1 July to 30 September (Table 30). In the 1986 survey, July 30 temperatures rose to 14 °C at about 9 km downstream of the outlet pipe (Figure 29). In August and September 1986, temperatures in the Nanaimo River reached 14 °C at Second Lake, approximately 15 km downstream of Fourth Lake. Increasing the outlet discharges to between 2.5 and 3.2 m³/s would require a lower elevation invert and would probably result in lower temperatures in the Nanaimo River. However, these temperature and volume values could be refined if a water balance for the reservoir was completed.

With temperatures between 12 and 18 °C considered optimal for rainbow trout growth (Raleigh et al. 1984), increasing summer temperatures from the existing range of 6.5-14 °C to an

estimated range of 14-16 °C over at least 9 km of habitat would be considered significant. With an average wetted channel width of 20 m, the total habitat area over the 9 km would equal about 180,000 m². This analysis suggests that water releases should be taken over a range of elevations to be most effective for steelhead / rainbow trout production. It is recommended that a detailed feasibility assessment with estimated costs for an outlet structure should be solicited from a civil engineer. The engineer should consider a multi-port structure with valved inverts at a range of elevations (e.g., 6, 10 and 14 m) that would take advantage of the warmer surface waters in the lake over the withdrawal period.

5.5 Off-channel Opportunities

Seventeen off-channel development opportunities were identified in the five watersheds (Table 31). The total length of the off-channel sites is estimated at over 4 km. All of the sites require further ground truthing after which those selected as high priorities should undergo groundwater monitoring and level or total station surveys. These investigations and surveys should be coordinated with M. Sheng at DFO Habitat Restoration Unit, South Coast Division.

Prior to channel construction at the high priority sites, groundwater standpipes should be installed and water levels monitored monthly for one year. A staff gauge should also be installed in the adjacent mainstem and water level readings should be taken on the same day as the standpipe elevations. A small track excavator can be used to install the standpipes on the floodplain adjacent to the wetted channel. It is preferable that the installations occur when the floodplain is 'dry' to minimize riparian area impacts. Approval from private landowners will be required to access the floodplain along most of these watersheds.

If initial groundwater levels are such that channel construction appears feasible, a level or total station survey of the proposed channel alignment should be undertaken. The survey should include elevations of the channel streambed, water surface, streambank and floodplain. The survey should also tie into the groundwater standpipe elevations, and the streambed and water surface of the adjacent river or creek at three locations along the length of the proposed channel. Based on the outcome of a feasibility assessment that follows standpipe monitoring and the elevation survey, a decision on whether or not to prepare a detailed design for the groundwater or side channel should be made.

6.0 PROJECT IMPLEMENTATION

6.1 Access, Logistics, Materials and Labour

Access for delivery of materials to the proposed restoration sites is generally good. In most

cases, permanent and deactivated logging roads or private landowner roads pass within 300 m of the restoration sites. Some minimal improvements would need to be made to the abandoned roads to allow truck access. Short access trails off the logging roads would need to be created to access individual LWD sites. It is recommended that a self-loading logging truck move the LWD to suitable staging areas near the project sites. Similarly, a dump truck should bring boulders to these locations. An excavator or forwarder should then move materials from these drop-off locations to each restoration site.

An excavator should be used to construct the LWD and boulder 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 and riffle structure construction is recommended.

The materials required to construct the prescriptions as outlined include:

- Large logs, preferably with branches and rootwads attached: 6-15 m long by 0.5-0.8 m average diameter;
- Rootwads only: >1.5 m diameter root plates;
- Boulders (0.8 m diameter) for ballasting the LWD;
- Gravel (6-80 mm diameter) for spawning area;
- Boulders (0.1-0.6 m diameter) for boulder clusters, riffles and spawning area;
- Galvanized cable, ½" or larger; and
- Galvanized wood staples and cable clamps.

Special equipment required:

- Excavator (e.g., Hitachi 200, Spyder or Cat E70B) for instream complexing);
- Dump and self-loading logging trucks;
- Forwarder;
- Rock and wood drill equipment, 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 costs for implementing the proposed works are summarized separately for the nine project areas in Table 32. To implement restoration work at all 371 restoration sites, the cost is estimated at approximately \$1,007,800. The estimates are based on the work being done as independent projects.

6.2 Fish Habitat Construction Timing Windows

The following table summarizes recommended timing windows for instream construction in Region 1 from the Department of Fisheries and Oceans Land Development Guidelines (Chilibeck 1992).

Species	Construction Window
Chinook salmon	15 Jul - 15 Sep
Coho salmon	15 Jun - 15 Sep
Pink salmon	1 May - 15 Aug
Chum salmon	15 May - 15 Sep
Sockeye salmon	1 Jun - 15 Sep
Kokanee	15 Jun - 31 Jul
Steelhead	1 Aug - 15 Nov
Rainbow trout (resident)	15 Aug - 15 Nov
Cutthroat trout (resident)	1 Aug - 30 Sep
Dolly Varden (resident)	1 Jun - 15 Sep
Available Window (pinks present)	15 Aug - 15 Aug
Available Window (no pinks)	15 Aug - 15 Sep

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 change from year to year with variations in spawner run timings and other environmental conditions. Actual permissible windows will

be determined by both federal and provincial fisheries staff. In cases where construction activities will be conducted entirely “in-the-dry”, extensions to these construction windows may be granted by agency staff. Note that if rainbow trout are not present in the project area, then the construction window commences on 1 August in Region 1.

6.3 Timing of Works, Priorities and Scheduling

A ‘Notification for Proposed Works and Changes In and About a Stream under Water Act Regulation 204/88’ for the proposed projects should be prepared for signature once specific sites have been confirmed for implementation (Appendix 8). It is anticipated that construction of the proposed restoration works in a portion of one watershed would proceed during the fisheries work window in one season. Depending on the emergence of trout fry and the presence of pink salmon in the target watershed, construction is recommended during August. Little Qualicum, Chemainus, and Oyster rivers would be considered the highest priorities for restoration work, followed by the Nanaimo River gravel placement, Quinsam River, Cold Creek, Deadwood Creek, and Haslam Creek. Installation of the standpipes in the potential high priority off-channel development sites should occur by late spring in order to capture the low flow period in the summer.

6.4 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 1-3 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).

7.0 LITERATURE CITED

- Anonymous. 1993. Nanaimo River water management plan. BC Ministry of Environment, Lands and Parks, Water Management, Nanaimo, BC. 147 p.
- Anonymous. 1996. Channel assessment procedure field guidebook. Province of B.C. Forest Practices Code.
- Burt, D. 1999. Literature review on fish and fish habitat of the Quinsam River system (Draft). Prepared for BC Hydro.
- Cederholm, C.J., D.H. Johnson, R.E. Bilby, L.G. Dominguez, A.M. Garrett, W.H. Graeber, E.L. Greda, M.D. Kunze, B.G. Marcot, J.F. Pamisano, R.W. Plotnikoff, W.G. Percy, C.A. Simenstad, and P.C. Trotter. 2000. Pacific salmon and wildlife - ecological contexts, relationships, and implications for management. Special Edition Tech. Rept., Prepared for D.H. Johnson and T.A. O'Neil (Manag. Dirs.), Wildlife-Habitat Relationships in Oregon and Washington. Washington Dept. of Fish and Wildlife, Olympia.
- Chilibeck, B. 1992. Land Development Guidelines for the Protection of Aquatic Habitat. Co-published by Ministry of Environment, Lands and Parks and Department of Fisheries and Oceans. British Columbia, Canada. 128 pp.
- Chow, V.T. 1959. Open Channel Hydraulics. McGraw-Hill, New York, NY. 680 p.
- D'Aoust, S.G. and R.G. Millar. 1999. Large Woody Debris Fish Habitat Structure Performance and Ballasting Requirements. British Columbia Ministry of Environment, Lands and Parks, and British Columbia Ministry of Forests, Watershed Restoration Program, Management Report No. 8, 119 pp.
- Griffith, R.P. 1992. Feasibility of fisheries enhancement undertakings in selected Vancouver Island streams. R.P. Griffith and Associates, Sidney, BC.
- Hanelt, R. 2001. Haslam Creek fish and fish habitat assessment, prioritizing restoration & protection of the fisheries resource. Prepared for Nanaimo Fish and Game Protective Assoc., Nanaimo, BC
- Levy, D.A., L.U. Young, and L.W. Dwernychuk. [eds.] 1996. Strait of Georgia fisheries sustainability review. Hatfield Consultants Ltd., West Vancouver, BC. 441 p.

- Lane, E.W. 1955. Design of Stable Channels. ASCE Transactions 120: 1234-1279.
- Lirette, M.G., R.S. Hooton, and V.A. Lewynsky. 1987. Preliminary steelhead production capability estimates for selected Vancouver Island streams. Fish. Tech. Circ. No. 74, BC Ministry of Environment. 23 p.
- Newbury, R.W. and M.N. Gaboury. 1994. Stream Analysis and Fish Habitat Design: A Field Manual. Second edition. Newbury Hydraulics, Gibsons, BC. 262 p.
- Newbury, R.W., M.N. Gaboury, and D.J. Bates. 1997. Restoring Habitats in Channelized or Uniform Streams Using Riffle and Pool Sequences. In Slaney, P.A. and D. Zaldokas [eds.] Fish Habitat Rehabilitation Procedures. British Columbia Ministry of Environment, Lands and Parks, and British Columbia Ministry of Forests, Watershed Restoration Program, Technical Circular No. 9.
- Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat suitability information: Rainbow trout. U.S. Fish and Wildlife Serv., Fort Collins, Colorado.
- Slaney, P.A., R.J. Finnegan, and R.G. Millar. 1997. Accelerating the Recovery of Log-jam Habitats: Large Woody Debris-boulder Complexes. In Slaney, P.A. and D. Zaldokas [eds.] Fish Habitat Rehabilitation Procedures. British Columbia Ministry of Environment, Lands and Parks, and British Columbia Ministry of Forests, Watershed Restoration Program, Technical Circular No. 9.
- Slaney, P.A. and D. Zaldokas [eds.]. 1997. Fish Habitat Rehabilitation Procedures. British Columbia Ministry of Environment, Lands and Parks, and British Columbia Ministry of Forests, Watershed Restoration Program, Technical Circular No. 9.
- U.S. Federal Highway Administration. 1988. Use of RipRap for Bank Protection. Highway Engineering Circular No. 11. Washington, DC.
- Water Survey of Canada. 1999. Historical Streamflow Summary-British Columbia. Environment Canada, Ottawa.
- Wightman, J.C., B.R. Ward, R.A. Ptolemy, F.N. Axford. 1998. A recovery plan for east coast Vancouver Island steelhead trout (Draft). BC Ministry of Environment, Lands and Parks, Nanaimo, BC. 131 p.

TABLES

Table 1. General characteristics of the East Vancouver Island watersheds investigated in this project.

Stream	Drainage Area (km ²)	Accessible Length (km)	Average Bankfull Width at Restoration Sites (measured range in m)	Average Slope at Restoration Sites (measured range)	Estimated Bankfull Discharge for Watershed (m ³ /s)
Chemainus River	359	63.6	28 (21-34)	0.0077 (0.0008-0.0186)	230
Nanaimo River	820	93.7	33.5 (33-34)	0.0033	507
Haslam Creek	122	13.7	44 (24-75)	0.0065 (0.0031-0.0105)	40
Deadwood Creek	63	-	16 (12-28)	0.0103 (0.0047-0.025)	20
Little Qualicum River	248	9.5	21 (18-24)	0.0071 (0.0048-0.0116)	94
Oyster River	300	46.3	40 (25-54)	0.0086 (0.0063-0.0124)	61
Little Oyster River	40	-	14.5 (9-20)	0.009 (0.015-0.002)	12
Quinsam River	280	36	28 (18-42)	0.007 (0.0049-0.0091)	122
Cold Creek	4.4	-	6.5	0.0167	2

Table 2. Summary of return period maximum daily discharges for the East Vancouver Island study streams.

Gauge			Station Name	Years	No. of Years	Area (km ²)	Unit Discharge (l/s/km ²)					Average Monthly Discharge (l/s/km ²)												
							Mean Annual	2 yr	10 yr	25 yr	50 yr	Max	January	February	March	April	May	June	July	August	September	October	November	December
08HA001*	Chemainus River near Westholme	1914-17, 1952-99	52	355	54	642	1088	1287	1426	1513	101	90	72	63	42	20	8	3	5	35	97	116		
08HB041*	Jump Creek at the Mouth *	1970-94	25	62.2	75	951	1431	1540	1590	1752	119	129	95	64	64	39	21	19	19	56	135	143		
08HB003*	Haslam Creek near Cassidy *	1914-15, 1949-62, 1993-98	22	95.6	44	325	633	717	758	681	75	76	51	62	39	15	5	3	5	35	75	85		
08HB005*	Nanaimo River near Extension	1913-27, 1948-64	32	645	63	693	1281	1634	1921	1938	101	99	60	71	61	37	15	7	15	58	102	125		
08HB034*	Nanaimo River near Cassidy	1965-1999	35	684	58	618	1041	1215	1329	1146	104	95	79	58	49	29	13	9	12	44	98	113		
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		
08HD023	Little Oyster River at Yorke Road	1994-1999	6	38	-	-	-	-	-	-	-	-	16	21	11	3	3	0	3	-	-	-		
08HB033	Nanaimo River above Rockyrun Creek	1963-64	2	75.6	-	-	-	-	-	-	-	-	-	-	-	42	48	41	44	208	-	-		
		Mean of All * Gauges Above			53	529	913	1075	1188	1221	87	84	63	56	50	32	15	9	11	41	88	99		
		Mean of * Stations Above			60	638	1032	1128	1174	1217	97	102	73	63	52	27	13	11	12	45	105	114		
Gauge			Station Name	Years	No. of Years	Area (km ²)	Discharge (m ³ /s)					Average Monthly Discharge (m ³ /s)												
							Mean Annual	2 yr	10 yr	25 yr	50 yr	Max	January	February	March	April	May	June	July	August	September	October	November	December
08HA001*	Chemainus River near Westholme	1914-17, 1952-99	52	355	19	228	386	457	506	537	35.7	32.1	25.4	22.4	15.0	7.1	2.7	1.2	1.8	12.5	34.3	41.1		
08HB041*	Jump Creek at the Mouth *	1970-94	25	62.2	5	59	89	96	99	109	7.4	8.0	5.9	4.0	4.0	2.4	1.3	1.2	1.2	3.5	8.4	8.9		
08HB003*	Haslam Creek near Cassidy *	1914-15, 1949-62, 1993-98	22	95.6	4	31	60	69	73	65	7.2	7.3	4.9	5.9	3.7	1.4	0.5	0.3	0.5	3.3	7.2	8.1		
08HB005*	Nanaimo River near Extension	1913-27, 1948-64	32	645	40	447	827	1054	1239	1250	64.9	63.9	39.0	46.0	39.5	24.0	9.4	4.2	9.6	37.7	65.9	80.8		
08HB034*	Nanaimo River near Cassidy	1965-1999	35	684	40	422	712	831	909	784	70.9	65.2	54.1	39.5	33.4	19.5	8.9	6.0	8.3	29.8	67.2	77.0		
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		
08HD023	Little Oyster River at Yorke Road	1994-1999	6	38	-	-	-	-	-	-	-	-	0.6	0.8	0.4	0.1	0.1	0.0	0.1	-	-	-		
08HB033	Nanaimo River above Rockyrun Creek	1963-64	2	75.6	-	-	-	-	-	-	-	-	-	-	-	3.2	3.6	3.1	3.3	15.7	-	-		
	Estimate for Nanaimo River at Rockyrun Creek (based on * stations)			75.6	4.5	48.2	78.0	85.3	88.8	92.0	7.3	7.7	5.5	4.8	3.9	2.0	1.0	0.8	0.9	3.4	8.0	8.6		

Table 3. Summary of return period seven day moving average minimum discharges for the East Vancouver Island study streams.

Gauge	Station Name	Years	No. of Years	Area (km ²)	Unit Discharge (l/s/km ²)			
					2 yr	10 yr	25 yr	50 yr
08HA001*	Chemainus River near Westholme	1914-17, 1952-99	52	355	1.23	0.61	0.52	0.40
08HB041*	Jump Creek at the Mouth *	1970-94	25	62.2	8.84	3.01	1.61	-
08HB003*	Haslam Creek near Cassidy *	1914-15, 1949-62, 1993-98	22	95.6	1.58	0.66	-	-
08HB005*	Nanaimo River near Extension	1913-27, 1948-64	32	645	3.05	1.81	1.46	-
08HB034*	Nanaimo River near Cassidy	1965-1999	35	684	5.53	3.81	2.92	-
08HB029*	Little Qualicum River near Qualicum Beach	1960-1986	27	237	4.95	3.65	3.31	-
08HD011*	Oyster River below Woodhus Creek	1973-1999	26	298	4.38	2.09	1.78	-
08HD005*	Quinsam River near Campbell River	1956-1999	44	280	6.39	4.65	3.68	-
08HD023	Little Oyster River at Yorke Road	1994-1999	6	38	0.11	-	-	-
08HB033	Nanaimo River above Rockyrun Creek	1963-64	2	75.6	-	-	-	-
	Mean of All * Gauges Above				4.49	2.54	-	-
	Mean of * Stations Above				5.21	1.83	-	-
Gauge	Station Name	Years	No. of Years	Area (km ²)	Discharge (m ³ /s)			
					2 yr	10 yr	25 yr	50 yr
08HA001*	Chemainus River near Westholme	1914-17, 1952-99	52	355	0.44	0.22	0.18	0.14
08HB041*	Jump Creek at the Mouth *	1970-94	25	62.2	0.55	0.19	0.10	-
08HB003*	Haslam Creek near Cassidy *	1914-15, 1949-62, 1993-98	22	95.6	0.15	0.06	-	-
08HB005*	Nanaimo River near Extension	1913-27, 1948-64	32	645	1.97	1.17	0.94	-
08HB034*	Nanaimo River near Cassidy	1965-1999	35	684	3.78	2.61	2.00	-
08HB029*	Little Qualicum River near Qualicum Beach	1960-1986	27	237	1.17	0.87	0.79	-
08HD011*	Oyster River below Woodhus Creek	1973-1999	26	298	1.30	0.62	0.53	-
08HD005*	Quinsam River near Campbell River	1956-1999	44	280	1.79	1.30	1.03	-
08HD023	Little Oyster River at Yorke Road	1994-1999	6	38	0.004	-	-	-
08HB033	Nanaimo River above Rockyrun Creek	1963-64	2	75.6	-	-	-	-
	Estimate for Nanaimo River at Rockyrun Creek (based on * stations)			75.6	0.39	0.14	-	-

Table 4. Fish species present in the five study watersheds. Source: Fish Wizard web site.

	Chemainus	Nanaimo	Little Qualicum	Oyster	Quinsam
Sockeye Salmon	x	x	x		x
Pink Salmon	x	x	x	x	x
Chum Salmon	x	x	x	x	x
Chinook Salmon	x	x	x	x	x
Coho Salmon	x	x	x	x	x
Steelhead	x	x	x	x	x
Resident Rainbow Trout	x	x	x	x	x
Anadromous Cutthroat Trout	x	x	x	x	
Resident Cutthroat Trout	x	x	x	x	x
Dolly Varden	x	x	x	x	x
Kokanee		x	x		x
Brown Trout			x		
Smallmouth Bass			x		
Slimy Sculpin				x	
Prickly Sculpin		x			
Longnose Dace				x	
Aleutian Sculpin		x			
Pumpkinseed		x			

Table 5. Construction notes for specific restoration sites in Chemainus River and Chipman Creek.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
Section E - 0+000 m starting from Hell's Gate and progressing downstream to Island Hwy					
0+255	1	LO-3	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Locate upstream end of structure at base of existing riffle; four boulders >1 m diameter on the left bank.
0+306	2	DJ-5	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Locate structure in existing pool; 10 boulders of 0.8-1.2 m diameter on the right bank at 0+332 m.
0+430	3	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Locate structure in existing pool; incorporate existing LWD in structure; boulder ballast unavailable on site.
0+480	4	DJ-5	Left	Rest. Obj. 1	Campsite and good road access to river for machines and material delivery
0+512			Left		To provide pool with LWD cover near left bank. Locate structure in existing pool; boulder ballast unavailable on site.
0+650			Left		Access road to river.
1+102	5	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Locate structure at base of existing riffle; boulder ballast unavailable on site.
1+180	6	LT-5	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Locate structure at base of existing riffle; boulder ballast unavailable on site.
1+222	7	LO-1	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Two LO-1 structures; locate one structure at base of existing riffle; locate other structure about 5 m downstream; one 1.2 m diameter boulder on site; additional boulder ballast required.
Section F - 0+000 m starting at Centra Gas Pipeline and progressing downstream					
0+150	8	LO-3	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Anchor boles to bedrock and place rootwad ends in the pool; adequate number of 0.8-0.9 m boulder ballast at 0+188 m; excellent road access to site on right bank.
0+978	9	LT-5	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Anchor boles to bedrock and place rootwad ends in the pool; anchor rootwads with boulders; adequate number of 1.2-1.4 m boulder ballast immediately upstream; difficult access to structure site.
Section A - 0+000 starting upstream of Humbird Creek and Park Access and progressing downstream					
0+008	10	LO-3	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Locate in deeper thalweg between bank and central cobble bar.
0+022	11	LSP-5	Left	Rest. Obj.	To act as a spur and deflector at the head of the vegetated bar.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
				1	Cable and anchor existing debris; spur should project from bar to end of rootwad that J.Craig is standing on.
0+046	12	LO-3	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Locate in 0.7 m deep pool.
0+096	13	DJ-5	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Two debris jam structures; anchor to fractured (fair quality) bedrock at downstream end of 1.5 m deep pool.
0+350	14	LO-3	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Place and anchor boles of LO-3 on bank rather than in water; locate structure adjacent to undercut bank; increase scour pool depth by re-locating >0.6 m boulders from channel to increase crest elevation of riffle at 0+367 m.
0+411	15	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Locate in scour pool (2 m deep) at base of existing riffle.
0+528	16	LO-3	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 m wide x 10 m long) with residual water depth of 0.7 m prior to constructing LWD structure; adequate boulder ballast on site.
0+921	17	LSP-5	Left	Rest. Obj.	To deflect flow towards DJ-5 structure at 0+942; to narrow the channel width.
				1	Construct as debris catcher with logs running almost parallel to the flow and sloping at a 30° angle to the streambed; use 10-12 m long logs to project structure ~8 m from left bank.
0+942	18	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 m wide x 10 m long) with residual water depth of 0.7 m prior to constructing LWD structure; some boulder ballast on site.
1+270	19	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Locate in 2 m deep pool; adequate boulder ballast on site.
1+796	20	LO-3	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Locate upstream end of structure at base of existing riffle; anchor to bedrock and boulder ballast on site; six additional boulders required.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
Section B - 0+000 m starting at confluence with Chipman Creek and progressing downstream					
0+021	21	DJ-5 & Riffle Enhancement	Left	Rest. Obj.	To provide pool with LWD cover near left bank; to diversify hydraulic habitat on the downstream face of the existing riffle; to increase the area of high quality summer rearing habitat for steelhead parr.
				1	Two debris jam structures; five boulders for ballasting available on bank and in the channel; add 6-1 m diameter boulders to riffle at 0+033 m.
0+090	22	Boulder Cluster	Mid-stream	Rest. Obj.	To provide boulder cover on riffle toe; to improve steelhead parr rearing habitat.
				1	Arrange 12 - 1-1.2 m diameter boulders in clusters of four at downstream toe of riffle; create 0.4-0.5 m deep backwater pool downstream of largest boulder by grouping three other boulders in a semi-circle about 1 m downstream of largest boulder; largest boulder placed with longest axis perpendicular to the flow.
0+210	23	LO-2	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
Section C - 0+000 m starting upstream of Chipman Creek confluence and progressing downstream					
0+020	24	LO-2	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Anchor to fractured bedrock by drilling vertical holes for cable. Pool depth = 1.2 m.
				2	A sufficient number and size of rock do not exist on site to ballast LWD structure. Additional ballast rock will need to be brought to the site.
0+065	25	LO-1	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Remove large boulders upstream of two anchor boulders (1.1 and 2 m diameter) and place towards the right side to narrow the flow through a slot along the LO-1.
				2	LO-1 should include branches and rootwad. No additional boulder ballast required.
0+155	26	LO-3	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Remove large boulder (>2 m diameter) upstream and place towards the right side to narrow the flow through a slot along the LO-3.
0+380	27	LSP-5	Right	Rest. Obj.	To deflect flow away from right bank; to provide pool with LWD cover.
				1	Locate structure at base of existing riffle and near upstream end of eroding bank.
				2	Project spur into channel at least 1/3 of bankfull width.
0+465	28	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Incorporate existing LWD into structure; pull out downstream end and attach a brace to recreate a triangular structure.
0+615	29	LT-3	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate structure at base of existing riffle.
0+638	30	LT-3	Left	Rest. Obj.	To provide pool with LWD cover along left bank.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+937	31	DJ-5	Right	1 Rest. Obj.	Locate structure at base of existing riffle; cable existing rootwad to structure. To provide pool with LWD cover along right bank.
1+116	32	LO-3	Right	1 Rest. Obj.	Include 1 x 12 m cedar slab, and place at water surface and parallel with bank. Extend rootwads on logs into base of riffle and perpendicular to flow; anchor to bedrock. To provide pool with LWD cover along right bank.
1+611	33	DJ-5	Right	1 Rest. Obj.	Anchor to 2.4 m diameter boulder on site; move smaller diameter boulder upstream of site to position opposite first rootwad to concentrate flow along structure. To provide pool with LWD cover along right bank.
1+832	34	LT-3	Left	1 Rest. Obj.	Anchor to large diameter boulders on site; no additional ballast required. Move smaller diameter boulders upstream of site to position opposite of structure to concentrate flow at structure. To provide pool with LWD cover along right bank.
1+893	35	DJ-5	Left	1 Rest. Obj.	Locate structure at base of existing riffle; excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure. Anchor LWD to large cottonwood. To provide pool with LWD cover along left bank.
1+957	36	LO-3	Right	1 Rest. Obj.	Incorporate existing LWD into structure. To provide pool with LWD cover along right bank.
2+022	37	LO-1	Right	1 Rest. Obj.	Locate upstream end of structure at base of existing riffle; provide adequate boulder ballast as no trees or stumps are in close proximity. To provide pool with LWD cover along right bank.
Section D - 0+000 m starting downstream of Meade Creek mouth and progressing downstream					
0+000	38	DJ-5	Left	1 Rest. Obj.	Locate rootwad of existing log at base of existing riffle and anchor bole on the left side of existing boulder; bring in additional boulder ballast. To provide pool with LWD cover along left bank.
0+072	39	LS-1	Left	1 Rest. Obj.	Locate upstream end of structure at base of existing riffle; provide adequate boulder ballast as bedrock appears unsuitable for anchoring. To provide plunge pool along left bank.
0+100	40	LT-6	Right	1 Rest. Obj.	Install log with a slope, top of log should be 0.3 m higher on the left bank than at the gravel bar. At right end of log, bury top of log flush with top of gravel bar. To provide pool with LWD cover along right bank.
				1	Incorporate existing LWD into structure.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+153	41	LSP-5	Left	Rest. Obj. 1	To promote bar top aggradation; to enhance riparian vegetation growth and to narrow the channel. Locate structure at existing willows at upstream end of gravel bar; anchor using boulders or buried deadmen.
0+193	42	LO-4	Right	Rest. Obj. 1	Structure should be about 10 m wide and should leave a channel opening of 17 m to right bank. To provide pool with LWD cover along right bank. 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.
0+221	43	DJ-5	Right	Rest. Obj. 1	Remove potential blowdown and use other logs on site in structure; To provide pool with LWD cover along right bank. Incorporate existing LWD into structure.
0+269	44	LSP-5	Right	Rest. Obj. 1	To promote bar top aggradation; to enhance riparian vegetation growth and to narrow the channel. Locate structure off right bank at upstream end of gravel bar; anchor using boulders or buried deadmen.
0+273	45	LSP-5	Left	Rest. Obj.	Structure should be about 10 m wide and should leave a channel opening of 15 m to left bank. To provide pool with LWD cover along left bank.
0+283	46	LO-4	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate upstream end of structure at head of eroding bank; 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.
0+370	47	LO-3	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate upstream end of structure at base of 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.
0+454	48	LO-3	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate upstream end of structure at base of riffle; incorporated existing LWD and rootwad into structure.
1+010	49	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. No appropriate riparian vegetation for anchoring.
1+317	50	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate upstream end of structure at base of riffle; incorporate existing LWD into structure.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
1+468	51	LO-3	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate upstream end of structure at base of existing riffle; anchor to bedrock and other large diameter boulders on site.
0+000 m starting at Chipman Creek and progressing upstream in Chipman Creek					
0+070	52	LWD	Left & Center	Rest. Obj. 1	To provide pool with LWD cover. Anchor two logs with rootwads to bedrock on left bank - logs to be 0.6-0.7 m diameter x 10-12 m long with ~2 m diameter rootwads; place rootwad of upstream log in gap in bedrock; anchor all to bedrock.
				2	Anchor one log with rootwad and branches in center of channel - log to be 0.8 m diameter x 10-12 m long with 2-3 m diameter rootwad; anchor to boulders.

Note: Unless stated otherwise, it is assumed that:

- 1 - A sufficient number and size of rock do not exist on site to ballast LWD structure. Additional ballast rock will need to be brought to the site.
- 2 - Anchor LWD to live trees or stumps on streambank with diameter >20 cm. Alternatively, embed tops of logs 2-3 m horizontally and 1 m vertically into the bank. Backfill trench with spoil from excavation.

Table 6. Summary of materials required for LWD and boulder structures in Chemainus River and Chipman Creek.

						LWD Ballast		Riffle Boulders		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Volume (m ³)	Comments
Section E - 0+000 m starting from Hell's Gate and progressing downstream to Island Hwy										
1	0+255	LO-3	Left	3	0.5 x 6	2	0.8			With rootwads; 4-1 m boulders onsite
2	0+306	DJ-5	Left	5	0.5 x 8-10	0	0.8			Two logs with rootwads, three without
3	0+430	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
4	0+512	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
5	1+102	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
6	1+180	LT-5	Left	5	0.5 x 8-10	10	0.8			With rootwads
7	1+222	LO-1	Left	2	0.5 x 6	5	0.8			With rootwads; 1-1.2 m boulder onsite
Section F - 0+000 m starting at Centra Gas Pipeline and progressing downstream										
8	0+150	LO-3	Left	3	0.8 x 6	0	0.8			With rootwads; anchor to bedrock
9	0+978	LT-5	Right	5	0.5 x 8-10	10	0.8			With rootwads
Section A - 0+000 starting upstream of Humbird Creek and Park Access and progressing downstream										
10	0+008	LO-3	Right	3	0.5 x 6	10	0.8			With rootwads
11	0+022	LSP-5	Left	5	0.5 x 8-10	6	0.8			Without rootwads
12	0+046	LO-3	Right	3	0.5 x 6	10	0.8			With rootwads
13	0+096	DJ-5	Right	10	0.5 x 6	15	0.8			Four logs with rootwads, 6 without
14	0+350	LO-3	Left	3	0.5 x 10	10	0.8			With rootwads
15	0+411	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
16	0+528	LO-3	Right	3	0.5 x 6	0	0.8			With rootwads
17	0+921	LSP-5	Left	3	0.5 x 10-12	3	0.8			Without rootwads
18	0+942	DJ-5	Right	5	0.5 x 8-10	4	0.8			Two logs with rootwads, three without
19	1+270	DJ-5	Left	5	0.5 x 8-10	0	0.8			Two logs with rootwads, three without
20	1+796	LO-3	Left	3	0.5 x 6	6	0.8			With rootwads

						LWD Ballast		Riffle Boulders		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Volume (m ³)	Comments
Section B - 0+000 m starting at confluence with Chipman Creek and progressing downstream										
21	0+021	DJ-5 & Riffle Enhancement	Left	10	0.5 x 8-10	8	0.8	1.0		Six 1 m diameter boulders for riffle; four logs with rootwads, six without
22	0+090	Boulder Cluster	Mid-					0.8-1.2		12 boulders available on right & left
23	0+210	LO-2	Left	2	0.5 x 10-12	7	0.8			2.3 m diameter boulder on site
Section C - 0+000 m starting upstream of Chipman Creek confluence and progressing downstream										
24	0+020	LO-2	Left	2	0.5 x 6	7	0.8			With rootwads
25	0+065	LO-1	Left	1	0.5 x 6					1.1 and 2 m boulders on-site
26	0+155	LO-3	Left	3	0.5 x 6	10	0.8			With rootwads
27	0+380	LSP-5	Right	5	0.5 x 8-10	6	0.8			Without rootwads
28	0+465	DJ-5	Left	10	0.5 x 8-10	15	0.8			Four logs with rootwads, 6 without
29	0+615	LT-3	Left	3	0.5 x 8-10	6	0.8			With rootwads
30	0+638	LT-3	Left	3	0.5 x 8-10	6	0.8			With rootwads
31	0+937	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
32	1+116	LO-3	Right	3	0.5 x 6	10	0.8			One 2.4 m diam. boulder on-site
33	1+611	DJ-5	Right	5	0.5 x 8-10	0				Two logs with rootwads, three without
34	1+832	LT-3	Left	3	0.5 x 8-10	6	0.8			With rootwads
35	1+893	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
36	1+957	LO-3	Right	3	0.5 x 6	10	0.8			With rootwads
37	2+022	LO-1	Right	0	0.5 x 22	6	0.8			Log on site with 4 m rootwad
Section D - 0+000 m starting downstream of Meade Creek mouth and progressing downstream										
38	0+000	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
39	0+072	LS-1	Left	3	0.8 x 15	6	0.8			Without rootwad
40	0+100	LT-6	Right	3	0.5 x 8-10	6	0.8			With rootwads
41	0+153	LSP-5	Right	5	0.5 x 8-10	6	0.8			Without rootwads
42	0+193	LO-4	Right	4	0.5 x 6	13	0.8			With rootwads
43	0+221	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
44	0+269	LSP-5	Right	5	0.5 x 8-10	6	0.8			Without rootwads
45	0+273	LSP-5	Left	5	0.5 x 8-10	6	0.8			Without rootwads
46	0+283	LO-4	Left	4	0.5 x 6	13	0.8			With rootwads
47	0+370	LO-3	Left	3	0.5 x 6	10	0.8			With rootwads

						LWD Ballast		Riffle Boulders		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Volume (m ³)	Comments
48	0+454	LO-3	Left	3	0.5 x 6	10	0.8			With rootwads
49	1+010	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
50	1+317	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
51	1+468	LO-3	Right	3	0.5 x 6	10	0.8			With rootwads
0+000 m starting at Chipman Creek confluence and progressing upstream in Chipman Creek										
52	0+070	LWD	Left & Center	3	0.6-0.8 x 10- 12	21	0.8			With branches & rootwads
Total				212		375				

Table 7. Ballast requirements and boulder size options for the LWD structures in Chemainus River and Chipman Creek.
Buoyancy and sliding safety factors ≥ 1.5 ; ballast factor = 1; and specific gravity of LWD (S_L) = 0.5.
Modified after D'Aoust and Millar (1999).

					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 @ 130 or 280 kg/m	0.8 @ 430 or 500 kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (kg)	0.5 @ 190 kg	0.6 @ 300 kg	0.7 @ 480 kg	0.8 @ 700 kg	0.9 @ 1000 kg	1 @ 1400 kg
Section E - 0+000 m starting from Hell's Gate and progressing downstream to Island Hwy														
1	0+255	LO-3	3	6	5040	0	1980	7020	37	23	15	10	7	5
2	0+306	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
3	0+430	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
4	0+512	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
5	1+102	LT-6	6	6	4680	0	3960	8640	45	29	18	12	9	6
6	1+180	LT-5	5	6	3900	0	3300	7200	38	24	15	10	7	5
7	1+222	LO-1	2	6	3360	0	1320	4680	25	16	10	7	5	3
Section F - 0+000 m starting at Centra Gas Pipeline and progressing downstream														
8	0+150	LO-3	3	6	0	9000	1980	10980	58	37	23	16	11	8
9	0+978	LT-5	5	6	3900	0	3300	7200	38	24	15	10	7	5
Section A - 0+000 starting upstream of Humbird Creek and Park Access and progressing downstream														
10	0+008	LO-3	3	6	5040	0	1980	7020	37	23	15	10	7	5
11	0+022	LSP-5	5	6	3900	0	0	3900	21	13	8	6	4	3
12	0+046	LO-3	3	6	5040	0	1980	7020	37	23	15	10	7	5
13	0+096	DJ-5	10	6	7800	0	2640	10440	55	35	22	15	10	7
14	0+350	LO-3	3	6	5040	0	1980	7020	37	23	15	10	7	5
15	0+411	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
16	0+528	LO-3	3	6	5040	0	0	5040	27	17	11	7	5	4
17	0+921	LSP-5	3	6	2340	0	0	2340	12	8	5	3	2	2
18	0+942	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
19	1+270	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
20	1+796	LO-3	3	6	5040	0	1980	7020	37	23	15	10	7	5
Section B - 0+000 m starting at confluence with Chipman Creek and progressing downstream														

					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 @ 130 or 280 kg/m	0.8 @ 430 or 500 kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (kg)	0.5 @ 190 kg	0.6 @ 300 kg	0.7 @ 480 kg	0.8 @ 700 kg	0.9 @ 1000 kg	1 @ 1400 kg
21	0+021	DJ-5 & Riffle Enhancement	10	6	7800	0	2640	10440	55	35	22	15	10	7
22	0+090	Boulder Cluster	0	0	0	0	0	0	0	0	0	0	0	0
23	0+210	LO-2	2	6	3360	0	1320	4680	25	16	10	7	5	3
Section C - 0+000 m starting upstream of Chipman Creek confluence and progressing downstream														
24	0+020	LO-2	2	6	3360	0	1320	4680	25	16	10	7	5	3
25	0+065	LO-1	1	6	1680	0	660	2340	12	8	5	3	2	2
26	0+155	LO-3	3	6	5040	0	1980	7020	37	23	15	10	7	5
27	0+380	LSP-5	5	6	3900	0	0	3900	21	13	8	6	4	3
28	0+465	DJ-5	10	6	7800	0	2640	10440	55	35	22	15	10	7
29	0+615	LT-3	3	6	2340	0	1980	4320	23	14	9	6	4	3
30	0+638	LT-3	3	6	2340	0	1980	4320	23	14	9	6	4	3
31	0+937	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
32	1+116	LO-3	3	6	5040	0	1980	7020	37	23	15	10	7	5
33	1+611	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
34	1+832	LT-3	3	6	2340	0	1980	4320	23	14	9	6	4	3
35	1+893	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
36	1+957	LO-3	3	6	5040	0	1980	7020	37	23	15	10	7	5
37	2+022	LO-1	1	12	3360	0	660	4020	21	13	8	6	4	3
Section D - 0+000 m starting downstream of Meade Creek mouth and progressing downstream														
38	0+000	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
39	0+072	LS-1	3	6	2340	0	1980	4320	23	14	9	6	4	3
40	0+100	LT-6	3	6	2340	0	1980	4320	23	14	9	6	4	3
41	0+153	LSP-5	5	6	3900	0	0	3900	21	13	8	6	4	3
42	0+193	LO-4	4	6	6720	0	2640	9360	49	31	20	13	9	7
43	0+221	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
44	0+269	LSP-5	5	6	3900	0	0	3900	21	13	8	6	4	3

					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 @ 130 or 280 kg/m	0.8 @ 430 or 500 kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (kg)	0.5 @ 190 kg	0.6 @ 300 kg	0.7 @ 480 kg	0.8 @ 700 kg	0.9 @ 1000 kg	1 @ 1400 kg
45	0+273	LSP-5	5	6	3900	0	0	3900	21	13	8	6	4	3
46	0+283	LO-4	4	6	6720	0	2640	9360	49	31	20	13	9	7
47	0+370	LO-3	3	6	5040	0	1980	7020	37	23	15	10	7	5
48	0+454	LO-3	3	6	5040	0	1980	7020	37	23	15	10	7	5
49	1+010	DJ-5	5	6	3900	0	1320	5220	27	17	11	7	5	4
50	1+317	LT-6	6	6	4680	0	3960	8640	45	29	18	12	9	6
51	1+468	LO-3	3	6	5040	0	1980	7020	37	23	15	10	7	5
0+000 m starting at Chipman Creek confluence and progressing upstream in Chipman Creek														
52	0+070	LWD	3	10	0	12900	1980	14880	78	50	31	21	15	11

Table 8. Construction notes for specific restoration sites in Haslam Creek.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+000 m - starting at mouth of Haslam Creek and progressing upstream					
0+183	1	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Place bracing logs in crotch of overhanging trees.
0+250	2	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+278	3	LSP-5	Right	Rest. Obj. 2	Alder, cedar and hemlock on bank for anchoring.
				Rest. Obj. 1	To narrow channel slightly and deflect flow to structure at 0+250 m; to provide pool with LWD cover near right bank.
0+300			Left		Place one long partial spanning log at a 30-45 ⁰ angle downstream to deflect flow to 0+250 m structure; structure should be porous to promote local scour and cover close to right bank.
0+324	4	LO-4	Right	Rest. Obj. 1	Napoleon Creek confluence To provide pool with LWD cover near right bank. Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+438	5	LT-6	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
0+575	6	Existing LWD	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Existing LWD: 3 cedars with 2.5 m rootwads-0.7, 0.8, 0.9 x 30 m; 1 cedar-0.3x20 m; 1 doug. fir with 2 m rootwad-0.8x30 m; anchor most of existing LWD in its present position; rearrange some of the LWD to protect point of attack and erosion on bank; anchor to cedar on streambank; pool 1 m deep.
0+600	7	LSP-5	Left	Rest. Obj. 1	To act as a spur and deflect flow away from eroding bank; to provide pool with LWD cover near left bank. To reduce erosion behind each structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity.
0+686	8	LO-4	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+768	9	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Due to steepness of bank (~3 m), brace logs should be laid in on the side of the bank or excavated into trenches.
0+830	10	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. First upstream log in structure should be upstream of large maple overhanging pool.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
1+049	11	LO-4- Sweeper	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
1+125	12	LO-3 + Existing LWD	Left	Rest. Obj.	1 Pool 0.7 m deep with shale bedrock bottom; good anchor trees on streambank. To provide pool with LWD cover near left bank.
1+289	13	LO-4	Right	Rest. Obj.	1 Incorporate existing log into structure; place one LO-1 upstream of existing log and the other two LO-1's downstream; existing log is 0.9 x 25 m hemlock; existing pool is 1.1 m deep. To provide pool with LWD cover along right bank.
1+946	14	LSP-5	Right	Rest. Obj.	1 Poor quality anchoring to alder/maple trees on bank; maple log (0.8 x 30 m) on bar at 1+319 m. 2 Riprap on bank but additional boulder ballast required. To act as a spur and deflect flow away from bank; to reduce bank erosion; to provide pool with LWD cover along right bank during moderate flows.
2+044	15	LO-1- Sweeper	Left	Rest. Obj.	1 Four LSP-5 structures should be constructed, extending through section with no trees in riparian zone. 2 To reduce erosion behind each structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity. To provide pool with LWD cover along left bank.
2+108	16	LT-6	Left	Rest. Obj.	1 Locate structure upstream of existing slab that is creating a 0.8 m deep scour pool; sweeper should extend over this scour pool. To provide pool with LWD cover along left bank.
2+200	17	LSP-5	Right	Rest. Obj.	1 Embed existing cedar log into bank, and use as the first upstream log in the structure; rootwad on right bank about 10 m upstream that can be used in structure. To act as a spur and deflect flow away from bank; to reduce bank erosion; to provide pool with LWD cover along right bank during moderate flows.
2+303	18	LT-3	Right	Rest. Obj.	1 Four LSP-5 structures should be constructed, extending through section where maple trees are being undermined on eroding bank (2+150 to 2+250 m). 2 To reduce erosion behind each structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity. To provide pool with LWD cover along right bank.
2+362	19	LO-1- Sweeper	Left	Rest. Obj.	1 Construct around existing rootwad and cottonwood; location is an old bridge site and has good access. To provide pool with LWD cover along left bank.
				1	Construct two structures in existing pool (1 m deep); anchor to cottonwoods and maple on bank.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
2+810	20	LO-4	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. At upstream end of structure, rootwad of log should be located just downstream of riprap spur; balance of LWD should be located in thalweg away from eroding bank about 3-4 m.
3+109	21	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate upstream end of structure at base of existing riffle; incorporate existing LWD into structure.
3+185	22	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate upstream end of structure at base of existing riffle; leave a gap between the first and last three LWD to reduce sedimentation within the structure.
3+410	23	LO-1- Sweeper	Right & Left	Rest. Obj. 1	To provide pool with LWD cover along right bank. Construct two structures, one adjacent to large (>2 m diameter) boulder near right bank and the other downstream along left bank.
3+517	24	Sweeper	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Provide cover over bedrock controlled pool ~1.8 m deep; provide adequate boulder ballast as bedrock appears unsuitable for anchoring; place some of the boulder ballast on bedrock benches above water.
3+746	25	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Construct near downstream end of meander bend and in ~1.2 m deep pool; good road access.
3+892	26	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. 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.
3+989	27	Existing LWD	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Use existing large boulders on bank to reduce buoyancy; two cedar logs - 0.5 and 0.7 x 30 m, and 1 hemlock - 0.5 x 24 m.
4+116	28	LO-1- Sweeper	Left	Rest. Obj. 1	To provide pool with LWD cover along right bank. Construct two structures, with LO-1 portion in the thalweg and the sweeper anchored to trees on the streambank.
4+210	29	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate upstream end opposite existing maple on gravel bar; move maple 2-3 m towards the left bank and anchor.
4+279	30	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate opposite cottonwood on bank, about 10 m downstream of LSP-5 at 4+290 m.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
4+290	31	LSP-5	Right	Rest. Obj.	To act as a spur and deflect flow away from bank; to reduce bank erosion; to provide pool with LWD cover along right bank.
				1	Locate structure at cedar rootwad and point of attack on streambank
				2	To reduce erosion behind each structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity.
4+373	32	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate upstream end of structure at base of existing riffle; incorporate existing LWD into structure; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
4+504	33	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left 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 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
4+596	34	Sweeper	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate sweeper downstream of existing fir rootwad; minimize boulder ballast instream by placing ballast on the bank and by anchoring to alder/cottonwood trees.
4+900	35	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Incorporate existing LWD with rootwad into structure; locate upstream end about 10 m downstream of LSP-5 at 4+929 m..
4+929	36	LSP-5	Left	Rest. Obj.	To act as a spur and deflect flow away from bank; to reduce bank erosion; to provide pool with LWD cover along left bank.
				1	Locate structure at cedar rootwad and point of attack on streambank
				2	To reduce erosion behind each structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity.
5+015	37	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate in deep pool (~1.8 m).
5+834	38	LT-6	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate upstream end of structure at base of existing riffle; bulk of structure in deep pool (0.9 m).
6+059	39	Existing Sweeper	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Anchor existing log using boulder ballast.
6+299	40	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate in deep pool (~0.7 m); tie structure into existing fir rootwad on bank.
6+332	41	LT-3	Left	Rest. Obj.	To provide pool with LWD cover along left bank.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
				1	Locate upstream end of structure at base of existing riffle; incorporate existing LWD into structure; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure. .
6+405	42	LT-3	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate upstream end of structure at base of existing riffle; incorporate existing LWD into structure; excavate streambed to create a long narrow pool (2.5 m wide x 5 m long) with residual water depth of 0.6 m prior to constructing LWD structure. .
7+049	43	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Remove existing blowdown from steep bedrock bank and anchor to bedrock as an LT-6 type structure; pool 1.8-2.0 m deep.
0+000 m - starting at mouth of right bank overflow channel located at 5+341 m in Haslam Creek and progressing upstream					
0+020	44	LT-6	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate structure in deep pool (1.0 m).
0+062	45	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate structure in deep pool (1.1 m); rootwad on bank that could be used in structure.
0+095	46	LT-6	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate first log of structure upstream of instream rootwad, and bulk of structure in deep pool (1.3 m).
0+189	47	LT-3	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Incorporate existing LWD for left bank into structure; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+226	48	Boulder Cluster	Right	Rest. Obj.	To increase boulder cover in scour pool of riffle.
				1	Place four 0.6 m diameter boulders in scour pool.
0+267	49	LT-3	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate structure in deep pool (1 m); project into channel up to 50% of width.
0+000 m - starting at mouth of left bank overflow channel located at 5+515 m in Haslam Creek and progressing upstream					
0+046	50	LT-3	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate structure in pool; using an existing log on the bank, construct a single log deflector at a 30° angle downstream to concentrate flows on left bank.
0+150	51	LT-6	Right	Rest. Obj.	To provide pool with LWD cover along right bank.

Note: Unless stated otherwise, it is assumed that:

- 1 - A sufficient number and size of rock do not exist on site to ballast LWD structure. Additional ballast rock will need to be brought to the site.
- 2 - Anchor LWD to live trees or stumps on streambank with diameter >20 cm. Alder, cedar, hemlock or maple common on streambanks. Alternatively, embed tops of logs 2-3 m horizontally and 1 m vertically into the bank. Backfill trench with spoil from excavation.

Table 9. Summary of materials required for LWD and boulder structures in Haslam Creek.

						LWD Ballast		Boulders	
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Comments
0+000 m - starting at mouth of Haslam Creek and progressing upstream									
1	0+183	LT-6	Right	6	0.5 x 8-10	12	0.8		With rootwads
2	0+250	LT-6	Left	6	0.5 x 8-10	28	0.8		With rootwads
3	0+278	LSP-5	Right	5	0.5 x 8-10	6	0.8		Without rootwads
4	0+324	LO-4	Right	4	0.5 x 6	13	0.8		With rootwads
5	0+438	LT-6	Right	6	0.5 x 8-10	12	0.8		Without rootwads
6	0+575	Existing LWD	Left	0	0.7-0.9 x 20-30	22	0.8		With rootwads; anchor only
7	0+600	LSP-5	Left	5	0.5 x 8-10	6	0.8		Without rootwads
8	0+686	LO-4	Left	4	0.5 x 6	13	0.8		With rootwads
9	0+768	LT-6	Right	6	0.5 x 8-10	12	0.8		With rootwads
10	0+830	LT-6	Left	6	0.5 x 8-10	12	0.8		Complex Alcove
11	1+049	LO-4-Sweeper	Right	6	0.5 x 6/12	17	0.8		Four 6 m LO-1 with rootwads; Two 12 m long
12	1+125	LO-3	Left	3	0.5 x 6	10	0.8		With rootwads
12	1+125	Existing LWD	Left	0	0.9 x 25	13	0.8		Ballast only
13	1+289	LO-4	Right	4	0.5 x 6	13	0.8		With rootwads
14	1+946	LSP-5	Right	20	0.5 x 8-10	22	0.8		Without rootwads
15	2+044	LO-1-Sweeper	Left	2	0.5 x 6/12	5	0.8		6 m LO-1 with rootwad; 12 m long Sweeper
16	2+108	LT-6	Left	6	0.5 x 8-10	12	0.8		With rootwads
17	2+200	LSP-5	Right	20	0.5 x 8-10	22	0.8		Without rootwads
18	2+303	LT-3	Right	3	0.5 x 8-10	6	0.8		With rootwads
19	2+362	LO-1-Sweeper	Left	4	0.5 x 6/12	11	0.8		Two 6 m LO-1 with rootwad; Two 12 m long
20	2+810	LO-4	Right	4	0.5 x 6	13	0.8		With rootwads
21	3+109	LT-6	Left	6	0.5 x 6	12	0.8		With rootwads
22	3+185	LT-6	Right	6	0.5 x 6	12	0.8		With rootwads
23	3+410	LO-1-Sweeper	Right & Left	4	0.5 x 6/12	11	0.8		Two 6 m LO-1 with rootwad; Two 12 m long Sweeper
24	3+517	Sweeper	Right	3	0.5 x 12	6	0.8		With branches
25	3+746	DJ-5	Right	5	0.5 x 8-10	7	0.8		Two logs with rootwads, three without

						LWD Ballast		Boulders	
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Comments
26	3+892	LT-6	Left	12	0.5 x 8-10	25	0.8		With rootwads
27	3+989	Existing LWD	Right	0		0	0		Use boulders and LWD on site
28	4+116	LO-1-Sweeper	Left	4	0.5 x 6/12	11	0.8		Two 6 m LO-1 with rootwad; Two 12 m long
29	4+210	LT-6	Right	6	0.5 x 8-10	12	0.8		With rootwads
30	4+279	LT-6	Right	6	0.5 x 8-10	12	0.8		With rootwads
31	4+290	LSP-5	Right	5	0.5 x 8-10	6	0.8		Without rootwads
32	4+373	LT-6	Left	6	0.5 x 8-10	12	0.8		With rootwads
33	4+504	LT-6	Left	6	0.5 x 8-10	12	0.8		With rootwads
34	4+596	Sweeper	Right	1	0.5 x 12	2	0.8		With branches
35	4+900	LT-6	Left	6	0.5 x 8-10	12	0.8		With rootwads
36	4+929	LSP-5	Left	5	0.5 x 8-10	6	0.8		Without rootwads
37	5+015	DJ-5	Left	5	0.5 x 8-10	7	0.8		Two logs with rootwads, three without
38	5+834	LT-6	Right	6	0.5 x 8-10	12	0.8		With rootwads
39	6+059	Existing Sweeper	Right	0	0.5 x 12	3	0.8		Anchor only
40	6+299	LT-6	Left	6	0.5 x 8-10	12	0.8		With rootwads
41	6+332	LT-3	Left	3	0.5 x 8-10	6	0.8		With rootwads
42	6+405	LT-3	Right	3	0.5 x 8-10	6	0.8		With rootwads
43	7+049	Existing LWD	Left	0		0	0		Anchor to bedrock
0+000 m - starting at mouth of right bank overflow channel located at 5+341 m in Haslam Creek and progressing upstream									
44	0+020	LT-6	Right	6	0.5 x 8-10	12	0.8		With rootwads
45	0+062	LT-6	Left	6	0.5 x 8-10	12	0.8		With rootwads
46	0+095	LT-6	Right	6	0.5 x 8-10	12	0.8		With rootwads
47	0+189	LT-3	Left	3	0.5 x 8-10	6	0.8		With rootwads
48	0+226	Boulder Cluster	Right					0.6	4 boulders
49	0+267	LT-3	Left	3	0.5 x 8-10	6	0.8		With rootwads
0+000 m - starting at mouth of left bank overflow channel located at 5+515 m in Haslam Creek and progressing upstream									
50	0+046	LT-3	Left	3	0.5 x 8-10	6	0.8		With rootwads
51	0+150	LT-6	Right	6	0.5 x 8-10	12	0.8		With rootwads
Total				257		550			

Table 10. Ballast requirements and boulder size options for the LWD structures in Haslam Creek.
Buoyancy and sliding safety factors ≥ 1.5 ; ballast factor = 1; and specific gravity of LWD (S_L) = 0.5.
Modified after D'Aoust and Millar (1999).

					Log (m)			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 @ 130 or 280 kg/m	0.8 @ 430kg/ m	0.9 @ 540kg/ m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (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 mouth of Haslam Creek and progressing upstream															
1	0+183	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
2	0+250	LT-6	6	6	15600	0	0	3960	19560	103	65	41	28	20	14
3	0+278	LSP-5	5	6	3900	0	0	0	3900	21	13	8	6	4	3
4	0+324	LO-4	4	6	6720	0	0	2640	9360	49	31	20	13	9	7
5	0+438	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
6	0+575	Existing LWD	5	20	0	12900	0	2640	15540	82	52	32	22	16	11
7	0+600	LSP-5	5	6	3900	0	0	0	3900	21	13	8	6	4	3
8	0+686	LO-4	4	6	6720	0	0	2640	9360	49	31	20	13	9	7
9	0+768	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
10	0+830	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
11	1+049	LO-4-Sweeper	6	6	8280	0	0	3960	12240	64	41	26	17	12	9
12	1+125	LO-3	3	6	5040	0	0	1980	7020	37	23	15	10	7	5
12	1+125	Existing LWD	1	15	0	0	8100	660	8760	46	29	18	13	9	6
13	1+289	LO-4	4	6	6720	0	0	2640	9360	49	31	20	13	9	7
14	1+946	LSP-5	20	6	15600	0	0	0	15600	82	52	33	22	16	11
15	2+044	LO-1-Sweeper	2	6	2460	0	0	1320	3780	20	13	8	5	4	3
16	2+108	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
17	2+200	LSP-5	20	6	15600	0	0	0	15600	82	52	33	22	16	11
18	2+303	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
19	2+362	LO-1-Sweeper	4	6	4920	0	0	2640	7560	40	25	16	11	8	5
20	2+810	LO-4	4	6	6720	0	0	2640	9360	49	31	20	13	9	7
21	3+109	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
22	3+185	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
23	3+410	LO-1-Sweeper	4	6	4920	0	0	2640	7560	40	25	16	11	8	5
24	3+517	Sweeper	3	6	2340	0	0	1980	4320	23	14	9	6	4	3

Site	Chainage (m)	Structure Type	No. of Logs	Average Submerged Length of Each Log (m)	Log (m)			Rootwad	Alternative Quantities for Each Boulder Diameter (m)							
					0.5 @ 130 or 280 kg/m	0.8 @ 430kg/ m	0.9 @ 540kg/ m		660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (kg)	0.5 @ 190 kg	0.6 @ 300 kg	0.7 @ 480 kg	0.8 @ 700 kg	0.9 @ 1000 kg	1 @ 1400 kg
25	3+746	DJ-5	5	6	3900	0	0		1320	5220	27	17	11	7	5	4
26	3+892	LT-6	12	6	9360	0	0		7920	17280	91	58	36	25	17	12
27	3+989	Existing LWD	0	0	0	0	0		0	0	0	0	0	0	0	0
28	4+116	LO-1-Sweeper	4	6	4920	0	0		2640	7560	40	25	16	11	8	5
29	4+210	LT-6	6	6	4680	0	0		3960	8640	45	29	18	12	9	6
31	4+290	LT-6	6	6	4680	0	0		3960	8640	45	29	18	12	9	6
30	4+279	LSP-5	5	6	3900	0	0		0	3900	21	13	8	6	4	3
32	4+373	LT-6	6	6	4680	0	0		3960	8640	45	29	18	12	9	6
33	4+504	LT-6	6	6	4680	0	0		3960	8640	45	29	18	12	9	6
34	4+596	Sweeper	1	6	780	0	0		660	1440	8	5	3	2	1	1
36	4+929	LT-6	6	6	4680	0	0		3960	8640	45	29	18	12	9	6
35	4+900	LSP-5	5	6	3900	0	0		0	3900	21	13	8	6	4	3
37	5+015	DJ-5	5	6	3900	0	0		1320	5220	27	17	11	7	5	4
39	6+059	LT-6	6	6	4680	0	0		3960	8640	45	29	18	12	9	6
39	6+059	Existing Sweeper	1	10	1300	0	0		660	1960	10	7	4	3	2	1
40	6+299	LT-6	6	6	4680	0	0		3960	8640	45	29	18	12	9	6
41	6+332	LT-3	3	6	2340	0	0		1980	4320	23	14	9	6	4	3
42	6+405	LT-3	3	6	2340	0	0		1980	4320	23	14	9	6	4	3
43	7+049	Existing LWD	0	0	0	0	0		0	0	0	0	0	0	0	0
0+000 m - starting at mouth of right bank overflow channel located at 5+341 m in Haslam Creek and progressing upstream																
44	0+020	LT-6	6	6	4680	0	0		3960	8640	45	29	18	12	9	6
45	0+062	LT-6	6	6	4680	0	0		3960	8640	45	29	18	12	9	6
46	0+095	LT-6	6	6	4680	0	0		3960	8640	45	29	18	12	9	6
47	0+189	LT-3	3	6	2340	0	0		1980	4320	23	14	9	6	4	3
48	0+226	Boulder Cluster	0	0	0	0	0		0	0	0	0	0	0	0	0
49	0+267	LT-3	3	6	2340	0	0		1980	4320	23	14	9	6	4	3
0+000 m - starting at mouth of left bank overflow channel located at 5+515 m in Haslam Creek and progressing upstream																
50	0+046	LT-3	3	6	2340	0	0		1980	4320	23	14	9	6	4	3
51	0+150	LT-6	6	6	4680	0	0		3960	8640	45	29	18	12	9	6

Table 11. Construction notes for specific restoration sites in Deadwood Creek.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+000 m - starting at mouth of Deadwood Creek and progressing upstream					
0+081	1	LO-3	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
0+096	2	LSP-5	Left	Rest. Obj.	To act as a spur and deflect flow away from eroding bank; to provide pool with LWD cover near left bank.
0+100	3	LS-1	Right	1	To reduce erosion behind each structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity.
				Rest. Obj.	To create a scour pool with cover and diversify instream habitat.
0+180	4	DJ-5	Right	1	Span across at upstream end of scour pool; angle log at about 30 ⁰ downstream so that upstream end is buried 2 m into left bank gravel bar and downstream end is buried 1.5 m into right bank; top of log to be placed horizontal and <0.25 m above low water surface in center of channel.
				Rest. Obj.	To provide pool with LWD cover near right bank.
0+220	5	LS-1 & LT-3	Right	1	Two debris jam structures; Four 0.8-1.0 x 15 m logs on top of trestle crossing that could be used in this structure and at 0+220 m; anchor to trestle piles (12) on right bank; some 0.9-1.1 riprap on left bank; minimize instream boulder ballast.
				Rest. Obj.	To provide pool with LWD cover near right bank.
0+230	6	LT-6	Right	1	Use one 0.8 x 15 m logs from the trestle site to create an LS-1 located 3 m upstream of the alder clump on the right bank.
				2	Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LT-3 structure near alder clump.
0+274	7	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover near right bank.
0+309	8	DJ-5	Right	Rest. Obj.	To reduce flows to overflow channel; to provide pool with LWD cover near left bank.
				1	Construct at head of overflow channel; leave structure porous to allow some flows to overflow channel; incorporate existing debris in structure.
0+356	9	LT-6	Left	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Extend rootwads on logs up to 3 m away from streambank and perpendicular to the flow; rootplate should be upstream of bole; incorporate existing LWD into structure.
0+451	10	LT-6	Right	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Two structures; locate upstream end just upstream of leaning douglas fir and extend downstream to leaning cedar; position structure to ensure a smooth radius of curvature on meander.
0+512	11	LT-6	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate upstream end of structure at base of existing riffle; incorporate existing LWD into structure.
				Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Locate structure in deep pool (1.1 m); place and anchor brace logs in alder clump.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+590	12	LT-6	Left	Rest. Obj. 1	To re-arrange debris jam at outlet of historic channel; to provide pool with LWD cover near left bank. Dismantle debris jam and incorporate existing logs into LT-6 type structure on left bank; maintain a bankfull channel width of 6-7 m.
0+630	13	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Incorporate existing fir log (5 m long) and rootwad at 0+622 m into structure; locate structure around existing underscoured rootwad.
0+731	14	LSP-5	Left	Rest. Obj. 1	To act as a spur and deflect flow away from bank; to reduce bank erosion; to provide pool with LWD cover along left bank. To reduce erosion behind structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity.
0+767	15	DJ-5	Right	Rest. Obj. 1	To re-establish discharges in the historic left bank channel; provide pool with LWD cover on right bank. Open up a 7 m wide channel by removing logs from left side of jam; construct a DJ-5 type structure with LWD on site.
0+796	16	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate structure in pool; place and anchor brace logs in alder clump.
0+856	17	LT-3	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Excavate pool deeper and slightly larger (2.5 m wide x 10 m long with residual water depth of 0.6 m) prior to constructing LWD structure; anchor existing underscoured rootwad to structure.
0+939	18	LT-6	Right	Rest. Obj. 1	Nanaimo Lakes Road Bridge
1+030					To provide pool with LWD cover along right bank. Lay in brace logs in existing notches in bank.
1+062					To reduce bank erosion; to provide pool with LWD cover along right bank. Construct two structures; locate upstream end of first structure at base of existing riffle and other structure; do not leave a gap between the first and second structures; incorporate existing LWD into structure.
1+130	20	LT-3	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate structure in scour pool at base of existing riffle; incorporate existing LWD and potential blowdown into structure.
1+244	21	LT-3	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Place structure in 0.8 m deep pool; some 0.5-0.6 m boulder ballast on site; 2.5% gradient.
1+403	22	LO-1-Sweeper	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Do not disturb boulders on right bank to maintain deflection of flow to left bank; pool is 0.7 m deep; some 0.6-0.8 m boulder ballast available downstream.
1+435	23	LT-3	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate in 0.8 m deep pool; structure should also protect eroding bank.
1+515	24	LO-1-Sweeper	Left	Rest. Obj.	To provide pool with LWD cover along left bank.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
1+601	25	LO-1-Sweeper	Right	1	Locate in 0.9 m deep pool; anchor to douglas fir on bank.
				Rest. Obj.	To provide pool with LWD cover along right bank.
1+634	26	LO-1-Sweeper	Right	1	Locate in 0.8 m deep pool; anchor to douglas firs located 5 m from channel.
				Rest. Obj.	To provide pool with LWD cover along right bank.
1+786	27	LO-1	Right	1	Construct 2 structures in 0.55 m deep pool and along eroding bank; anchor to douglas firs on bank.
				Rest. Obj.	To provide pool with LWD cover along right bank.
1+877	28	LT-3	Left	1	Place LO-1 upstream of existing fir rootwad; incorporate other rootwad on left bank into structure.
				Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Place in 0.7 m pool; incorporate rootwad into structure; two 0.6 m diameter boulders on site and five 0.9-1.0 m boulders at 1+849 m.
1+952	29	LT-3	Right	1	Locate in 0.55 m pool; four 0.9 m boulders on site.
				Rest. Obj.	To provide pool with LWD cover along right bank.
2+010	30	LT-3	Left	1	Place in 1.3 m pool; incorporate cedar rootwad into structure; one 1 m and three 0.5 m boulders on site.
				Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Excavate streambed to create a long narrow pool (2.5 m wide x 8 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
2+040	31	LT-3	Right	1	Locate in 1 m pool; anchor structure around triple douglas fir rootwads on site; two 0.6 m boulders on site.
				Rest. Obj.	To provide pool with LWD cover along right bank.
2+085	32	LT-6	Right	1	Locate in 0.55 m pool; four 0.9 m boulders on site.
				Rest. Obj.	To provide mid-channel pool with LWD cover.
				1	Anchor to existing boulders; pre-excavate the pool to a residual depth of 0.8 m prior to constructing structure; place oversized boulders from excavate on downstream face of riffle.
2+326	34	LT-6	Right	1	Excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6-0.7 m prior to constructing LWD structure; one 1 m and three 0.6 m boulders on site, and two 0.9 m boulders at 2+364 m.
				Rest. Obj.	To provide pool with LWD cover along right bank.
2+540	35	LT-3	Left	1	Adequate number of 0.6-0.7 m boulders for ballast on site.
				Rest. Obj.	To provide pool with LWD cover along left bank.
2+588	36	LO-1-Sweeper	Right	1	Adequate boulder ballast on site; pre-excavate the pool to a residual depth of 0.8 m prior to constructing structure; place oversized boulders from excavate on downstream face of riffle.
				Rest. Obj.	To provide LWD cover along right bank.
2+666	37	Sweeper	Right	1	Place over 1.4 m pool; adequate boulder ballast on site.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
2+715	38	LT-3	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate in pool (~0.7 m), adjacent to clump of alder.
3+004	39	Sweeper	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Adequate boulder ballast (1 m diameter) on site.
3+059	40	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate upstream end of structure at base of existing riffle; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
3+185	41	LT-3	Left	Rest. Obj. 2 1	Adequate boulder ballast (1-1.8 m diameter) on site. To provide pool with LWD cover along left bank. Locate structure at base of existing riffle; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
3+267	42	Sweeper	Left	Rest. Obj. 2 1	Adequate boulder ballast (1-1.2 m diameter) on site. To provide pool with LWD cover along left bank. Focus flows to the left bank by shifting the boulders at the upstream end of the site towards the right bank.
3+393	43	DJ-5	Left	Rest. Obj. 1	Adequate boulder ballast (1 m diameter) on site. To provide pool with LWD cover along left bank. Locate structure in pool (0.7 m); project into cross section up to 50% of present channel width.
3+431	44	LO-1-Sweeper	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate structure at base of existing riffle; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
3+494	45	LTS-3	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure; project into cross section up to 50% of present channel width.
3+501	46	DL-1	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate structure at 30-45° angle downstream; position higher in elevation on the right bank to deflect flow towards the left bank structure at 3+501 m.
3+560	47	Sweeper	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Two sweepers in deep pool (1.3 m); allow sweepers to float.
3+606	48	LO-1-Sweeper	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate rootwad of LO-1 structure in scour pool of existing riffle; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
3+755	49	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate upstream end of structure at base of existing riffle; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
3+802	50	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate structure in deep pool (1.1 m); project into channel up to 50% of channel width.
3+885	51	DJ-5	Right	Rest. Obj.	To reduce bank erosion; to provide pool with LWD cover along right bank.
				1	Two structures; create a meander jam in the deep pool (1.8 m); good access - right beside Branch 1.
				2	To reduce erosion behind each structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity.
3+969	52	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate upstream end of structure 5 m upstream of underscoured rootwad; bulk of structure should be in the deep pool (1.3 m).
4+042	53	DJ-5	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate structure near existing undersoured rootwads at downstream end of meander pool.
4+056	54	LT-6	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate structure in deep pool (1.1 m); project into channel up to 50% of channel width.
4+130	55	DJ-5	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate structure in deep pool (1.0 m); minimize LWD projection into channel to observed wetted width.
4+211	56	DJ-5	Left	Rest. Obj.	To smooth meander radius of curvature; to provide pool with LWD cover along left bank.
				1	Two structures; locate in deep pool (1.2 m); tie existing instream rootwads into structure; use 12 m long logs to re-align meander radius of curvature to 2.3 times bankfull width.
4+410	57	Sweeper	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate structure as floating cover over existing pool (1.3 m); do not disturb existing logs and rootwad.
4+520	58	LT-6	Right	Rest. Obj.	To provide pool with LWD cover along 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 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
4+712	59	DJ-5	Right	Rest. Obj.	To reduce bank erosion; to provide pool with LWD cover along right bank.
				1	Two structures; use existing debris in structure; good road access.
				2	To reduce erosion behind each structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity.
4+835	60	LT-6	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate structure in deep pool (1.5 m); project into channel up to 50% of channel width.

Note: Unless stated otherwise, it is assumed that:

1 - A sufficient number and size of rock do not exist on site to ballast LWD structure. Additional ballast rock will need to be brought to the site.

2 - Anchor LWD to live trees or stumps on streambank with diameter >20 cm. Alder, cedar, hemlock or maple common on streambanks.

Alternatively, embed tops of logs 2-3 m horizontally and 1 m vertically into the bank. Backfill trench with spoil from excavation.

Table 12. Summary of materials required for LWD and boulder structures in Deadwood Creek.

						LWD Ballast		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Comments
0+000 m - starting at mouth of Deadwood Creek and progressing upstream								
1	0+081	LO-3	Left	3	0.5 x 5-6	10	0.8	With rootwads
2	0+096	LSP-5	Left	5	0.5 x 8-10	6	0.8	Without rootwads
3	0+100	LS-1	Right	1	0.6 x 15	5	0.8	Without rootwad
4	0+180	DJ-5	Right	10	0.5 x 8-10	4	0.8	Two logs with rootwads, three without
5	0+220	LS-1 & LT-3	Right	4	0.5 x 8-10	7	0.8	LS-1 without rootwad, LT-3 with rootwads
6	0+230	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
7	0+274	DJ-5	Left	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
8	0+309	DJ-5	Right	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
9	0+356	LT-6	Left	12	0.5 x 8-10	25	0.8	With rootwads
10	0+451	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
11	0+512	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
12	0+590	LT-6	Left	0	0	25	0.8	Construct and anchor two structures using existing LWD
13	0+630	LT-6	Left	6	0.5 x 8-10	12	0.8	With rootwads
14	0+731	LSP-5	Left	5	0.5 x 8-10	6	0.8	Without rootwads
15	0+767	DJ-5	Right	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
16	0+796	LT-6	Left	6	0.5 x 8-10	12	0.8	With rootwads
17	0+856	LT-3	Right	3	0.5 x 8-10	6	0.8	With rootwads
18	1+030	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
19	1+062	LT-52	Right	18	0.5 x 8-10	37	0.8	With rootwads
20	1+130	LT-3	Right	3	0.5 x 8-10	6	0.8	With rootwads
21	1+244	LT-3	Left	3	0.5 x 8-10	6	0.8	With rootwads
22	1+403	LO-1-Sweeper	Left	2	0.5 x 6/12	5	0.8	6 m LO-1 with rootwad; 12 m long Sweeper
23	1+435	LT-3	Right	3	0.5 x 8-10	6	0.8	With rootwads
24	1+515	LO-1-Sweeper	Left	2	0.5 x 6/12	5	0.8	6 m LO-1 with rootwad; 12 m long Sweeper
25	1+601	LO-1-Sweeper	Right	2	0.5 x 6/12	5	0.8	6 m LO-1 with rootwad; 12 m long Sweeper
26	1+634	LO-1-Sweeper	Right	4	0.5 x 6/12	11	0.8	6 m LO-1 with rootwad; 12 m long Sweeper
27	1+786	LO-1	Right	1	0.5 x 6	3	0.8	With rootwad
28	1+877	LT-3	Left	3	0.5 x 8-10	6	0.8	With rootwads
29	1+952	LT-3	Right	3	0.5 x 8-10	6	0.8	With rootwads
30	2+010	LT-3	Left	3	0.5 x 8-10	6	0.8	With rootwads
31	2+040	LT-3	Right	3	0.5 x 8-10	6	0.8	With rootwads

						LWD Ballast		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Comments
32	2+085	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
33	2+194	LO-1	Mid-stream	1	0.5 x 6	3	0.8	With rootwad
34	2+326	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
35	2+540	LT-3	Left	3	0.5 x 8-10	6	0.8	With rootwads
36	2+588	LO-1-Sweeper	Right	2	0.5 x 6/12	5	0.8	6 m LO-1 with rootwad; 12 m long Sweeper
37	2+666	Sweeper	Right	1	0.5 x 12	2	0.8	With branches
38	2+715	LT-3	Left	3	0.5 x 8-10	6	0.8	With rootwads
39	3+004	Sweeper	Left	1	0.5 x 12	0	0.8	With branches; boulder ballast on site
40	3+059	LT-6	Right	6	0.5 x 8-10	0	0.8	With rootwads; boulder ballast on site
41	3+185	LT-3	Left	3	0.5 x 8-10	0	0.8	With rootwads; boulder ballast on site
42	3+267	Sweeper	Left	1	0.5 x 12	0	0.8	With branches; boulder ballast on site
43	3+393	DJ-5	Left	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
44	3+431	LO-1-Sweeper	Left	2	0.5 x 6/12	5	0.8	6 m LO-1 with rootwad; 12 m long Sweeper
45	3+494	LTS-3	Right	3	0.5 x 8-10	6	0.8	With rootwads
46	3+501	DL-1	Left	1	0.7 x 10	5	0.8	Without rootwad
47	3+560	Sweeper	Right	2	0.5 x 12	4	0.8	With branches
48	3+606	LO-1-Sweeper	Right	2	0.5 x 6/12	5	0.8	6 m LO-1 with rootwad; 12 m long Sweeper
49	3+755	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
50	3+802	LT-6	Left	6	0.5 x 8-10	12	0.8	With rootwads
51	3+885	DJ-5	Right	10	0.5 x 8-10	15	0.8	Four logs with rootwads, 6 without
52	3+969	LT-6	Left	6	0.5 x 8-10	12	0.8	With rootwads
53	4+042	DJ-5	Right	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
54	4+056	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
55	4+130	DJ-5	Right	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
56	4+211	DJ-5	Left	10	0.5 x 8-12	15	0.8	Four logs with rootwads, 6 without
57	4+410	Sweeper	Right	1	0.5 x 12	2	0.8	With branches
58	4+520	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
59	4+712	DJ-5	Right	10	0.5 x 8-10	15	0.8	Four logs with rootwads, 6 without
60	4+835	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
Total				269		506		

Table 13. Ballast requirements and boulder size options for the LWD structures in Deadwood Creek.
Buoyancy and sliding safety factors ≥ 1.5 ; ballast factor = 1; and specific gravity of LWD (S_L) = 0.5.
Modified after D'Aoust and Millar (1999).

					Log (m)			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 @ 130 or 280 kg/m	0.6 @ 240kg /m	0.7 @ 330k g/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (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 mouth of Deadwood Creek and progressing upstream															
1	0+081	LO-3	3	6	5040	0	0	1980	7020	37	23	15	10	7	5
2	0+096	LSP-5	5	6	3900	0	0	0	3900	21	13	8	6	4	3
3	0+100	LS-1	1	15	0	3600	0	0	3600	19	12	8	5	4	3
4	0+180	DJ-5	10	6	7800	0	0	1320	9120	48	30	19	13	9	7
5	0+220	LS-1 & LT-3	4	6	3120	0	0	1980	5100	27	17	11	7	5	4
6	0+230	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
7	0+274	DJ-5	5	6	3900	0	0	1320	5220	27	17	11	7	5	4
8	0+309	DJ-5	5	6	3900	0	0	1320	5220	27	17	11	7	5	4
9	0+356	LT-6	12	6	9360	0	0	7920	17280	91	58	36	25	17	12
10	0+451	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
11	0+512	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
12	0+590	LT-6	12	6	9360	0	0	7920	17280	91	58	36	25	17	12
13	0+630	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
14	0+731	LSP-5	5	6	3900	0	0	0	3900	21	13	8	6	4	3
15	0+767	DJ-5	5	6	3900	0	0	1320	5220	27	17	11	7	5	4
16	0+796	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
17	0+856	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
18	1+030	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
19	1+062	LT-52	18	6	14040	0	0	11880	25920	136	86	54	37	26	19
20	1+130	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
21	1+244	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
22	1+403	LO-1-Sweeper	2	6	2460	0	0	1320	3780	20	13	8	5	4	3
23	1+435	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
24	1+515	LO-1-Sweeper	2	6	2460	0	0	1320	3780	20	13	8	5	4	3
25	1+601	LO-1-Sweeper	2	6	2460	0	0	1320	3780	20	13	8	5	4	3

					Log (m)			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 @ 130 or 280 kg/m	0.6 @ 240kg /m	0.7 @ 330kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (kg)	0.5 @ 190 kg	0.6 @ 300 kg	0.7 @ 480 kg	0.8 @ 700 kg	0.9 @ 1000 kg	1 @ 1400 kg
26	1+634	LO-1-Sweeper	4	6	4920	0	0	2640	7560	40	25	16	11	8	5
27	1+786	LO-1	1	6	1680	0	0	660	2340	12	8	5	3	2	2
28	1+877	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
29	1+952	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
30	2+010	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
31	2+040	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
32	2+085	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
33	2+194	LO-1	1	6	1680	0	0	660	2340	12	8	5	3	2	2
34	2+326	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
35	2+540	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
36	2+588	LO-1-Sweeper	2	6	2460	0	0	1320	3780	20	13	8	5	4	3
37	2+666	Sweeper	1	6	780	0	0	660	1440	8	5	3	2	1	1
38	2+715	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
39	3+004	Sweeper	1	6	780	0	0	660	1440	8	5	3	2	1	1
40	3+059	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
41	3+185	LT-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
42	3+267	Sweeper	1	6	780	0	0	660	1440	8	5	3	2	1	1
43	3+393	DJ-5	5	6	3900	0	0	1320	5220	27	17	11	7	5	4
44	3+431	LO-1-Sweeper	2	6	2460	0	0	1320	3780	20	13	8	5	4	3
45	3+494	LTS-3	3	6	2340	0	0	1980	4320	23	14	9	6	4	3
46	3+501	DL-1	1	10	0	0	3300	0	3300	17	11	7	5	3	2
47	3+560	Sweeper	2	6	1560	0	0	1320	2880	15	10	6	4	3	2
48	3+606	LO-1-Sweeper	2	6	2460	0	0	1320	3780	20	13	8	5	4	3
49	3+755	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
50	3+802	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
51	3+885	DJ-5	10	6	7800	0	0	2640	10440	55	35	22	15	10	7
52	3+969	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
53	4+042	DJ-5	5	6	3900	0	0	1320	5220	27	17	11	7	5	4
54	4+056	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6

					Log (m)			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 @ 130 or 280 kg/m	0.6 @ 240kg /m	0.7 @ 330kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (kg)	0.5 @ 190 kg	0.6 @ 300 kg	0.7 @ 480 kg	0.8 @ 700 kg	0.9 @ 1000 kg	1 @ 1400 kg
55	4+130	DJ-5	5	6	3900	0	0	1320	5220	27	17	11	7	5	4
56	4+211	DJ-5	10	6	7800	0	0	2640	10440	55	35	22	15	10	7
57	4+410	Sweeper	1	6	780	0	0	660	1440	8	5	3	2	1	1
58	4+520	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6
59	4+712	DJ-5	10	6	7800	0	0	2640	10440	55	35	22	15	10	7
60	4+835	LT-6	6	6	4680	0	0	3960	8640	45	29	18	12	9	6

Table 14. Construction notes for specific restoration sites in Little Qualicum River.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
Section A - Starting at 0+000 m at powerline and progressing downstream					
0+040	1	LO-1- Sweeper	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Cable in existing log with rootwad and add another LO-1 about 2 m downstream and on stream side of existing log; add cross brace from LO-1 to tree on streambank.
0+118	2	Boulder Cluster	Right	Rest. Obj.	To provide boulder cover on riffle toe; to improve steelhead parr rearing habitat.
				1	Arrange eight 1-1.2 m diameter boulders in clusters of four at downstream toe of riffle; create 0.4-0.5 m deep backwater pool downstream of largest boulder by grouping three other boulders in a semi-circle about 1 m downstream of largest boulder; largest boulder placed with longest axis perpendicular to the
0+160	3	LO-4	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate from bush downstream and extend along riprap; bring in boulder ballast.
0+300	4	LT-6	Right	Rest. Obj.	To provide pool with LWD cover along right bank; to redefine channel thalweg.
				1	Remove larger riprap from channel to redefine thalweg along right bank; use excavated riprap as boulder cover at base of riffle; locate two LT-6 LWD structures from base of riffle to end of pool beside large fir tree.
0+451	5	DJ-5	Right	Rest. Obj.	To provide LWD cover along right bank.
				1	Locate in 2 m deep pool adjacent to overhanging cedar.
0+515	6	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Locate in 1.5 m deep pool adjacent to overhanging cedar.
0+608	7	LT-3	Right	Rest. Obj.	To provide boulder cover along right bank.
				1	Locate in scour pool at base of riffle.
0+617	8	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Locate in 0.7 m deep pool, immediately downstream of riffle.
0+670	9	LO-1 & Rootwad	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	To provide triangular bracing, place a 6 m long log with rootwad attached under existing instream cottonwoods and anchor bole on left bank; add rootwad only to right side of existing sweepers.
0+697	10	LO-2	Left	Rest. Obj.	To provide LWD cover along left bank.
				1	Place log with rootwad attached downstream of existing rootwad plates; add and anchor small woody debris (SWD) behind existing debris to reduce bank erosion
0+756	11	DJ-5	Right	Rest. Obj.	To provide LWD cover along right bank.
				1	Locate upstream end of structure at base of existing riffle; concentrate most of structure in 0.6 m deep pool; if necessary, excavate to maintain 0.6 m residual depth.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+800	12	LO-2	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Locate upstream end of structure at base of existing riffle; concentrate most of structure in 0.6 m deep pool; if necessary, excavate to maintain 0.6 m residual depth; add SWD to reduce bank erosion.
0+867	13	LT-3	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Locate in scour pool at base of riffle.
0+940	14	LT-3	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate upstream end of structure at base of existing riffle; embed logs into bank; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+963	15	DJ-5	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Construct debris jam adjacent to leaning alder on left bank; excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure; embed logs into streambank.
1+020	16	LO-4	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Locate on the right side and downstream of existing instream alder log; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
1+060	17	LT-3	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Construct at base of riffle and in 0.7 m deep scour pool.
1+080	18	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Construct debris jam adjacent to leaning alder on right bank; excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD
1+105	19	LO-2	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Angle logs off bank similar to existing alder log with rootwad attached; place LO-2 upstream of alder
1+120	20	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate debris jam 3 m downstream of alder log and in 1.2 m deep pool.
1+155	21	LO-4	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Use two existing instream logs and add to additional logs with rootwads attached; use boulders to ballast all the logs; add SWD on right side of structure (i.e., sweepers) to reduce bank erosion.
1+240	22	DJ-5	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate debris jam in 0.9 m deep pool; use longer long logs to anchor boles on streambank; shale bedrock appears unsuitable for anchoring.
1+276	23	Riffle Enhancement	Fullspan	Rest. Obj. 1	To diversify hydraulic habitat on the downstream face of the existing riffle; to increase the area of high quality steelhead parr summer rearing habitat. Diversify the downstream face of the riffle using 0.5- 1.2 m diameter boulders.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
Section B - Starting at 0+000 m at L.Q. hatchery water inlet pipe and progressing downstream					
0+030	24	LO-4	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate in thalweg about 1.5 m to the left of existing riprap; ballast with 1 m diameter boulders.
0+120	25	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Locate structure in 1.1 m deep pool; use one log as long sweeper that extends from the streambank over structure and into pool; existing log with rootwad on right bank should remain as is.
0+182	26	DJ-5	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate structure in 0.7 m deep pool; use one log as long sweeper that extends from the streambank over structure and into pool.
0+238	27	LO-2	Mid-stream	Rest. Obj. 1	To provide mid-channel LWD cover. Locate structure on left side of existing 3 m diameter boulder; logs should have branches and attached rootwads.
0+295	28	DJ-5	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate beside existing instream log and in 0.8 m deep pool.
0+360	29	Riffle Enhancement	Fullspan	Rest. Obj. 1	To diversify hydraulic habitat on the downstream face of the existing riffle; to increase the area of high quality steelhead parr summer rearing habitat. Diversify the downstream face of the riffle using 0.5- 1.2 m diameter boulders.
0+380	30	LO-3	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
0+400	31	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate debris jam at existing alder log with rootwad, and in 2 m deep pool.
0+460	32	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate upstream end of structure at base of existing riffle; concentrate most of structure in 1.5 m deep pool; construct as debris catcher.
0+558	33	Boulder Cluster	Mid-stream	Rest. Obj. 1	To provide boulder cover on riffle toe; to improve steelhead parr rearing habitat. Arrange 16 - 1-1.2 m diameter boulders in clusters of four at downstream toe of riffle; create 0.4-0.5 m deep backwater pool downstream of largest boulder by grouping three other boulders in a semi-circle about 1 m downstream of largest boulder; largest boulder placed with longest axis perpendicular to the
Section C - Starting at 0+000 m and progressing downstream					
0+111	34	Spur +DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Cable in existing maple rootwad.
0+207	35	LO-1+RW	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Locate upstream end of structure at base of existing riffle.
0+240	36	LO-1+ DJ-5	Left	Rest. Obj.	To provide pool with LWD cover along left bank.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+307	37	DJ-5	Left	1 Rest. Obj.	Locate in deep pool; use cable to 'necklace' leaning spruce to other riparian trees. To provide pool with LWD cover along left bank.
0+330	38	LO-3	Left	1 Rest. Obj.	Locate in deep pool; incorporate existing instream alder log with rootwad attached into structure. To provide pool with LWD cover along left bank.
0+388	39	Alcove	Right	Rest. Obj.	To provide LWD cover to alcove on right bank.
0+405	40	DJ-5	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
0+448	41	LO-3	Right	1 Rest. Obj.	Two debris jam structures; locate at 'point of attack', upstream of existing log debris. To provide pool with LWD cover along right bank.
0+542	42	DJ-5	Left	1 Rest. Obj.	Locate structure at base of existing riffle. To provide pool with LWD cover near left bank.
0+650	43	LO-1	Right	1 Rest. Obj.	Locate debris jam in deep pool; use longer long logs to anchor boles on streambank; move large instream alder slightly upstream so bole directs flow into debris jam. To provide pool with LWD cover near right bank.
0+757	44	DJ-5	Left	1 Rest. Obj.	Locate structure at base of existing riffle. To provide pool with LWD cover near left bank.
0+800	45	LO-4	Left	1 Rest. Obj.	Locate in 1.3 m deep pool. To provide pool with LWD cover near left bank.
0+870	46	LX-3	Left	1 Rest. Obj.	Locate upstream end of structure at base of existing riffle To provide pool with LWD cover near left bank.
0+934	47	Boulder Cluster	Mid- stream	1 Rest. Obj.	Locate in >1.5 m deep pool. To provide boulder cover on downstream face of riffle; to improve steelhead parr rearing habitat.
Section D - Starting at 0+000 m and progressing downstream					
0+000	48	Riffle Enhancemen	Fullspa n	1 Rest. Obj.	Arrange 16 - 1-1.2 m diameter boulders in clusters of four at downstream toe of riffle; create 0.4-0.5 m deep backwater pool downstream of largest boulder by grouping three other boulders in a semi-circle about 1 m downstream of largest boulder; largest boulder placed with longest axis perpendicular to the To diversify hydraulic habitat on the downstream face of the existing riffle; to increase the area of high quality steelhead parr summer rearing habitat.
0+020	49	LT-3	Left	1 Rest. Obj.	Narrow the wetted width at the crest of the riffle by pinching off 4 m on the right side and 3 m on the left side of the riffle crest using 0.5-0.7 m diameter boulders. Diversify the downstream face of the riffle using about 15 - 0.8 m diameter boulders. To provide pool with LWD cover along left bank.
0+050	50	LSP-5	Left	1 Rest. Obj.	Locate structure at base of existing riffle; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure. To deflect flow away from base of left bank; to provide pool with LWD cover along left bank.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+070	51	LO-4	Left	1	Locate at apex of left bank corner near point of attack.
				Rest. Obj.	To provide pool with LWD cover along left bank.
0+109	52	LO-3	Left	1	Incorporate existing rootwad into structure; concentrate structure in 1.0 m deep thalweg.
				Rest. Obj.	To provide pool with LWD cover along left bank.
0+225	53	LT-3	Left	1	Place structure in deep thalweg; tie in existing LWD.
				Rest. Obj.	To provide pool with LWD cover along left bank.
0+305	54	DJ-5	Left	1	Use existing cedar log with rootwad in structure; place rootwad close to riffle scour pool.
				Rest. Obj.	To provide pool with LWD cover along left bank.
0+370	55	Boulder Cluster	Mid- stream	1	Two structures; upstream end located at leaning tree.
				Rest. Obj.	To provide boulder cover on riffle toe; to improve steelhead parr rearing habitat.
0+400	56	LT-3	Right	1	Arrange 12 - 1-1.2 m diameter boulders in clusters of four at downstream toe of riffle; create 0.4-0.5 m deep backwater pool downstream of largest boulder by grouping three other boulders in a semi-circle about 1 m downstream of largest boulder; largest boulder placed with longest axis perpendicular to the
				Rest. Obj.	To provide pool with LWD cover along right bank.
0+560	57	Logs & Rootwad	Right	1	Locate structure in deep pool.
				Rest. Obj.	To complex existing alcove with LWD cover.
0+560	58	LT-6	Left	1	Complex with 10 logs, preferably with branches, and 10 rootwads only; deepen pool (20 x 25 m long) to a residual depth of 1 m; with larger boulders (>0.3 m) from excavation, raise riffle at outlet 0.2-0.25 m.
				Rest. Obj.	To provide pool with LWD cover along left bank.
0+710	59	LT-6	Left	1	Locate structure at base of existing riffle; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
				Rest. Obj.	To provide pool with LWD cover along left bank.
0+745	60	LT-6	Left	1	Excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+940	61	LSP-5	Right	1	To provide pool with LWD cover along left bank.
				Rest. Obj.	To deflect flow away from base of right bank; to provide pool with LWD cover along right bank.
0+950	62	LO-4	Right	1	Locate at apex of right bank corner near point of attack.
				Rest. Obj.	To provide pool with LWD cover along right bank.
1+105	63	DJ-5	Left	1	Locate structure in deep thalweg.
				Rest. Obj.	To provide pool with LWD cover along left bank.
1+131	64	LT-6	Left	1	Locate structure immediately downstream of confluence with alcove channel.
				Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate structure in deep pool, immediately upstream of hardpan on streambed.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
1+200	65	LSP-5	Right	Rest. Obj. 1	To deflect flow away from base of right bank; to provide pool with LWD cover along right bank. Locate just upstream of group of cedars on bank; to reduce erosion behind each structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity.
1+255	66	Logs&RW	Left	Rest. Obj. 1	To complex existing alcove with LWD cover. Complex with 5 logs, preferably with branches, and 5 rootwads only; deepen pool (4 x 30 m long) to a residual depth of 0.8 m.
1+355	67	LSP-5	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate along eroding section (102 m) of bank downstream to end of riprap; project length of spur should be 5 m and spacing should be about 20 m; to reduce erosion behind each structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity.
Section E - Starting at 0+000 m at Ozero's bridge crossing and progressing downstream					
0+025	68	LO-3	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate rootwads in deep (>2 m) pool and perpendicular to flow; place boles at base of bank and anchor to boulders.
0+091	69	LO-4	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate structure at base of existing riffle; embed logs into bank to provide additional anchoring; large diameter boulder should be used to anchor at least one log.
0+175	70	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Two debris jam structures; use cedar on bank as anchor point; locate structure in deep pool.
0+349	71	DJ-5	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate structure at base of existing riffle in 1.1 m deep pool; anchor to maple and cedar on bank.
0+370	72	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate structure in 1.2 m deep pool.
0+435	73	DJ-5	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate structure in 1.7 m deep pool.

Note: Unless stated otherwise, it is assumed that:

- 1 - A sufficient number and size of rock do not exist on site to ballast LWD structure. Additional ballast rock will need to be brought to the site.
- 2 - Anchor LWD to live trees or stumps on streambank with diameter >20 cm. Alternatively, embed tops of logs 2-3 m horizontally and 1 m vertically into the bank. Backfill trench with spoil from excavation.

Table 15. Summary of materials required for LWD and boulder structures in Little Qualicum River.

						LWD Ballast		Riffle Boulders		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Volume (m³)	Comments
Section A - Starting at 0+000 m at powerline and progressing downstream										
1	0+040	LO-1-Sweeper	Left	2	0.5 x 6/12	5	0.8			6 m LO-1 with rootwad; 12 m long Sweeper
2	0+118	Boulder Cluster	Right					1.0-1.2		Total of 8 boulders
3	0+160	LO-4	Right	4	0.5 x 6	13	0.8			With rootwads
4	0+300	LT-6	Right	12	0.5 x 8-10	25	0.8			With rootwads
5	0+451	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
6	0+515	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
7	0+608	LT-3	Right	3	0.5 x 8-10	6	0.8			With rootwads
8	0+617	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
9	0+670	LO-1 & Rootwad	Left	2	0.5 x 6	4	0.8			LO-1 structure and rootwad only
10	0+697	LO-2	Left	2	0.5 x 6	7	0.8			With rootwads
11	0+756	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
12	0+800	LO-2	Left	2	0.5 x 6	7	0.8			With rootwads
13	0+867	LT-3	Right	3	0.5 x 8-10	6	0.8			With rootwads
14	0+940	LT-3	Left	3	0.5 x 8-10	6	0.8			With rootwads
15	0+963	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
16	1+020	LO-4	Left	4	0.5 x 6	13	0.8			With rootwads
17	1+060	LT-3	Left	3	0.5 x 8-10	6	0.8			With rootwads
18	1+080	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
19	1+105	LO-2	Right	2	0.5 x 6	7	0.8			With rootwads
20	1+120	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
21	1+155	LO-4	Right	2	0.5 x 6	13	0.8			With rootwads; 2 logs on-site
22	1+240	DJ-5	Left	5	0.5 x 10-12	9	0.8			Two logs with rootwads, three without
23	1+276	Riffle Enhancement	Fullspan					0.5-0.8 1.0-1.2	30 30	

						LWD Ballast		Riffle Boulders		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Volume (m ³)	Comments
Section B - Starting at 0+000 m at L.Q. hatchery water inlet pipe and progressing downstream										
24	0+030	LO-4	Right	4	0.5 x 6	7	1.0			With rootwads
25	0+120	DJ-5	Right	5	0.5 x 8-12	7	0.8			Two logs with rootwads, three without
26	0+182	DJ-5	Left	5	0.5 x 8-12	7	0.8			Two logs with rootwads, three without
27	0+238	LO-2	Mid-stream	2	0.5 x 6	7	0.8			3 m diameter boulder on-site
28	0+295	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
29	0+360	Riffle Enhancement	Fullspan					0.5-0.8 1.0-1.2	30 30	
30	0+380	LO-3	Right	3	0.5 x 6	10	0.8			With rootwads
31	0+400	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
32	0+460	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
33	0+558	Boulder Cluster	Mid-stream					1.0-1.2		16 Boulders
Section C - Starting at 0+000 m and progressing downstream										
34	0+111	Spur +DJ-5	Right	7	0.5 x 8	10	0.8			Two logs with rootwads, five without
35	0+207	LO-1 & RW	Left	2	0.5 x 6	4	0.8			LO-1 structure and rootwad only
36	0+240	LO-1 & DJ-5	Left	6	0.5 x 6-8	11	0.8			Three logs with rootwads, three without
37	0+307	DJ-5	Left	5	0.5 x 6	7	0.8			Use large alder bole and RW
38	0+330	LO-3	Left	3	0.5 x 8-10	10	0.8			Two logs with rootwads, three without
39	0+388	Alcove	Right	20	0.5 x 6-10	14	0.8			Ten rootwads only and ten logs
40	0+405	DJ-5	Right	10	0.5 x 8	15	0.8			Position at attack point
41	0+448	LO-3	Right	3	0.5 x 8	10	0.8			With rootwads
42	0+542	DJ-5	Left	5	0.5 x 12-15	9	0.8			Two logs with rootwads, three without
43	0+650	LO-1	Right	1	0.5 x 8	3	0.8			
44	0+757	DJ-5	Left	5	0.5 x 8	7	0.8			Two logs with rootwads, three without
45	0+800	LO-4	Left	4	0.5 x 8	13	0.8			good parr site
46	0+870	LX-3	Left	3	0.5 x 8	6	0.8			With rootwads
47	0+934	Boulder Cluster	Mid-stream					1.0-1.2		16 Boulders
Section D - Starting at 0+000 m and progressing downstream										
48	0+000	Riffle	Fullspan					0.5-0.8	30	Boulders on crest and downstream face
49	0+020	LT-3	Left	3	0.5 x 8-10	6	0.8			With rootwads
50	0+050	LSP-5	Left	5	0.5 x 8-10	6	0.8			Without rootwads
51	0+070	LO-4	Left	4	0.5 x 6	13	0.8			With rootwads
52	0+109	LO-3	Left	3	0.5 x 6	10	0.8			Without rootwads

						LWD Ballast		Riffle Boulders		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Volume (m ³)	Comments
53	0+225	LT-3	Left	3	0.5 x 8-10	6	0.8			With rootwads
54	0+305	DJ-5	Left	10	0.5 x 8-10	13	0.8			Four logs with rootwads, 6 without
55	0+370	Boulder Cluster	Mid-stream					1.0-1.2		12 Boulders
56	0+400	LT-3	Right	3	0.5 x 8-10	6	0.8			With rootwads
57	0+560	Logs & RW	Right	10	0.5 x 8-10	10	0.8			Complex Alcove
58	0+560	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
59	0+710	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
60	0+745	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
61	0+940	LSP-5	Right	5	0.5 x 8-10	6	0.8			Without rootwads
62	0+950	LO-4	Right	4	0.5 x 6	13	0.8			With rootwads
63	1+105	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
64	1+131	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
65	1+200	LSP-5	Right	5	0.5 x 8-10	6	0.8			Without rootwads
66	1+255	Logs & RW	Left	5	0.5 x 8-10	10	0.8			Complex Alcove
67	1+355	LSP-5	Right	25	0.5 x 8-10	28	0.8			Without rootwads
Section E - Starting at 0+000 m at Ozero's bridge crossing and progressing downstream										
68	0+025	LO-3	Right	3	0.5 x 6	10	0.8			With rootwads
69	0+091	LO-4	Left	4	0.5 x 6	13	0.8			With rootwads
70	0+175	DJ-5	Right	10	0.5 x 10-15	19	0.8			Four logs with rootwads, 6 without
71	0+349	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
72	0+370	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
73	0+435	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
Total				339		610			150	

Table 16. Ballast requirements and boulder size options for the LWD structures in Little Qualicum River.
Buoyancy and sliding safety factors ≥ 1.5 ; ballast factor = 1; and specific gravity of LWD (S_L) = 0.5.
Modified after D'Aoust and Millar (1999).

					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 @ 130 or 280 kg/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
Section A - Starting at 0+000 m at powerline and progressing downstream															
1	0+040	LO-1-Sweeper	2	6	2460	1320	3780	108	42	20	13	8	5	4	3
2	0+118	Boulder Cluster	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0+160	LO-4	4	6	6720	2640	9360	267	104	49	31	20	13	9	7
4	0+300	LT-6	12	6	9360	7920	17280	494	192	91	58	36	25	17	12
5	0+451	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4
6	0+515	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4
7	0+608	LT-3	3	6	2340	1980	4320	123	48	23	14	9	6	4	3
8	0+617	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4
9	0+670	LO-1 & Rootwad	2	6	1680	1320	3000	86	33	16	10	6	4	3	2
10	0+697	LO-2	2	6	3360	1320	4680	134	52	25	16	10	7	5	3
11	0+756	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4
12	0+800	LO-2	2	6	3360	1320	4680	134	52	25	16	10	7	5	3
13	0+867	LT-3	3	6	2340	1980	4320	123	48	23	14	9	6	4	3
14	0+940	LT-3	3	6	2340	1980	4320	123	48	23	14	9	6	4	3
15	0+963	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4
16	1+020	LO-4	4	6	6720	2640	9360	267	104	49	31	20	13	9	7
17	1+060	LT-3	3	6	2340	1980	4320	123	48	23	14	9	6	4	3
18	1+080	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4
19	1+105	LO-2	2	6	3360	1320	4680	134	52	25	16	10	7	5	3
20	1+120	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4
21	1+155	LO-4	4	6	6720	2640	9360	267	104	49	31	20	13	9	7
22	1+240	DJ-5	5	8	5200	1320	6520	186	72	34	22	14	9	7	5
23	1+276	Riffle Enhancement	0	0	0	0	0	0	0	0	0	0	0	0	0
Section B - Starting at 0+000 m at L.Q. hatchery water inlet pipe and progressing downstream															

					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 @ 130 or 280 kg/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	
24	0+030	LO-4	4	6	6720	2640	9360	267	104	49	31	20	13	9	7	
25	0+120	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4	
26	0+182	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4	
27	0+238	LO-2	2	6	3360	1320	4680	134	52	25	16	10	7	5	3	
28	0+295	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4	
29	0+360	Riffle Enhancement	0	0	0	0	0	0	0	0	0	0	0	0	0	
30	0+380	LO-3	3	6	5040	1980	7020	201	78	37	23	15	10	7	5	
31	0+400	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4	
32	0+460	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4	
33	0+558	Boulder Cluster	0	0	0	0	0	0	0	0	0	0	0	0	0	
Section C - Starting at 0+000 m and progressing downstream																
34	0+111	Spur +DJ-5	7	6	5460	1320	6780	194	75	36	23	14	10	7	5	
35	0+207	LO-1 & RW	2	6	1680	1320	3000	86	33	16	10	6	4	3	2	
36	0+240	LO-1 & DJ-5	6	6	5580	1980	7560	216	84	40	25	16	11	8	5	
37	0+307	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4	
38	0+330	LO-3	3	6	5040	1980	7020	201	78	37	23	15	10	7	5	
39	0+388	Alcove	10	6	3000	6600	9600	274	107	51	32	20	14	10	7	
40	0+405	DJ-5	10	6	7800	2640	10440	298	116	55	35	22	15	10	7	
41	0+448	LO-3	3	6	5040	1980	7020	201	78	37	23	15	10	7	5	
42	0+542	DJ-5	5	8	5200	1320	6520	186	72	34	22	14	9	7	5	
43	0+650	LO-1	1	6	1680	660	2340	67	26	12	8	5	3	2	2	
44	0+757	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4	
45	0+800	LO-4	4	6	6720	2640	9360	267	104	49	31	20	13	9	7	
46	0+870	LX-3	3	6	2340	1980	4320	123	48	23	14	9	6	4	3	
47	0+934	Boulder Cluster	0	0	0	0	0	0	0	0	0	0	0	0	0	
Section D - Starting at 0+000 m and progressing downstream																
48	0+000	Riffle Enhancement	0	0	0	0	0	0	0	0	0	0	0	0	0	
49	0+020	LT-3	3	6	2340	1980	4320	123	48	23	14	9	6	4	3	
50	0+050	LSP-5	5	6	3900	0	3900	111	43	21	13	8	6	4	3	
51	0+070	LO-4	4	6	6720	2640	9360	267	104	49	31	20	13	9	7	
52	0+109	LO-3	3	6	5040	1980	7020	201	78	37	23	15	10	7	5	

					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 @ 130 or 280 kg/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
53	0+225	LT-3	3	6	2340	1980	4320	123	48	23	14	9	6	4	3
54	0+305	DJ-5	10	6	7800	1320	9120	261	101	48	30	19	13	9	7
55	0+370	Boulder Cluster	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0+400	LT-3	3	6	2340	1980	4320	123	48	23	14	9	6	4	3
57	0+560	Logs & RW	10	6	7800	6600	14400	411	160	76	48	30	21	14	10
58	0+560	LT-6	6	6	4680	3960	8640	247	96	45	29	18	12	9	6
59	0+710	LT-6	6	6	4680	3960	8640	247	96	45	29	18	12	9	6
60	0+745	LT-6	6	6	4680	3960	8640	247	96	45	29	18	12	9	6
61	0+940	LSP-5	5	6	3900	0	3900	111	43	21	13	8	6	4	3
62	0+950	LO-4	4	6	6720	2640	9360	267	104	49	31	20	13	9	7
63	1+105	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4
64	1+131	LT-6	6	6	4680	3960	8640	247	96	45	29	18	12	9	6
65	1+200	LSP-5	5	6	3900	0	3900	111	43	21	13	8	6	4	3
66	1+255	Logs & RW	5	6	3900	3300	7200	206	80	38	24	15	10	7	5
67	1+355	LSP-5	25	6	19500	0	19500	557	217	103	65	41	28	20	14
Section E - Starting at 0+000 m at Ozero's bridge crossing and progressing downstream															
68	0+025	LO-3	3	6	5040	1980	7020	201	78	37	23	15	10	7	5
69	0+091	LO-4	4	6	6720	2640	9360	267	104	49	31	20	13	9	7
70	0+175	DJ-5	10	8	10400	2640	13040	373	145	69	43	27	19	13	9
71	0+349	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4
72	0+370	LT-6	6	6	4680	3960	8640	247	96	45	29	18	12	9	6
73	0+435	DJ-5	5	6	3900	1320	5220	149	58	27	17	11	7	5	4

Table 17. Construction notes for specific restoration sites in Oyster River.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
Section B - 0+000 m starting at mouth of Little Oyster River and progressing downstream					
0+201	1	LO-1- Sweeper	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Some ballast on site (1.8 m diameter boulder); anchor sweeper to right bank and place along left side of LO-1; rootwad of LO-1 placed in scour pool of riffle and perpendicular to flow.
0+280	2	LO-4	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Place LWD in thalweg of pool (1 m deep).
0+412	3	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Two 1.3 m diameter boulders on site, but need additional ballast; place structure upstream of large boulders.
0+456	4	LO-1- Sweeper	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Place LO-1 structure just outside of 1 m diameter cedar that's currently being under-cut on the bank; concentrate sweeper over deep thalweg.
0+825	5	Boulder Cluster	Left	Rest. Obj.	To provide boulder cover along left bank; to improve steelhead parr rearing habitat.
				1	Remove larger boulders at base of left bank and arrange in clusters in thalweg.
1+005	6	Boulder Cluster	Left	Rest. Obj.	To provide boulder cover along left bank; to improve steelhead parr rearing habitat.
				1	Arrange 15 - 1.2 m diameter boulders in clusters in deeper part of glide.
1+087	7	LT-5	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
1+205	8	Boulder Cluster	Right	Rest. Obj.	To provide boulder cover along right bank; to improve steelhead parr rearing habitat.
				1	Arrange 12 - 1.2 m diameter boulders in clusters in deeper part of glide.
1+461	9	LT-6	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Use 12 to 14 long LWD; large sitka spruce on bank for anchoring; site adjacent to farmer's fence.
1+563	10	LO-1	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Pull existing hemlock (0.6 x 28 m with 4 m rootwad) blowdown into channel; position at base of riffle; 8-0.8 m boulders on site.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
1+731	11	Boulder Cluster	Left	Rest. Obj.	To provide boulder cover along left bank; to improve steelhead parr rearing habitat.
				1	Arrange 6 - 1.2 m diameter boulders in clusters in deeper part of glide.
1+842	12	Boulder Cluster	Left	Rest. Obj.	To provide boulder cover along left bank; to improve steelhead parr rearing habitat.
				1	Arrange 15 - 1.2 m diameter boulders in clusters in deeper part of glide.
1+937	13	LT-6	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Upstream log in structure should be 0.7 x 12 m and embedded into right bank.
2+111	14	LO-4	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Riprapped bank but additional boulder ballast required; place LWD along thalweg.
2+390	15	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate immediately downstream of side channel confluence at 2+378 m; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure; use at least two 15 m long logs to anchor on streambank.
2+539	16	LO-1	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Anchor to 1.4 m diameter boulder on left side of boulder; place rootwad in scour pool below riffle.
2+544	17	LO-1	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Locate about 4 m downstream and on left side of large instream stump; also anchor with cable to 1.4 m boulder upstream.
2+720	18	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Use at least four 15 m long logs to anchor / embed in streambank; rootwads on instream logs should be 2.5-3 m in diameter.
2+745; 2+765; 2+785; 2+826	19-22	LO-1- Sweeper	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Upstream log in structure should be 0.7 x 12 m; a trench should be excavated on the left bank and this log should be placed in the trench, boulder ballasted and then buried; instream log with rootwad should be located on the left side of the 1.3 m deep thalweg.
2+895	23	Anchor Log	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Cable existing cottonwood sweeper to clump of trees and two boulders placed on the streambank.
2+986	24	Boulder Cluster	Right	Rest. Obj.	To provide boulder cover along right bank; to improve steelhead parr rearing habitat.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
3+154	25	LO-1- Sweeper	Right	1	Arrange 12 - 1.2 to 1.5 m diameter boulders in clusters in deeper part of scour pool about 5 m downstream of riffle.
				Rest. Obj.	To provide pool with LWD cover near right bank.
3+280	26	LO-1- Sweeper	Right	1	Anchor LO-1 to existing 1.9 m diameter boulder; excavate streambed to create a small narrow pool (2 m wide x 4 m long) with residual water depth of 0.6 m prior to constructing LWD structure; rootwad of LO-1 placed in an excavated scour pool; sufficient boulder ballast on site; anchor sweeper to right bank and place along left side of LO-1.
				Rest. Obj.	To provide pool with LWD cover near right bank.
3+571	27	DJ-5	Right	1	Locate in 0.8 m deep pool upstream of riffle crest; anchor sweeper to right bank and place along left side of LO-1.
				Rest. Obj.	To provide pool with LWD cover near right bank.
3+788	28	LO-1	Left	1	Concentrate structure in 0.8 m deep pool; position some rootwad plates parallel and the others perpendicular to streamflow.
				Rest. Obj.	To provide pool with LWD cover along left bank.
3+995	29	LT-6	Right	1	Use 1.2 m boulder ballast to provide for future boulder cover.
				Rest. Obj.	To provide pool with LWD cover near right bank.
4+125	30	DJ-5	Right	1	Locate structure at base of riffle; excavate trenches and bury boles in bank.
				Rest. Obj.	To provide pool with LWD cover near right bank.
4+258	31	DJ-5	Right	1	Two debris jam structures; place 25 m downstream of spanning log in back eddy.
				Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Two structures; locate immediately downstream of side channel confluence in 0.7 m deep pool.
Section D - 0+000 m starting at Hideaway Resort and progressing downstream					
0+157	32	LO-1- Sweeper	Left	1	Rest. Obj. To provide pool with LWD cover along left bank.
				1	Some ballast on site (one 1.3 m diameter boulder); anchor sweeper to left bank and place along right side of LO-1; rootwad of LO-1 placed in scour pool of riffle and perpendicular to flow.
0+348	33	LT-6	Right	1	Rest. Obj. To provide pool with LWD cover near right bank.
				1	Four 0.6 m boulders on site; adjacent to campsite.
0+419	34	LT-6	Left	1	Rest. Obj. To provide pool with LWD cover along left bank.
				1	Locate upstream end of structure at base of existing riffle; concentrate most of structure in 0.8 m deep pool.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+580	35	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Four boulders on site (2, 2, 1.8, 0.9 m diameter) can be used for ballast; pool 1.1 m deep; site located at end of Bracken Rd. access trail.
0+890	36	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Locate upstream end of structure at base of existing riffle; incorporate existing logs into structure.
1+129	37	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Locate upstream end of structure at base of existing riffle.
1+143	38	LO-1	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. One 2 m diameter boulder on site; place log with branches (rootwad not necessary) on right side of boulder.
1+238	39	DJ-5	Left	Rest. Obj. 1	To provide scour pool with LWD cover at confluence with left bank side channel. Locate structure at base of existing riffle; about eight 0.8 m diameter boulders on site.
1+662	40	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
1+686	41	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
1+879	42	Sweeper	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Anchor sweeper to cedar on bank and locate over scour pool at base of riffle.
2+102	43	LO-1- Sweeper	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Anchor sweeper to cedar on right bank and place along left side of LO-1; rootwad of LO-1 placed perpendicular to flow.
2+176	44	LT-6	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
Section C - 0+000 starting at Hideaway Resort and progressing upstream					
0+209	45	LO-1	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Place upstream of existing sweeper; boulder ballast / anchor existing sweeper.
0+379	46	LO-1- Sweeper	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
0+412	47	LO-1- Sweeper	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
0+435	48	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Locate in 1.4 m deep pool; excavate trenches and bury boles in bank.
0+453	49	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Locate at base of riffle in 1 m deep pool.
0+659	50	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+749	51	LT-6	Left	1	Locate near douglas fir on bank and in 0.9 m deep pool; excavate trenches and bury boles in bank.
0+797	52	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate adjacent to under-scoured stump; three 0.8 m boulders on site; concentrate ballast on bank rather than in 0.8 m deep pool.
0+960	53	LO-1- Sweeper	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
1+191	54	LO-1- Sweeper	Left	1	Locate LO-1 immediately downstream of hardpan section on streambed and in 1.1 m deep pool.
				Rest. Obj.	To provide pool with LWD cover along left bank.
1+338	55	LO-1- Sweeper	Left	1	Locate structure at base of existing riffle in 0.8 m deep pool.
				Rest. Obj.	To provide pool with LWD cover along left bank.
1+546	56	LO-1- Sweeper	Left	1	Locate structure at base of existing riffle in 0.8 m deep pool; two 0.8 m diameter boulders on site.
				Rest. Obj.	To provide pool with LWD cover along left bank.
2+242	57	LO-1- Sweeper	Left	1	Locate structure at base of existing riffle in 0.9 m deep pool and about 5 m from bank; 1.2 to 1.5 m diameter boulders on right bank.
				Rest. Obj.	To provide pool with LWD cover along left bank.
2+522	58	LO-1- Sweeper	Left	1	Locate structure in 1.4 m deep pool; 1.2 and 0.8 m boulders on site.
				Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate structure at base of existing riffle; Four 0.7 m diameter boulders on site.

Note: Unless stated otherwise, it is assumed that:

- 1 - A sufficient number and size of rock do not exist on site to ballast LWD structure. Additional ballast rock will need to be brought to the site.
- 2 - Anchor LWD to live trees or stumps on streambank with diameter >20 cm. Alternatively, embed tops of logs 2-3 m horizontally and 1 m vertically into the bank. Backfill trench with spoil from excavation.

Table 18. Summary of materials required for LWD and boulder structures in Oyster River.

						LWD Ballast		Boulders		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Volume (m³)	Comments
Section B - 0+000 m starting at mouth of Little Oyster River and progressing downstream										
1	0+201	LO-1-Sweeper	Right	2	0.7 x 6/15	8	0.8			9 m LO-1 with rootwad; 15 m long Sweeper
2	0+280	LO-4	Right	4	0.5 x 6	13	0.8			With rootwads
3	0+412	DJ-5	Left	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
4	0+456	LO-1-Sweeper	Left	2	0.7 x 6/15	8	0.8			9 m LO-1 with rootwad; 15 m long Sweeper
5	0+825	Boulder Cluster	Left					0	0	Boulders on site
6	1+005	Boulder Cluster	Left					1.2		Add 15 boulders
7	1+087	LT-5	Right	5	0.5 x 8-10	10	0.8			With rootwads
8	1+205	Boulder Cluster	Right					1.2		Add 12 boulders
9	1+461	LT-6	Right	6	0.5 x 12-14	12	0.8			With rootwads
10	1+563	LO-1	Right	0	0.6 x 28	0				LWD and ballast on-site
11	1+731	Boulder Cluster	Left					1.2		Add 6 boulders
12	1+842	Boulder Cluster	Left					1.2		Add 15 boulders
13	1+937	LT-6	Right	6	0.5 x 8-10; 0.7 x 12	14	0.8			With rootwads
14	2+111	LO-4	Right	4	0.5 x 6	13	0.8			With rootwads
15	2+390	DJ-5	Left	5	0.5 x 10-15	7	0.8			Two logs with rootwads, three without
16	2+539	LO-1	Right	1	0.5 x 6	2	0.8			With rootwad; 1.4 m boulder on-site
17	2+544	LO-1	Right	1	0.5 x 6	3	0.8			With rootwad
18	2+720	LT-6	Left	6	0.5 x 6/15	12	0.8			With rootwads; 4 logs to be 15 m long
19	2+745	LO-1-Sweeper	Left	2	0.7 x 6/15	8	0.8			6 m LO-1 with rootwad; 15 m long Sweeper
20	2+765	LO-1-Sweeper	Left	2	0.7 x 6/15	8	0.8			7 m LO-1 with rootwad; 15 m long Sweeper
21	2+785	LO-1-Sweeper	Left	2	0.7 x 6/15	8	0.8			8 m LO-1 with rootwad; 15 m long Sweeper
22	2+826	LO-1-Sweeper	Left	2	0.7 x 6/15	8	0.8			9 m LO-1 with rootwad; 15 m long Sweeper

						LWD Ballast		Boulders		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Volume (m ³)	Comments
23	2+895	Anchor Log	Left	0		2	0.8			Cable to bank trees
24	2+986	Boulder Cluster	Right					1.2-1.5		Add 12 boulders
25	3+154	LO-1-Sweeper	Right	2	0.7 x 6/15	0	0.8			9 m LO-1 with rootwad; 15 m long Sweeper
26	3+280	LO-1-Sweeper	Right	2	0.7 x 6/15	8	0.8			9 m LO-1 with rootwad; 15 m long Sweeper
27	3+571	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
28	3+788	LO-1	Left	1	0.5 x 6	2	1			With rootwad; use 1-1.2 m ballast
29	3+995	LT-6	Right	6	0.5 x 8-10	12	0.8			With rootwads
30	4+125	DJ-5	Right	10	0.5 x 8-10	15	0.8			Four LWD with rootwads; six without
31	4+258	DJ-5	Right	10	0.5 x 8-11	15	0.8			Four LWD with rootwads; six without
Section D - 0+000 m starting at Hideaway Resort and progressing downstream										
32	0+157	LO-1-Sweeper	Left	2	0.5 x 6/12	5	0.8			6 m LO-1 with rootwad; 12 m long Sweeper
33	0+348	LT-6	Right	6	0.5 x 8-10	12	0.8			With rootwads
34	0+419	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
35	0+580	LT-6	Right	6	0.5 x 10-12	3	0.8			With rootwads
36	0+890	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
37	1+129	LT-6	Right	6	0.5 x 8-10	12	0.8			With rootwads
38	1+143	LO-1	Left	1	0.5 x 6	0	0.8			Without rootwad but with branches;
39	1+238	DJ-5	Left	5	0.5 x 8-10	0	0.8			Two logs with rootwads, three without
40	1+662	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
41	1+686	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
42	1+879	Sweeper	Left	1	0.5 x 12	2	0.8			Without rootwad
43	2+102	LO-1-Sweeper	Right	2	0.5 x 6/12	5	0.8			6 m LO-1 with rootwad; 12 m long Sweeper
44	2+176	LT-6	Right	6	0.5 x 8-10	12	0.8			With rootwads

						LWD Ballast		Boulders		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Diameter (m)	Volume (m ³)	Comments
Section C - 0+000 starting at Hideaway Resort and progressing upstream										
45	0+209	LO-1	Right	1	0.5 x 6	5	0.8			With rootwad; includes ballast for
46	0+379	LO-1-Sweeper	Right	2	0.5 x 6/12	5	0.8			6 m LO-1 with rootwad; 12 m long Sweeper
47	0+412	LO-1-Sweeper	Right	2	0.5 x 6/12	5	0.8			6 m LO-1 with rootwad; 12 m long Sweeper
48	0+435	LT-6	Right	6	0.5 x 8-10	12	0.8			With rootwads
49	0+453	DJ-5	Right	5	0.5 x 8-10	7	0.8			Two logs with rootwads, three without
50	0+659	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
51	0+749	LT-6	Left	6	0.5 x 8-10	12	0.8			With rootwads
52	0+797	LT-6	Left	6	0.5 x 8-10	9	0.8			With rootwads; 3-0.8 m boulders on-
53	0+960	LO-1-Sweeper	Left	2	0.5 x 6/12	0	0.8			6 m LO-1 with rootwad; 12 m long Sweeper
54	1+191	LO-1-Sweeper	Left	2	0.5 x 6/12	5	0.8			6 m LO-1 with rootwad; 12 m long Sweeper
55	1+338	LO-1-Sweeper	Left	2	0.5 x 6/12	2	0.8			6 m LO-1 with rootwad; 12 m long Sweeper
56	1+546	LO-1-Sweeper	Left	2	0.5 x 6/12	0	0.8			6 m LO-1 with rootwad; 12 m long Sweeper
57	2+242	LO-1-Sweeper	Left	2	0.5 x 6/12	2	0.8			6 m LO-1 with rootwad; 12 m long Sweeper
58	2+522	LO-1-Sweeper	Left	2	0.5 x 6/12	5	0.8			6 m LO-1 with rootwad; 12 m long Sweeper
Total				196		382				

Table 19. Ballast requirements and boulder size options for the LWD structures in Oyster River.

Buoyancy and sliding safety factors ≥ 1.5 ; ballast factor = 1; and specific gravity of LWD (S_L) = 0.5.

Modified after D'Aoust and Millar (1999).

					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 @ 130 or 280 kg/m	0.7 @ 330 or 400 kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (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
Section B - 0+000 m starting at mouth of Little Oyster River and progressing downstream															
1	0+201	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4
2	0+280	LO-4	4	6	6720	0	2640	9360	104	49	31	20	13	9	7
3	0+412	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
4	0+456	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4
5	0+825	Boulder Cluster	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1+005	Boulder Cluster	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1+087	LT-5	5	6	3900	0	3300	7200	80	38	24	15	10	7	5
8	1+205	Boulder Cluster	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1+461	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
10	1+563	LO-1	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1+731	Boulder Cluster	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1+842	Boulder Cluster	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1+937	LT-6	6	6	3900	1980	3960	9840	109	52	33	21	14	10	7
14	2+111	LO-4	4	6	6720	0	2640	9360	104	49	31	20	13	9	7
15	2+390	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
16	2+539	LO-1	1	6	1680	0	660	2340	26	12	8	5	3	2	2
17	2+544	LO-1	1	6	1680	0	660	2340	26	12	8	5	3	2	2
18	2+720	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
19	2+745	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4
20	2+765	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4

					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 @ 130 or 280 kg/m	0.7 @ 330 or 400 kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (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
21	2+785	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4
22	2+826	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4
23	2-895	Anchor Log	0	0	0	0	0	0	0	0	0	0	0	0	0
24	2+986	Boulder Cluster	0	0	0	0	0	0	0	0	0	0	0	0	0
25	3+154	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4
26	3+280	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4
27	3+571	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
28	3+788	LO-1	1	6	1680	0	660	2340	26	12	8	5	3	2	2
29	3+995	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
30	4+125	DJ-5	10	6	7800	0	2640	10440	116	55	35	22	15	10	7
31	4+258	DJ-5	10	6	7800	0	2640	10440	116	55	35	22	15	10	7
Section D - 0+000 m starting at Hideaway Resort and progressing downstream															
32	0+157	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
33	0+348	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
34	0+419	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
35	0+580	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
36	0+890	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
37	1+129	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
38	1+143	LO-1	1	6	1680	0	660	2340	26	12	8	5	3	2	2
39	1+238	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
40	1+662	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
41	1+686	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
42	1+879	Sweeper	1	6	780	0	660	1440	16	8	5	3	2	1	1
43	2+102	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
44	2+176	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6

					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 @ 130 or 280 kg/m	0.7 @ 330 or 400 kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (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
Section C - 0+000 starting at Hideaway Resort and progressing upstream															
45	0+209	LO-1	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
46	0+379	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
47	0+412	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
48	0+435	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
49	0+453	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
50	0+659	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
51	0+749	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
52	0+797	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
53	0+960	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
54	1+191	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
55	1+338	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
56	1+546	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
57	2+242	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
58	2+522	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3

Table 20. Construction notes for specific restoration sites in Little Oyster River.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+000 m - starting at mouth of Little Oyster River and progressing upstream					
0+093			Right		Outlet of beaver pond / constructed side channel complex
0+165	1	LT-3	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure; use the larger boulders (>0.5 m) to diversify and raise the crest elevation of the riffle downstream.
0+223	2	LT-3	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+354	3	LT-3	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure. Napoleon Creek confluence
0+366	4	LT-3	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure; locate structure in scour pool at base of existing riffle.
0+400	5	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure; embed logs into streambank.
0+415	6	DJ-5	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank; to narrow the channel width to about 9 m. To deflect flow towards right bank and LT-6 structure at 0+400 m, construct at head of gravel bar; in addition to boulder ballast, bury deadmen to anchor structure on bar.
0+474	7	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Two debris jam structures; construct near downstream end of meander bend and in ~0.9 m deep pool; leave existing diagonal log in place.
0+517	8	LTS-3	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Upstream log in structure should be 0.7 x 12 m, embedded into left bank and flush with gravel bar top on right bank.
0+570	9	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Upstream log in structure should be 0.7 x 12 m and embedded into right bank; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+604	10	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Upstream log in structure should be 0.7 x 12 m and embedded into left bank; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+733	11	DJ-5	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure; embed logs into streambank.
0+783	12	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Upstream log in structure should be 0.7 x 12 m and embedded into right bank; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
1+040	13	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Upstream log in structure should be 0.7 x 12 m and embedded into left bank; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
1+092	14	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Upstream log in structure should be 0.7 x 12 m and embedded into left bank; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
1+235	15	DJ-5	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Construct debris jam across inlet to overflow channel on left bank; ensure structure is porous to maintain some discharge in overflow channel; excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure; embed logs into streambank.
1+292	16	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Upstream log in structure should be 0.7 x 12 m, embedded into right bank and flush with gravel bar top on left bank; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
1+330	17	LT-3	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure; embed logs into streambank.
1+363	18	LT-6	Right	Rest. Obj.	To provide pool with LWD cover near right bank.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
				1	Upstream log in structure should be 0.7 x 12 m and embedded into right bank; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
1+430	19	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Upstream log in structure should be 0.7 x 12 m and embedded into left bank; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure.

Note: Unless stated otherwise, it is assumed that:

- 1 - A sufficient number and size of rock do not exist on site to ballast LWD structure. Additional ballast rock will need to be brought to the site.
- 2 - Anchor LWD to live trees or stumps on streambank with diameter >20 cm. Alder, cedar, hemlock or maple common on streambanks. Alternatively, embed tops of logs 2-3 m horizontally and 1 m vertically into the bank. Backfill trench with spoil from excavation.

Table 21. Summary of materials required for LWD and boulder structures in Little Oyster River.

						LWD Ballast		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Comments
0+000 m - starting at mouth of Little Oyster and progressing upstream								
1	0+165	LT-3	Right	3	0.5 x 8-10	6	0.8	With rootwads
2	0+223	LT-3	Left	3	0.5 x 8-10	6	0.8	With rootwads
3	0+354	LT-3	Right	3	0.5 x 8-10	6	0.8	With rootwads
4	0+366	LT-3	Left	3	0.5 x 8-10	6	0.8	With rootwads
5	0+400	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
6	0+415	DJ-5	Left	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
7	0+474	DJ-5	Right	10	0.5 x 8-10	15	0.8	Four logs with rootwads, 6 without
8	0+517	LTS-3	Left	3	0.5 x 8-10; 0.7 x 12	8	0.8	With rootwads
9	0+570	LT-6	Right	6	0.5 x 8-10; 0.7 x 12	14	0.8	With rootwads
10	0+604	LT-6	Left	6	0.5 x 8-10; 0.7 x 12	14	0.8	With rootwads
11	0+733	DJ-5	Left	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
12	0+783	LT-6	Right	6	0.5 x 8-10; 0.7 x 12	14	0.8	With rootwads
13	1+040	LT-6	Left	6	0.5 x 8-10; 0.7 x 12	14	0.8	With rootwads
14	1+092	LT-6	Left	6	0.5 x 8-10; 0.7 x 12	14	0.8	With rootwads
15	1+235	DJ-5	Left	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
16	1+292	LT-6	Right	6	0.5 x 8-10; 0.7 x 12	14	0.8	With rootwads
17	1+330	LT-3	Left	3	0.5 x 8-10	6	0.8	With rootwads
18	1+363	LT-6	Right	6	0.5 x 8-10; 0.7 x 12	14	0.8	With rootwads
19	1+430	LT-6	Left	6	0.5 x 8-10; 0.7 x 12	14	0.8	With rootwads
Total				97		198		

Table 22. Ballast requirements and boulder size options for the LWD structures in Little Oyster River.
Buoyancy and sliding safety factors ≥ 1.5 ; ballast factor = 1; and specific gravity of LWD (S_L) = 0.5.
Modified after D'Aoust and Millar (1999).

					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 @ 130 kg/m	0.7 @ 330kg /m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (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 mouth of Little Oyster and progressing upstream															
1	0+165	LT-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3
2	0+223	LT-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3
3	0+354	LT-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3
4	0+366	LT-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3
5	0+400	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
6	0+415	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
7	0+474	DJ-5	10	6	7800	0	2640	10440	116	55	35	22	15	10	7
8	0+517	LTS-3	3	6	1560	1980	1980	5520	61	29	18	12	8	6	4
9	0+570	LT-6	6	6	3900	1980	3960	9840	109	52	33	21	14	10	7
10	0+604	LT-6	6	6	3900	1980	3960	9840	109	52	33	21	14	10	7
11	0+733	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
12	0+783	LT-6	6	6	3900	1980	3960	9840	109	52	33	21	14	10	7
13	1+040	LT-6	6	6	3900	1980	3960	9840	109	52	33	21	14	10	7
14	1+092	LT-6	6	6	3900	1980	3960	9840	109	52	33	21	14	10	7
15	1+235	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
16	1+292	LT-6	6	6	3900	1980	3960	9840	109	52	33	21	14	10	7
17	1+330	LT-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3
18	1+363	LT-6	6	6	3900	1980	3960	9840	109	52	33	21	14	10	7
19	1+430	LT-6	6	6	3900	1980	3960	9840	109	52	33	21	14	10	7

Table 23. Construction notes for specific restoration sites in Quinsam River.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
Section A - 0+000 m starting at Quinsam Hatchery Fence and progressing downstream					
0+185	1	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Locate upstream end of structure near base of existing riffle.
0+410	2	LO-3	Right	Rest. Obj. 1	To provide pool with LWD cover near left bank. Locate structure adjacent to 30 m fir log along bank; first upstream log of structure place 2 m downstream of existing rootwad.
0+530	3	LO-1	Left	Rest. Obj. 1	To narrow channel slightly and deflect flow to structure at 0+250 m; to provide pool with LWD cover near right bank. Place LO-1 downstream and on the right of 1.6 m diameter boulder; use ~0.7 x 8 m log with attached 1.5-2.0 m rootwad.
0+746	4	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Existing logs on site but poor condition; anchor to existing boulders but also bring in additional ballast; locate in 1.1 m deep pool on stream-side of existing logs.
0+819	5	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Place in 1.2 m deep pool, upstream of ~1.8 m diameter boulder; upstream end of structure adjacent to maple.
0+994	6	LO-1- Sweeper	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Place LO-1 between the 1.3 and 1.5 m diameter boulders; place sweeper upstream of LO-1, with upstream end near base of existing riffle; pool 0.9 m deep.
1+039	7	LO-4	Left	Rest. Obj. 1 2	To reduce bank erosion; to provide pool with LWD cover near left bank. To reduce erosion behind each structure along the bank face, add additional large and small woody debris to the bank side of the structure to decrease porosity. Upstream end of structure should start immediately downstream of constriction between debris jam and left bank.
1+138	8	LT-6	Right	Rest. Obj. 1	To provide pool with LWD cover near right bank. Construct in thalweg along right bank; if necessary, excavate streambed deeper 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.
1+150			Left		Cold Creek confluence
1+184	9	LT-5	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Place and anchor logs on the bank to brace instream LWD.
1+215	10	LT-6	Right	Rest. Obj.	To provide pool with LWD cover along right bank.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
				1	First upstream log in structure should be upstream and parallel to the face of existing woody debris; leave existing debris as is and construct structure on streamside of debris.
1+249	11	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Construct over top of existing conifer log with rootwad.
1+278	12	LSP-5	Right	Rest. Obj.	To act as a spur and deflect flow towards structure on left bank at 1+287 m; to provide pool with LWD cover along right bank.
				1	To reduce erosion behind structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity.
1+287	13	LT-6	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Construct in deepest part of run; anchor to hemlock on bank.
1+364	14	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate upstream end of structure at base of existing riffle.
1+428	15	DJ-5	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate structure upstream of existing 1.5 m diameter boulder; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure; 3-1 m diameter boulders on site, can be used as ballast.
1+479	16	LO-1- Sweeper	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Place 6 m downstream of pumphouse; 5-1 m diameter boulders on site, can be used as ballast.
1+551	17	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Construct in deepest part of run; locate upstream end of structure at base of existing riffle.
1+638	18	DJ-5	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Two structures; construct where existing debris has accumulated.
1+836	19	LO-1- Sweeper	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Construct structure in existing pool (0.9 m deep) between two riffles; poor anchor sites on the streambank.
1+935	20	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Construct structure in existing pool (1 m deep) between two path entry points; poor anchor sites on the streambank.
1+957	21	LT-6	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Construct structure in existing pool (0.9 m deep); poor anchor sites on the streambank, should embed boles.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
2+028	22	Existing Jam	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
2+084	23	DJ-5	Right	Rest. Obj. 1	Anchor existing log using six 1 m diameter boulder ballast. To provide pool with LWD cover along right bank.
2+114	24	LT-6	Right	Rest. Obj. 1	Locate in 1 m deep pool on upstream side of existing spruce rootwad; poor anchor sites on the streambank. To provide pool with LWD cover along right bank.
2+268	25	LT-6	Left	Rest. Obj. 1	Locate in 0.9 m deep pool, 30 m downstream of spruce rootwad at 2+084 m. To provide pool with LWD cover along left bank.
2+411	26	DJ-5	Left	Rest. Obj. 1	To reduce erosion behind structure along the bank face, ensure structure is tight to the bank and add additional large and small woody debris to its core to decrease porosity; incorporate existing debris into structure; site is adjacent to park path. To provide pool with LWD cover along left bank.
2+569	27	DJ-5	Left	Rest. Obj. 1	Two structures; construct at existing alder snag; poor anchor sites on the streambank. To provide pool with LWD cover along left bank.
2+637	28	LO-1- Sweeper	Left	Rest. Obj. 1	Remove existing boulders downstream of site to allow thalweg to run closer to bank; excavate streambed to create a long narrow pool (2.5 m wide x 10 m long) with residual water depth of 0.6 m prior to constructing LWD structure. To provide pool with LWD cover along left bank.
2+718	29	DJ-5	Left	Rest. Obj. 1	Locate upstream end of structure near base of existing riffle, with rootwad of LO-1 downstream of emergent boulder; anchor sweeper to trees on the streambank. To provide pool with LWD cover along right bank.
2+824	30	LO-3	Right	Rest. Obj. 1	Locate in 1.2 m deep pool at path entry point. To provide pool with LWD cover along right bank.
2+915	31	Sweeper	Right	Rest. Obj. 1	Construct in 1.1 m deep thalweg along right bank; Quinsam Road adjacent to site. To provide LWD cover along right bank.
3+095	32	LT-6	Right	Rest. Obj. 1	Three sweepers; locate parallel and as close as possible to bank edge; no instream ballast desired. To provide pool with LWD cover along right bank.
3+181	33	LO-3- Sweeper	Left	Rest. Obj. 1	Locate upstream end of structure at base of existing riffle. To provide pool with LWD cover along left bank.
				1	Anchor butt of sweeper to maple on streambank; locate LO-3 downstream and to stream side of sweeper.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
3+371	34	Sweeper	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Anchor butt of sweeper to boulders or trees on streambank; minimize instream ballast.
3+475					Highway 28 bridge
Section B - 0+000 m starting at Quinsam Hatchery Fence and progressing upstream					
0+306	35	DJ-5	Right	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Three structures; incorporate existing LWD into structure; place most of ballast on bench along base of streambank and some ballast instream; pool about 2 m deep; good access by service trail on left bank.
0+680	36	Sweeper	Right	Rest. Obj.	To act as a spur and deflect flow away from bank; to reduce bank erosion; to provide pool with LWD cover along left bank.
				1	Locate in run between riffles; no instream ballast desired.
0+918	37	LO-1- Sweeper	Right	Rest. Obj.	To provide pool with LWD cover along right bank.
				1	Locate LO-1 in scour pool (1 m deep) at base of riffle; 1.5 m boulder at downstream end of site.
0+970	38	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate in pool (1.1 m deep) just upstream of partial spanning debris on left bank.
1+120	39	DJ-5	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Two structures; locate rootwads in deepest part of pool; incorporate existing debris into structure.
1+248	40	LO-1- Sweeper	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate in 1 m deep pool and place sweeper under existing overhanging vegetation; place and anchor LO-1 to existing 1.2 m diameter boulder.
1+380	41	LO-1- Sweeper	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate LO-1 in 1 m deep pool; anchor LO-1 on right side of existing 1.8 m diameter boulder; place top of sweeper on upstream side of boulder.
1+564	42	LO-1- Sweeper	Left	Rest. Obj.	To provide pool with LWD cover along left bank.
				1	Locate LO-1 in central throat of the flow in scour pool below riffle; place top of sweeper on right side of LO-1.

Note: Unless stated otherwise, it is assumed that:

- 1 - A sufficient number and size of rock do not exist on site to ballast LWD structure. Additional ballast rock will need to be brought to the site.
- 2 - Anchor LWD to live trees or stumps on streambank with diameter >20 cm. Alder, cedar, hemlock or maple common on streambanks. Alternatively, embed tops of logs 2-3 m horizontally and 1 m vertically into the bank. Backfill trench with spoil from excavation.

Table 24. Summary of materials required for LWD and boulder structures in Quinsam River.

						LWD Ballast		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Comments
Section A - 0+000 m starting at Quinsam Hatchery Fence and progressing downstream								
1	0+185	DJ-5	Right	10	0.5 x 8-10	15	0.8	Four LWD with rootwads; six without
2	0+410	LO-3	Right	3	0.5 x 6	10	0.8	With rootwads
3	0+530	LO-1	Left	1	0.7 x 8	6	0.8	With 1.5-2 m rootwad
4	0+746	DJ-5	Right	5	0.5 x 10-12	4	0.8	Two logs with rootwads, three without
5	0+819	DJ-5	Right	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
6	0+994	LO-1-Sweeper	Left	2	0.5 x 6/12	2	0.8	6 m LO-1 with rootwad; 12 m long Sweeper; 1.3 & 1.5 m boulders on-site
7	1+039	LO-4	Left	4	0.7 x 6	17	0.8	With rootwads
8	1+138	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
9	1+184	LT-5	Left	5	0.5 x 8-10	10	0.8	With rootwads
10	1+215	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
11	1+249	DJ-5	Left	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
12	1+278	LSP-5	Right	5	0.5 x 8-10	7	0.8	Without rootwads
13	1+287	LT-6	Left	6	0.5 x 8-10	7	0.8	With rootwads
14	1+364	LT-6	Left	6	0.5 x 8-10	12	0.8	With rootwads
15	1+428	DJ-5	Right	5	0.5 x 8-10	2	0.8	Three 1 m diameter boulders on site; require two logs with
16	1+479	LO-1-Sweeper	Right	2	0.5 x 6/12	5	0.8	6 m LO-1 with rootwad; 12 m long Sweeper
17	1+551	LT-6	Left	6	0.5 x 8-10	12	0.8	With rootwads
18	1+638	DJ-5	Right	10	0.5 x 8-10	15	0.8	Four LWD with rootwads; six without
19	1+836	LO-1-Sweeper	Right	2	0.5 x 6/12	5	0.8	6 m LO-1 with rootwad; 12 m long Sweeper
20	1+935	LT-6	Left	6	0.5 x 8-10	12	0.8	With rootwads
21	1+957	LT-6	Left	6	0.5 x 8-10	12	0.8	With rootwads
22	2+028	Existing Jam	Left			6	1	Anchor existing debris jam
23	2+084	DJ-5	Right	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
24	2+114	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
25	2+268	LT-6	Left	6	0.5 x 8-10	12	0.8	With rootwads
26	2+411	DJ-5	Left	10	0.5 x 8-10	15	0.8	Four LWD with rootwads; six without
27	2+569	DJ-5	Left	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
28	2+637	LO-1-Sweeper	Left	2	0.7 x 6/15	8	0.8	6 m LO-1 with rootwad; 15 m long Sweeper

						LWD Ballast		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Comments
29	2+718	DJ-5	Left	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
30	2+824	LO-3	Right	3	0.5 x 6	10	0.8	With rootwads
31	2+915	Sweeper	Right	3	0.7 x 15	11	0.8	Without rootwads
32	3+095	LT-6	Right	6	0.5 x 8-10	12	0.8	With rootwads
33	3+181	LO-3-Sweeper	Left	4	0.5 x 6 / 0.7 x 15	14	0.8	LO-3 (0.5 x 6 m logs) with rootwads
34	3+371	Sweeper	Right	1	0.7 x 15	4	0.8	Without rootwad but with branches
Section B - 0+000 m starting at Quinsam Hatchery Fence and progressing upstream								
35	0+306	DJ-5	Right	15	0.5 x 8-10	22	0.8	Six logs with rootwads, nine without
36	0+680	Sweeper	Right	1	0.7 x 15	4	0.8	Without rootwad
37	0+918	LO-1-Sweeper	Right	2	0.7 x 6/15	8	0.8	6 m LO-1 with rootwad; 15 m long Sweeper
38	0+970	DJ-5	Left	5	0.5 x 8-10	7	0.8	Two logs with rootwads, three without
39	1+120	DJ-5	Left	10	0.5 x 8-10	15	1.8	Four LWD with rootwads; six without
40	1+248	LO-1-Sweeper	Left	2	0.7 x 6/15	8	0.8	6 m LO-1 with rootwad; 15 m long Sweeper
41	1+380	LO-1-Sweeper	Left	2	0.7 x 6/15	8	0.8	6 m LO-1 with rootwad; 15 m long Sweeper
42	1+564	LO-1-Sweeper	Left	2	0.7 x 6/15	8	0.8	6 m LO-1 with rootwad; 15 m long Sweeper
Total				201		396		

Table 25. Ballast requirements and boulder size options for the LWD structures in Quinsam River.
Buoyancy and sliding safety factors ≥ 1.5 ; ballast factor = 1; and specific gravity of LWD (S_L) = 0.5.
Modified after D'Aoust and Millar (1999).

					Log (m)		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 @ 130 or 280 kg/m	0.7 @ 330 or 400 kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (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
Section A - 0+000 m starting at Quinsam Hatchery Fence and progressing downstream															
1	0+185	DJ-5	10	6	7800	0	2640	10440	116	55	35	22	15	10	7
2	0+410	LO-3	3	6	5040	0	1980	7020	78	37	23	15	10	7	5
3	0+530	LO-1	1	8	0	3200	660	3860	43	20	13	8	6	4	3
4	0+746	DJ-5	5	8	5200	0	1320	6520	72	34	22	14	9	7	5
5	0+819	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
6	0+994	LO-1-Sweeper	2	6	2460	0	660	3120	35	16	10	7	4	3	2
7	1+039	LO-4	4	6	0	9600	2640	12240	136	64	41	26	17	12	9
8	1+138	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
9	1+184	LT-5	5	6	3900	0	3300	7200	80	38	24	15	10	7	5
10	1+215	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
11	1+249	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
12	1+287	LT-6	6	6	4680	0	0	4680	52	25	16	10	7	5	3
13	1+364	LT-6	6	6	4680	0	1	4681	52	25	16	10	7	5	3
14	1+364	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
15	1+428	DJ-5	5	7	4550	0	1320	5870	65	31	20	12	8	6	4
16	1+479	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
17	1+551	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
18	1+638	DJ-5	10	6	7800	0	2640	10440	116	55	35	22	15	10	7
19	1+836	LO-1-Sweeper	2	6	2460	0	1320	3780	42	20	13	8	5	4	3
20	1+935	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
21	1+957	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
22	2+028	Existing Jam	0	6	0	0	0	8600	96	45	29	18	12	9	6
23	2+084	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
24	2+114	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6

					Log (m)		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 @ 130 or 280 kg/m	0.7 @ 330 or 400 kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (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
25	2+268	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
26	2+411	DJ-5	10	6	7800	0	2640	10440	116	55	35	22	15	10	7
27	2+569	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
28	2+637	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4
29	2+718	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
30	2+824	LO-3	3	6	5040	0	1980	7020	78	37	23	15	10	7	5
31	2+915	Sweeper	3	6	0	5940	1980	7920	88	42	26	17	11	8	6
32	3+095	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
33	3+181	LO-3-Sweeper	4	6	5040	1980	2640	9660	107	51	32	20	14	10	7
34	3+371	Sweeper	1	6	0	1980	660	2640	29	14	9	6	4	3	2
Section B - 0+000 m starting at Quinsam Hatchery Fence and progressing upstream															
35	0+306	DJ-5	15	6	11700	0	3960	15660	174	82	52	33	22	16	11
36	0+680	Sweeper	1	6	0	1980	660	2640	29	14	9	6	4	3	2
37	0+918	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4
38	0+970	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
39	1+120	DJ-5	10	6	7800	0	2640	10440	116	55	35	22	15	10	7
40	1+248	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4
41	1+380	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4
42	1+564	LO-1-Sweeper	2	6	0	4380	1320	5700	63	30	19	12	8	6	4

Table 26. Construction notes for specific restoration sites in Cold Creek.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+000 m - starting at mouth of Cold Creek and progressing upstream					
0+055	1	LS-1	Fullspan	Rest. Obj.	To provide scour pool with LWD cover.
				1	Place log sill diagonally at 30 ⁰ angle downstream, with upstream end of log on top of right bank just downstream of crest of riffle, and downstream end adjacent to the riffle scour pool; bury downstream end into the left bank about 1.5 m; top of log should be <0.25 m above water surface in center of channel, and <0.15 m on left bank; riprap left bank to reduce erosion.
0+103	2	LT-3	Left	Rest. Obj.	Scour pool will be formed when flows overtop or under-scour the log. To narrow the channel width; to re-define meander pattern; to provide pool with LWD cover near left bank.
0+110	3	LS-1	Partial Span	Rest. Obj.	Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure. To narrow channel slightly and deflect flow to structure at 0+103 m; to provide scour pool with LWD cover.
				1	Place log sill diagonally at 30 ⁰ angle downstream across central gravel bar, with upstream end of log buried into right bank about 1 m, and downstream end near the left bank; top of log should be <0.25 m above water surface in center of channel, and at water surface near left bank.
0+120	4	LT-3	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+167	5	LT-3	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure; poor anchor sites on streambank.
0+202	6	LTS-3	Left	Rest. Obj.	To provide pool with LWD cover near left bank.
				1	Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure; place partial spanning log diagonally at 30 ⁰ angle downstream, with upstream end of log buried into left bank about 1 m, and downstream end near the right bank; top of log should be <0.25 m above water surface near left bank, and at water surface near right bank.
0+225	7	LT-6	Right	Rest. Obj.	To provide pool with LWD cover near right bank.
				1	Embed boles of brace logs into right bank or place boulder ballast on narrow bench on bank.

Chainage to Structure (m)	Site Number	Structure Type	Right or Left Bank	Restoration Objectives and Construction Notes	
0+240	8	LS-1	Fullspan	Rest. Obj. 1	To provide pool with LWD cover near right bank; to diversify hydraulic habitats. Place full-spanning log diagonally at 30° angle downstream, with upstream end of log on top of left bank about 1.5 m, and downstream end buried into the right bank about 1 m; top of log should be <0.25 m above water surface near center of channel, and at water surface near right bank; place on top of existing embedded log near right bank.
0+263	9	DJ-5	Left	Rest. Obj. 1	To provide pool with LWD cover near left bank. Excavate streambed to create a long narrow pool (2 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure; place on top of existing debris in meander bend pool.
0+306	10	LT-6	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Place along edge of low bank; anchor on bank using wooden piles.
0+334	11	LS-1	Fullspan	Rest. Obj. 1	To provide pool with LWD cover near left bank; to diversify hydraulic habitats. Place log sill diagonally at 30° angle downstream, with upstream end of log on top of right bank about 1 m, and downstream end near the left bank; top of log should be <0.25 m above water surface in center of channel, and at water surface near left bank; anchor to upstream side of existing 1.3 m diameter boulder.
0+350	12	LT-3	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Rootwads on logs should be located upstream, facing into flow.
0+373	13	DJ-5	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Excavate streambed to create a long narrow meander pool (3 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure; re-position five existing 0.6-0.7 m diameter boulders and use as ballast for the structure.
0+550	14	LT-3	Left	Rest. Obj. 1	To provide pool with LWD cover along left bank. Excavate streambed to create a long narrow meander pool (3 m wide x 6 m long) with residual water depth of 0.6 m prior to constructing LWD structure.
0+566	15	LT-3	Right	Rest. Obj. 1	To provide pool with LWD cover along right bank. Locate structure upstream of existing full-spanning log sill; excavate streambed to create a long narrow pool (2.5 m wide x 5 m long) with residual water depth of 0.6 m prior to constructing LWD structure.

Note: Unless stated otherwise, it is assumed that:

- 1 - A sufficient number and size of rock do not exist on site to ballast LWD structure. Additional ballast rock will need to be brought to the site.
- 2 - Anchor LWD to live trees or stumps on streambank with diameter >20 cm. Alder, cedar, hemlock or maple common on streambanks. Alternatively, embed tops of logs 2-3 m horizontally and 1 m vertically into the bank. Backfill trench with spoil from excavation.

Table 27. Summary of materials required for LWD and boulder structures in Cold Creek.

						LWD Ballast		
Site	Chainage (m)	Structure Type	Right or Left Bank	LWD Required	LWD Size (m)	Boulders Required	Diameter (m)	Comments
0+000 m - starting at mouth of Cold Creek and progressing upstream								
1	0+055	LS-1	Fullspan	1	0.6 x 15	5	0.8	Without rootwad
2	0+103	LT-3	Left	3	0.5 x 8-10	6	0.8	With rootwads
3	0+110	LS-1	Partial	1	0.6 x 15	5	0.8	Without rootwad
4	0+120	LT-3	Right	3	0.5 x 8-10	6	0.8	With rootwads
5	0+167	LT-3	Right	3	0.5 x 8-10	6	0.8	With rootwads
6	0+202	LTS-3	Left	3	0.5 x 6 / 15	6	0.8	With rootwads except for 15 m long spanning log
7	0+225	LT-6	Right	6	0.5 x 5-6	12	0.8	With rootwads
8	0+240	LS-1	Fullspan	1	0.5 x 14	3	0.8	Without rootwad
9	0+263	DJ-5	Left	5	0.5 x 5-6	7	0.8	Two logs with rootwads, three without
10	0+306	LT-6	Left	6	0.5 x 5-6	12	0.8	With rootwads
11	0+334	LS-1	Fullspan	1	0.6 x 12	4	0.8	Without rootwad
12	0+350	LT-3	Left	3	0.5 x 5-6	6	0.8	With rootwads
13	0+373	DJ-5	Right	5	0.5 x 5-6	2	0.8	Two logs with rootwads, three without
14	0+550	LT-3	Left	3	0.5 x 5-6	6	0.8	With rootwads
15	0+566	LT-3	Right	3	0.5 x 5-6	6	0.8	With rootwads
Total				47		92		

Table 28. Ballast requirements and boulder size options for the LWD structures in Cold Creek.

Buoyancy and sliding safety factors ≥ 1.5 ; ballast factor = 1; and specific gravity of LWD (S_L) = 0.5.

Modified after D'Aoust and Millar (1999).

					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 @ 130 kg/m	0.6 @ 240kg/m	660 kg/log (0.5x2x3 m)	Total Mass of Ballast Required (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 mouth of Cold Creek and progressing upstream															
1	0+055	LS-1	1	15	0	3600	0	3600	40	19	12	8	5	4	3
2	0+103	LT-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3
3	0+110	LS-1	1	15	0	3600	0	3600	40	19	12	8	5	4	3
4	0+120	LT-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3
5	0+167	LT-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3
6	0+202	LTS-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3
7	0+225	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
8	0+240	LS-1	1	14	1820	0	0	1820	20	10	6	4	3	2	1
9	0+263	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
10	0+306	LT-6	6	6	4680	0	3960	8640	96	45	29	18	12	9	6
11	0+334	LS-1	1	12	0	2880	0	2880	32	15	10	6	4	3	2
12	0+350	LT-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3
13	0+373	DJ-5	5	6	3900	0	1320	5220	58	27	17	11	7	5	4
14	0+550	LT-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3
15	0+566	LT-3	3	6	2340	0	1980	4320	48	23	14	9	6	4	3

Table 29. Stable and recommended minimum boulder diameters for boulder clusters and riffle enhancement.

Stream	Structure	Gradient (%)	Flow Depth (m)	Tractive Force (kg/m ²)	Stable Diameter (m)	Minimum Recommended Diameters (m)
Chemainus	Boulder Cluster	1.1	2.0	22	0.33	0.5-0.7
Chemainus	Riffle Enhancement	2.5	2.0	50	0.76	0.8
Haslam	Boulder Cluster	1.0	2.0	20	0.30	0.5-0.6
Little Qualicum	Boulder Cluster	0.5	2.0	10	0.15	0.5-0.7
Little Qualicum	Riffle Enhancement	2.5	2.0	50	0.76	0.8
Oyster	Boulder Cluster	0.5	2.0	10	0.15	0.5-0.7

Table 30. Flow release options for Fourth Lake with the resultant discharge and estimated water temperatures in Nanaimo River.

Location of Outlet Pipe Below FSL (m)	Elevation of Pipe (m)	Volume Available for Release (m ³)	Period of Discharge	Number of Discharging Days	Fourth Lake Discharge (m ³ /s)	Average Upper Nanaimo R. Discharge (u/s of outlet pipe)	Total Stream Discharge d/s of Outlet Pipe	Min. Water Temp. in Fourth Lake (C)	Upper Nanaimo River Temp. (C)	Estimated Stream Temp. in Nanaimo R. below Fourth Lake Outlet (C)	Measured Temp. (C)
1986 - Actual Temperature & Discharge			July 30		2.4	1.0	3.4	6.5	17.25	9.7	8.3
			Aug. 27		3.5	0.8	4.3	7	17.5	8.9	
			Sept. 8&9		3.1	0.9	4.0	7.5	17.5	9.7	7.5
4	312.7	4 x 10 ⁶	July 1-Sept 31	92	0.5			18.5			
			July		0.5	1.0	1.5	18.8	17	17.6	
			August		0.5	0.8	1.3	18.8	17	17.7	
			September		0.5	0.9	1.4	18.5	17	17.5	
6	310.7	12 x 10 ⁶	July 1-Sept 31	92	1.5			14.5			
			July		1.5	1.0	2.5	14.5	17	15.5	
			August		1.5	0.8	2.3	14.5	17	15.4	
			September		1.5	0.9	2.4	18.0	17	17.6	
8	308.7	16 x 10 ⁶	July 1-Sept 31	92	2.0			12.9			
			July		2.0	1.0	3.0	12.9	17	14.3	
			August		2.0	0.8	2.8	12.9	17	14.1	
			September		2.0	0.9	2.9	16.0	17	16.3	
10	306.7	20 x 10 ⁶	July 1-Sept 31	92	2.5			12.0			
			July		2.5	1.0	3.5	12	17	13.4	
			August		2.5	0.8	3.3	12	17	13.2	
			September		2.5	0.9	3.4	15	17	15.5	
12	304.7	23 x 10 ⁶	July 1-Sept 31	92	2.9			11.0			
			July		2.9	1.0	3.9	11	17	12.5	
			August		2.9	0.8	3.7	11	17	12.3	
			September		2.9	0.9	3.8	13	17	13.9	
14	302.7	25 x 10 ⁶	July 1-Sept 31	92	3.2			9.1			
			July		3.2	1.0	4.2	9.1	17	11.0	
			August		3.2	0.8	4.0	9.1	17	10.7	
			September		3.2	0.9	4.1	11	17	12.3	

Notes:

- 1) Fourth Lake water temperatures for various flow scenarios from 1979 survey; August temperatures assumed equal to July temperatures.
- 2) Upper Nanaimo River temperatures from 1986 surveys.
- 3) Upper Nanaimo River discharges from Table 1.

Table 31. Potential off-channel development sites in the East Vancouver Island watersheds.

River	Section	Chainage (m)	Outlet or Inlet	Right or Left Bank	Potential Length (m)	Comments
Chemainus	Section C	0+758	Outlet	Left		needs survey and further assessment
	Section E	U/S of Island Hwy		Right??		D.Clough indicated potential side channel on Russell Farm
Haslam	Section C	5+341 (5+700)	Outlet (inlet)	Right	360	has been prescribed for complexing
		5+515	Outlet	Left	250	has been prescribed for complexing
Deadwood		1+780 (2+125)	Outlet (inlet)	Left	250	needs survey and further assessment
Little Qualicum	Section C (Waring's)	0+560	Outlet	Right	25	could excavate 25 m to residual depth of 1 m and complex with LWD
		1+255	Outlet	Left	30	could excavate 30 m to residual depth of 1 m and complex with LWD
Little Qualicum	Section E (Ozero's)	0+141	Outlet	Right	300	needs survey and further assessment
		0+490	Outlet	Left	378	needs survey and further assessment
Oyster	Section B	2+378 (2+066)	Outlet (inlet)	Left	250	could deepen lower 175-200 m; needs survey and further assessment
		3+062 (2+420)	Outlet (inlet)	Right	600	needs survey and further assessment
		3+934 (3+629)	Outlet (inlet)	Right	300	needs survey and further assessment
		4+258	Inlet	Right		needs survey and further assessment
Oyster	Section D	1+238 (0+890)	Outlet (inlet)	Left	350	needs survey and further assessment
Quinsam	Section B	1+691	Outlet	Right		needs survey and further assessment
		0+350 (1+248)	Outlet (inlet)	Right	900	could construct a backwater alcove along base of RB steep valley wall; needs survey and further assessment
		0+631	Outlet	Left	85	could construct a backwater alcove or series of beaded ponds; needs survey and further assessment
Total Length					4078	

Table 32. Cost estimate (2002) for restoration projects in selected East Vancouver Island watersheds.

				Chemainus River		Haslam Creek		Deadwood Creek		Nanaimo River (spawning gravel)		Little Qualicum River		Oyster River		Little Oyster River		Quinsam River		Cold Creek	
	Description	Unit	Unit Cost	Approx. Quantity	Cost	Approx. Quantity	Cost	Approx. Quantity	Cost	Approx. Quantity	Cost	Approx. Quantity	Cost	Approx. Quantity	Cost	Approx. Quantity	Cost	Approx. Quantity	Cost	Approx. Quantity	Cost
Major Equipment:																					
1	Excavator, all found	hour	\$125	250	\$31,250	245	\$30,625	0	\$0	0	\$0	351	\$43,875	279	\$34,875	0	\$0	202	\$25,250	72	\$9,000
2	Excavators mob/demob.	km	\$1	80	\$112	50	\$70	100	\$140	100	\$140	112	\$157	89	\$125	29	\$41	65	\$91	23	\$32
3	Excavator, Spyder	hour	\$165		\$0	0	\$0	288	\$47,520	40	\$6,600	0	\$0	0	\$0	91	\$15,015	0	\$0	0	\$0
3	Forwarder/small excavator	hour	\$100	100	\$10,000	98	\$9,800	115	\$11,500	40	\$4,000	140	\$14,000	112	\$11,200	37	\$3,700	81	\$8,100	29	\$2,900
4	Dump Truck, all found	hour	\$70	100	\$7,000	98	\$6,860	115	\$8,050	40	\$2,800	140	\$9,800	112	\$7,840	37	\$2,590	81	\$5,670	29	\$2,030
5	Self-loading Logging Truck, all found	hour	\$80	100	\$8,000	98	\$7,840	115	\$9,200	0	\$0	140	\$11,200	112	\$8,960	37	\$2,960	81	\$6,480	29	\$2,320
Sub-total major equipment					\$56,362		\$55,195		\$76,410		\$13,540		\$79,032		\$63,000		\$24,306		\$45,591		\$16,282
Manpower:																					
1	Project Coordinator (1)	pers-day	\$500	25	\$12,500	25	\$12,500	30	\$15,000	5	\$2,500	35	\$17,500	28	\$14,000	9	\$4,500	20	\$10,000	7	\$3,500
2	Restoration Specialist (1)	pers-day	\$730	4	\$2,920	4	\$2,920	4	\$2,920	2	\$1,460	4	\$2,920	4	\$2,920	1	\$730	20	\$14,600	1	\$730
3	Semi-skilled Labour (2)	pers-day	\$250	40	\$10,000	39	\$9,750	50	\$12,500	8	\$2,000	56	\$14,000	45	\$11,250	15	\$3,750	20	\$5,000	12	\$3,000
Sub-total manpower					\$25,420		\$25,170		\$30,420		\$5,960		\$34,420		\$28,170		\$8,980		\$29,600		\$7,230
Light Equipment:																					
1	Drilling Equipment Rental	week	\$500	4	\$2,000	4	\$2,000	4	\$2,000	0	\$0	6	\$3,000	4	\$2,000	1	\$500	20	\$10,000	1	\$500
Sub-total light equipment					\$2,000		\$2,000		\$2,000		\$0		\$3,000		\$2,000		\$500		\$10,000		\$500
Materials:																					
1	LWD With and Without Rootwads	log	\$200	212	\$42,400	257	\$51,400	269	\$53,800	0	\$0	339	\$67,800	196	\$39,200	97	\$19,400	201	\$40,200	47	\$9,400
*2	Ballast Rock (0.8 m) for LWD Structures	m ³	\$10	191	\$1,910	281	\$2,810	258	\$2,580	0	\$0	311	\$3,110	195	\$1,950	101	\$1,010	202	\$2,020	47	\$470
3	Boulders for Clusters / Riffles	m ³	\$10	5	\$50	2	\$20	0	\$0	40	\$400	150	\$1,500	70	\$700	0	\$0	0	\$0	0	\$0
4	Spawning gravel	m ³	\$8	0	\$0	0	\$0	0	\$0	70	\$560	0	\$0	0	\$0	0	\$0	0	\$0	0	\$0
5	Miscellaneous (epoxy, clamps, cable, etc)		\$1,000	3	\$3,000	3	\$3,000	3	\$3,000	0.5	\$500	4	\$4,212	3	\$3,346	1	\$1,096	20	\$20,000	1	\$865
Sub-total materials					\$47,360		\$57,230		\$59,380		\$1,460		\$76,622		\$45,196		\$21,506		\$62,220		\$10,735
Total Cost					\$131,142		\$139,595		\$168,210		\$20,960		\$193,073		\$138,366		\$55,292		\$147,411		\$34,748
Total of 371 restoration sites; by watershed:				52		51		60		1		73		58		19		42		15	
Total estimated cost for all projects:					\$1,007,836																

Note: *Assume 0.8 m diameter boulder has a volume of 0.51 m³

FIGURES

Figure 1



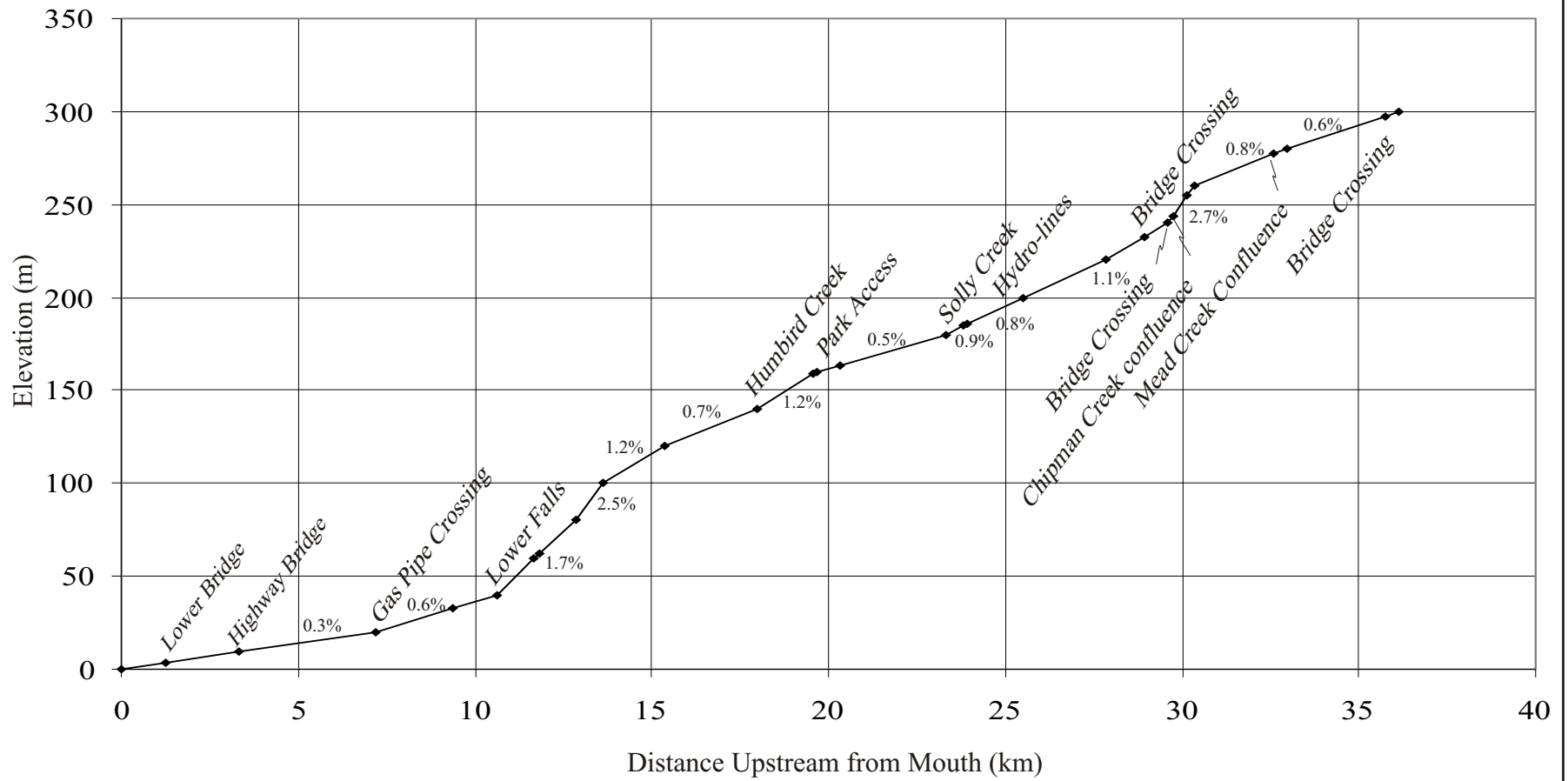


Figure 2. Longitudinal profile of Chemainus River.

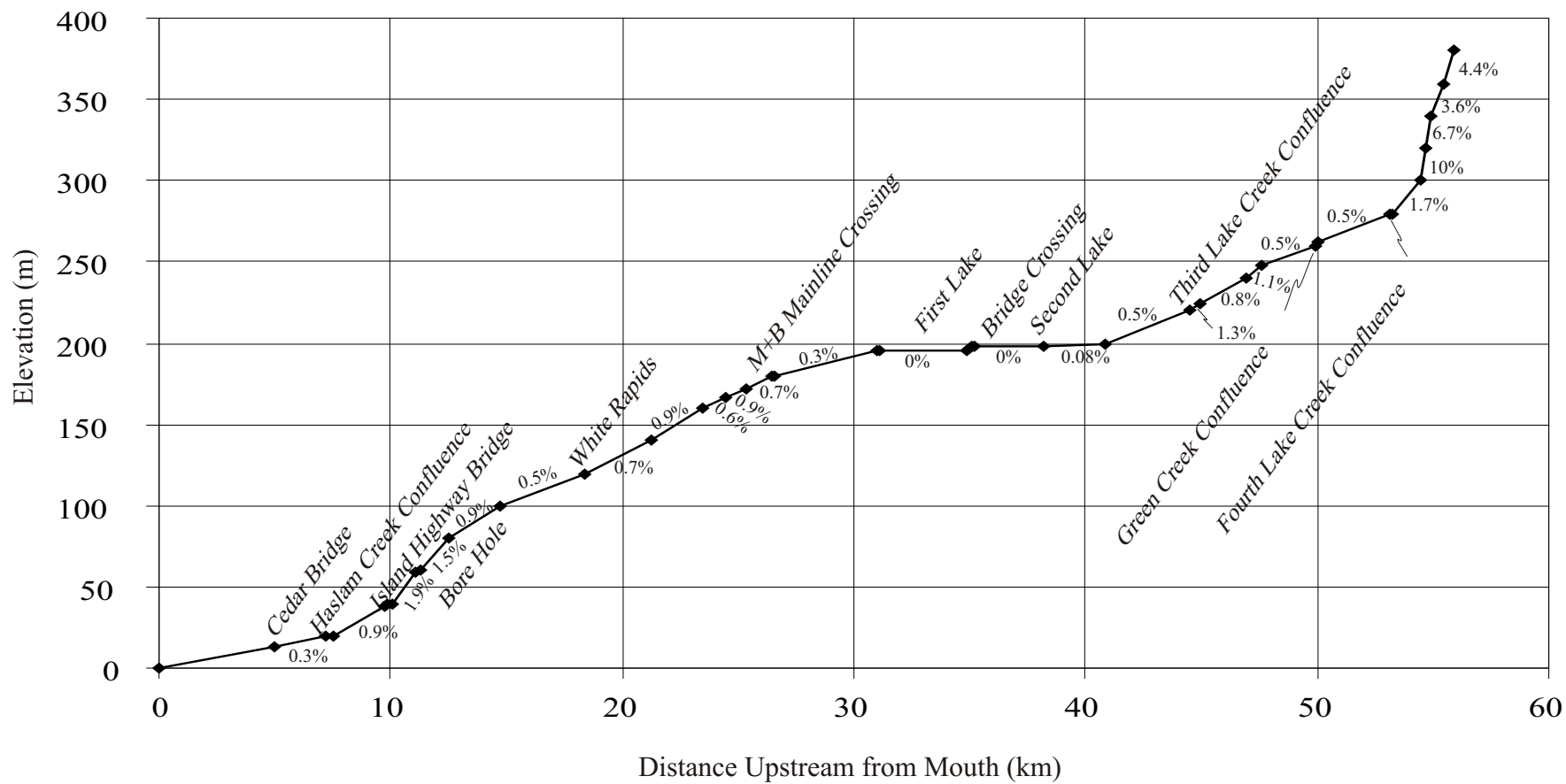


Figure 3. Longitudinal profile of Nanaimo River.

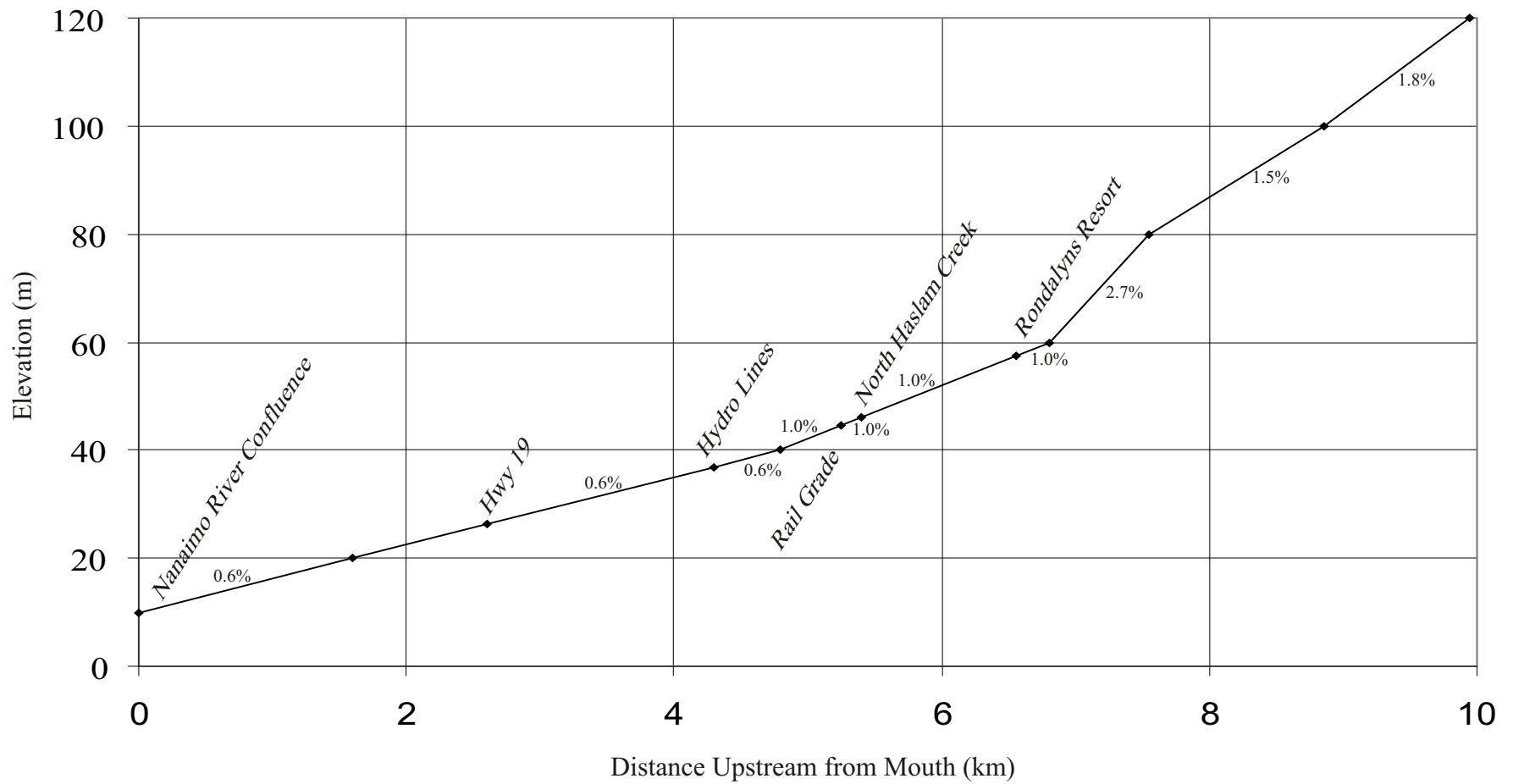


Figure 4. Longitudinal profile of Haslam Creek, Nanaimo River.

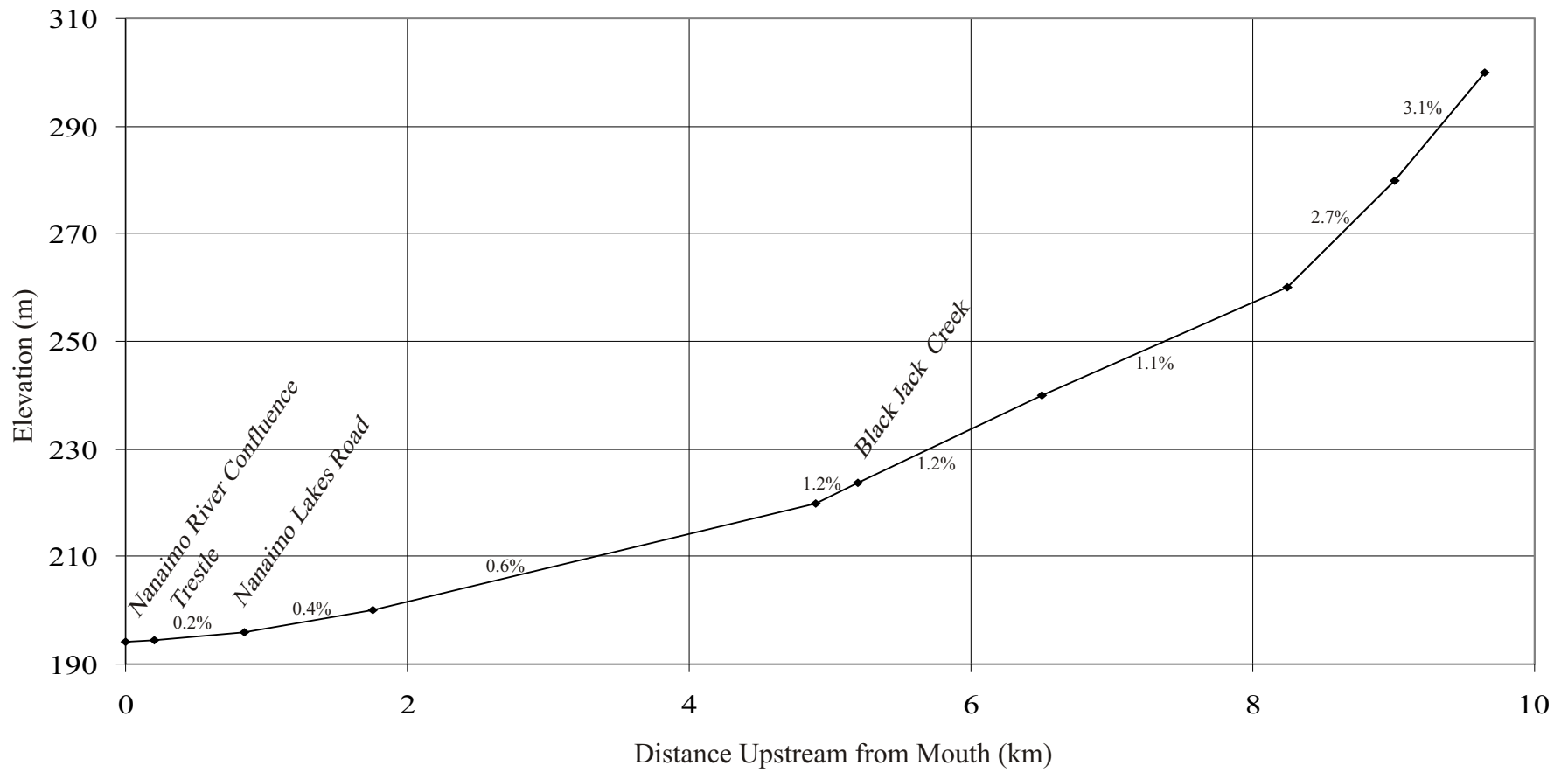


Figure 5. Longitudinal profile of Deadwood Creek, Nanaimo River.

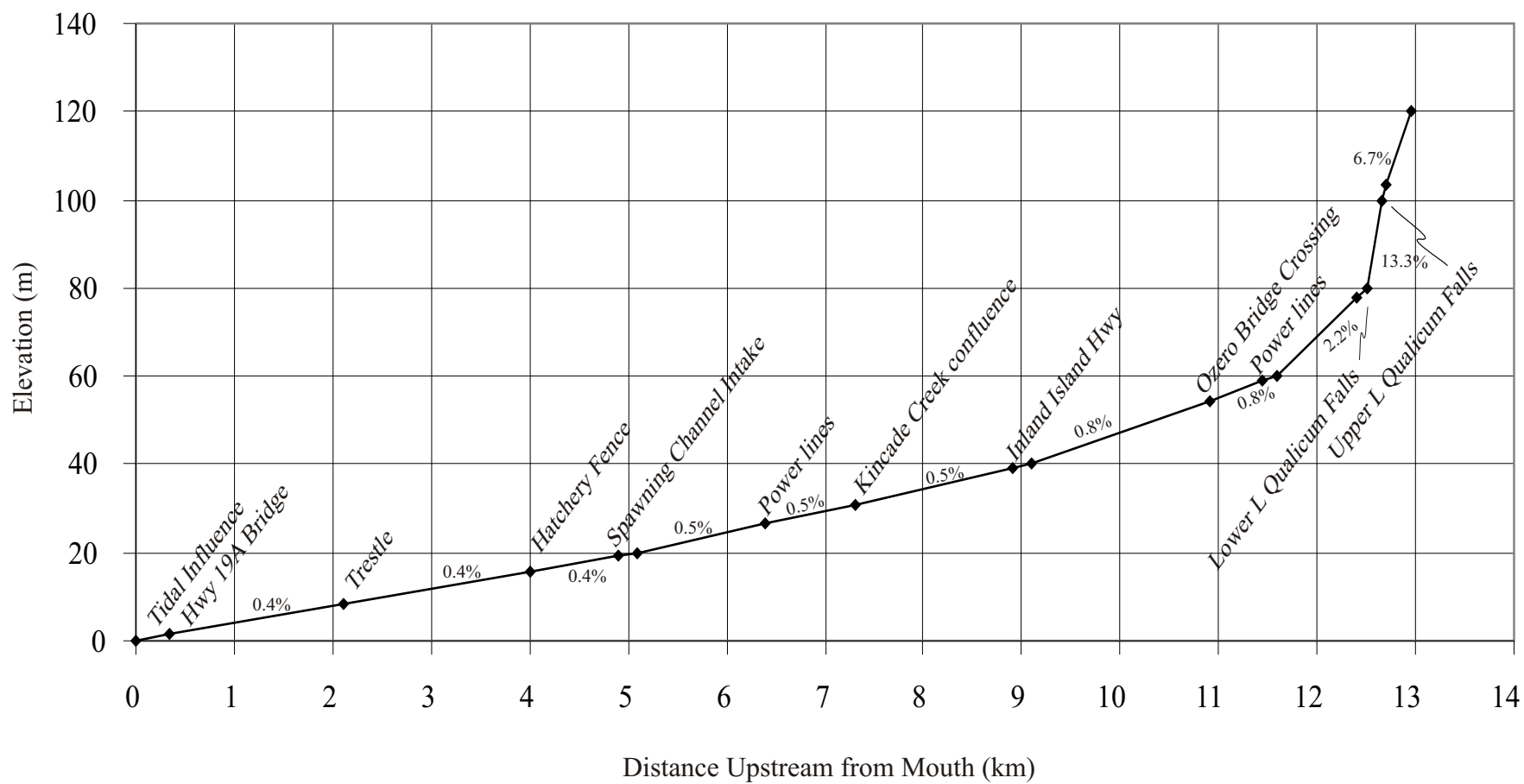


Figure 6. Longitudinal profile of Little Qualicum River.

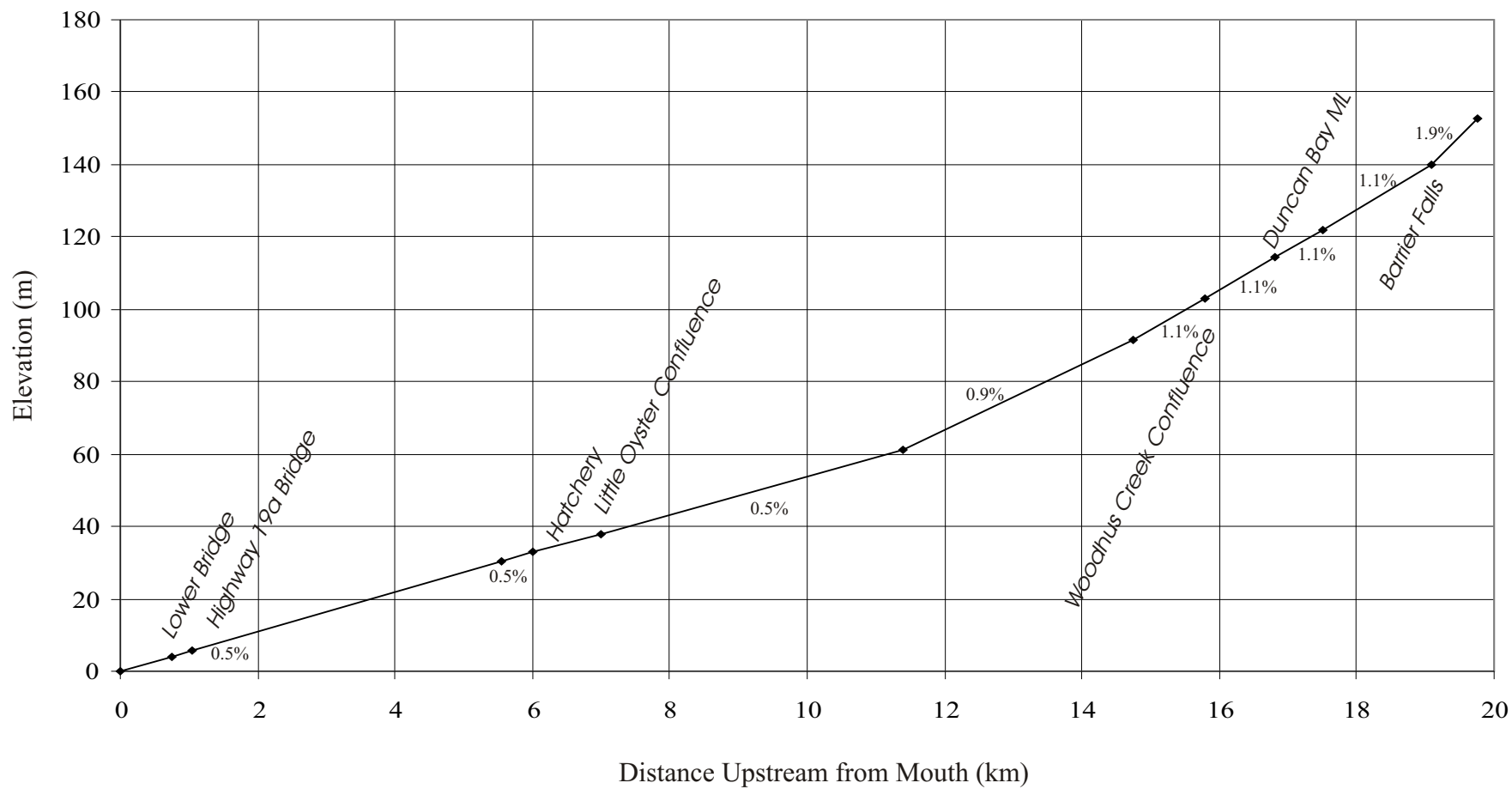


Figure 7. Longitudinal profile of Oyster River.

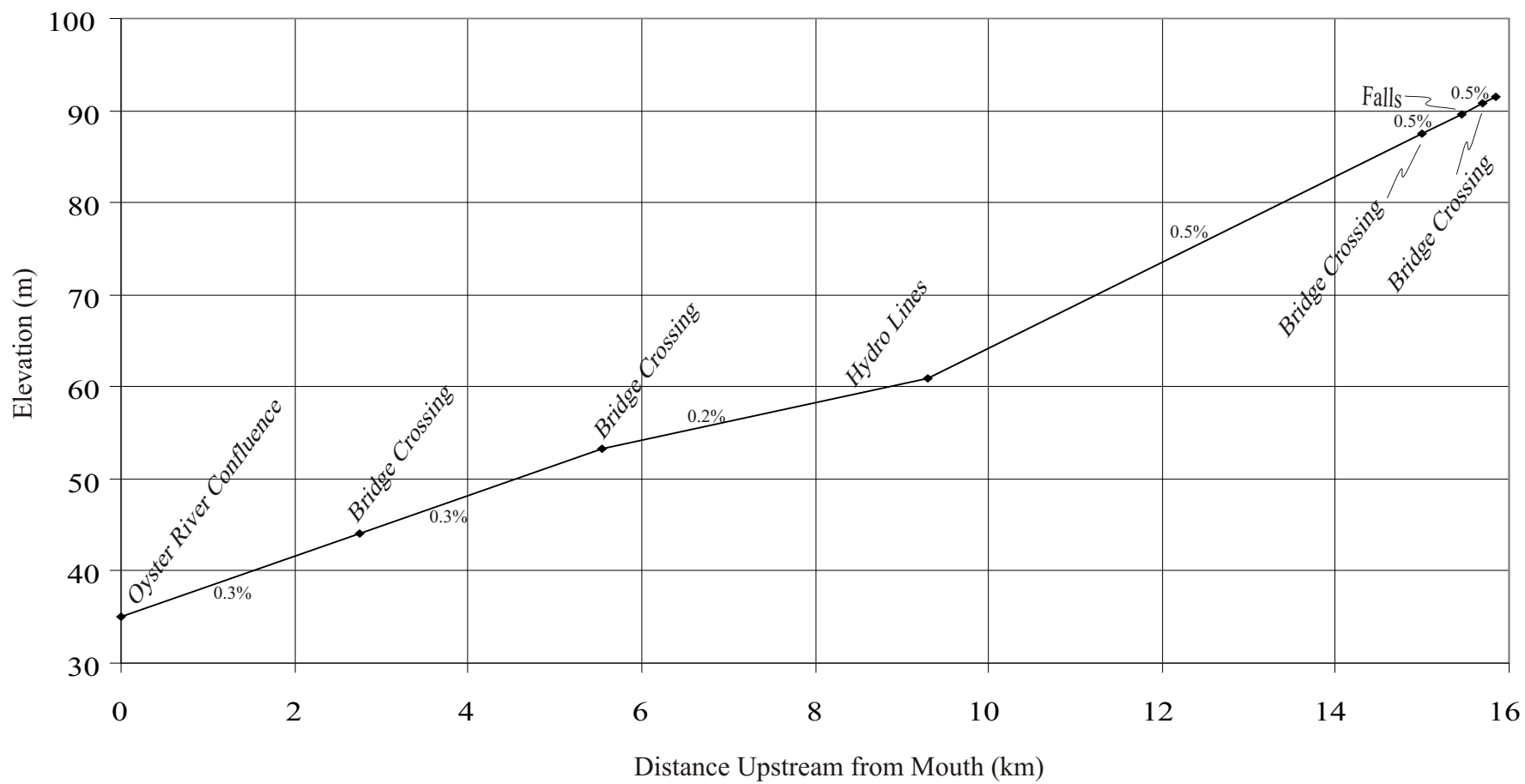


Figure 8. Longitudinal profile of Little Oyster River, Oyster River.

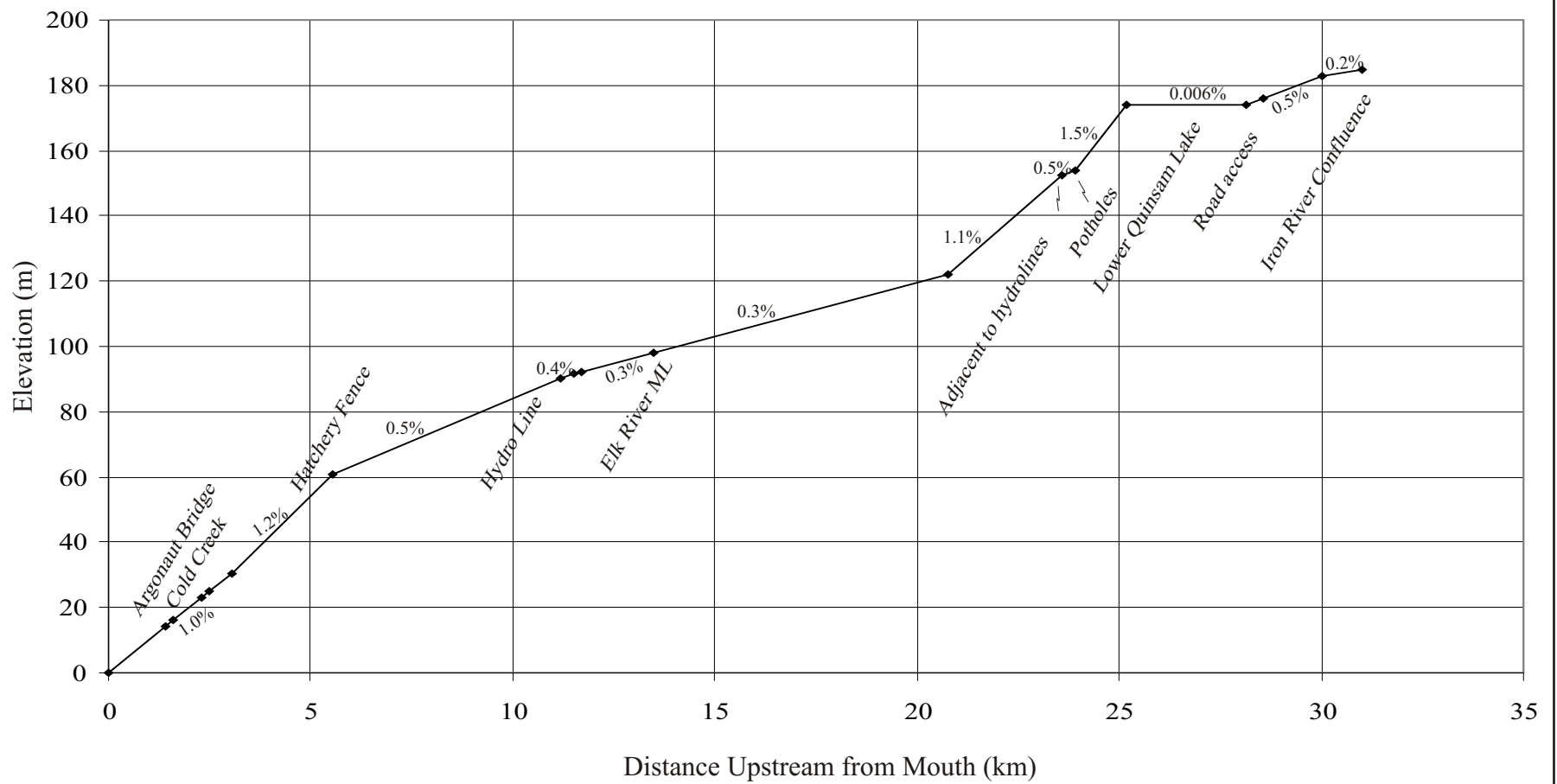
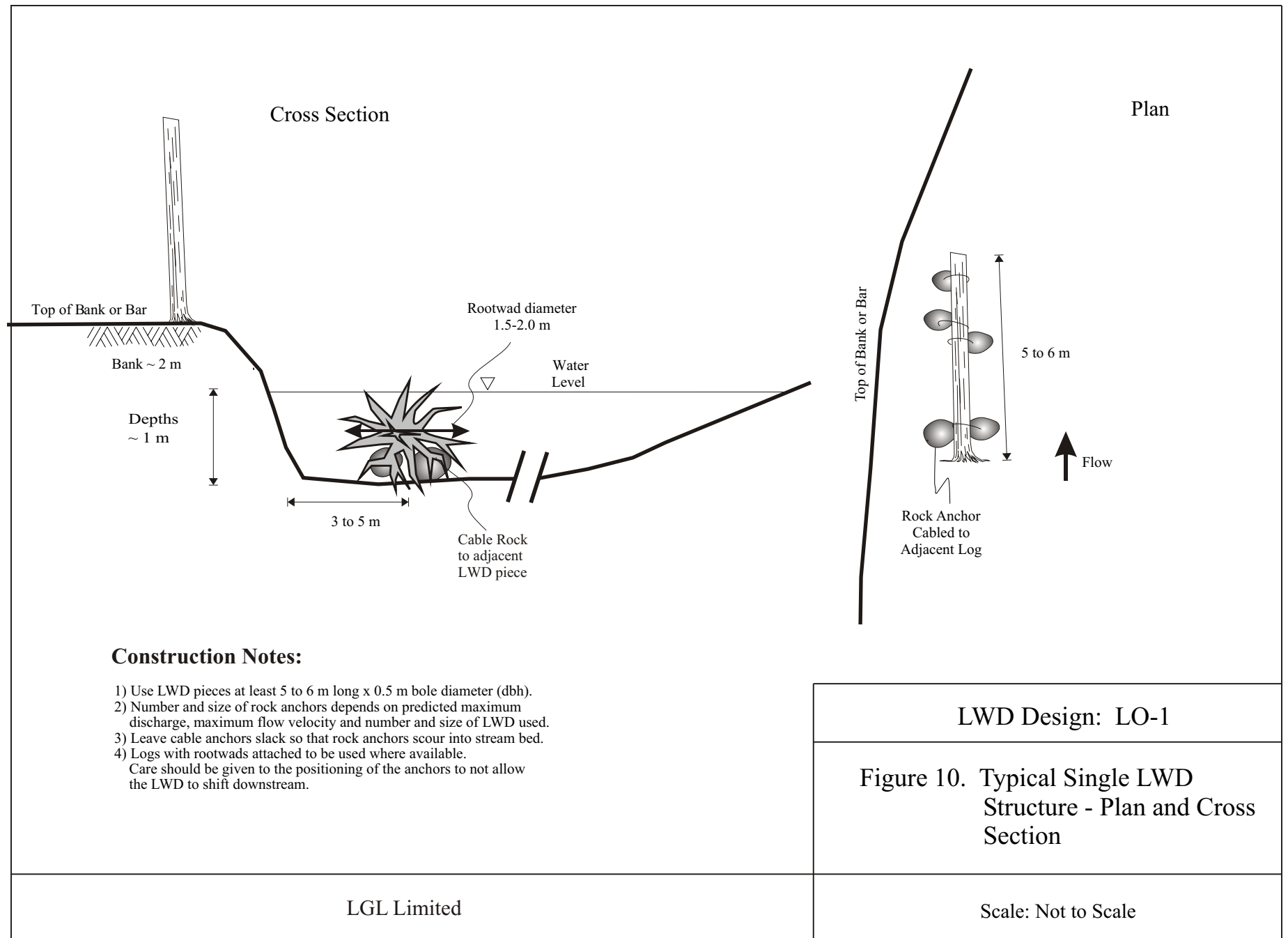
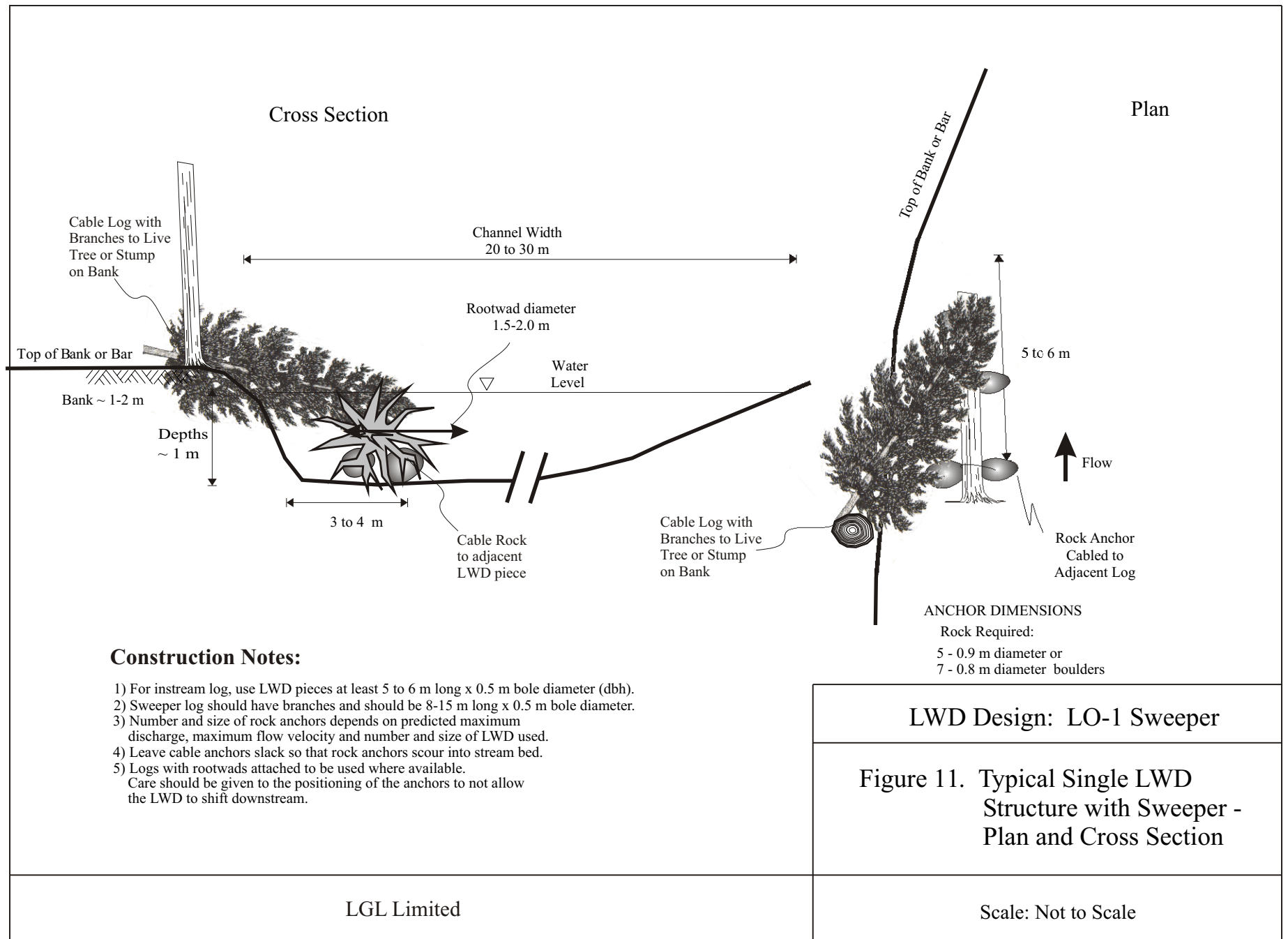
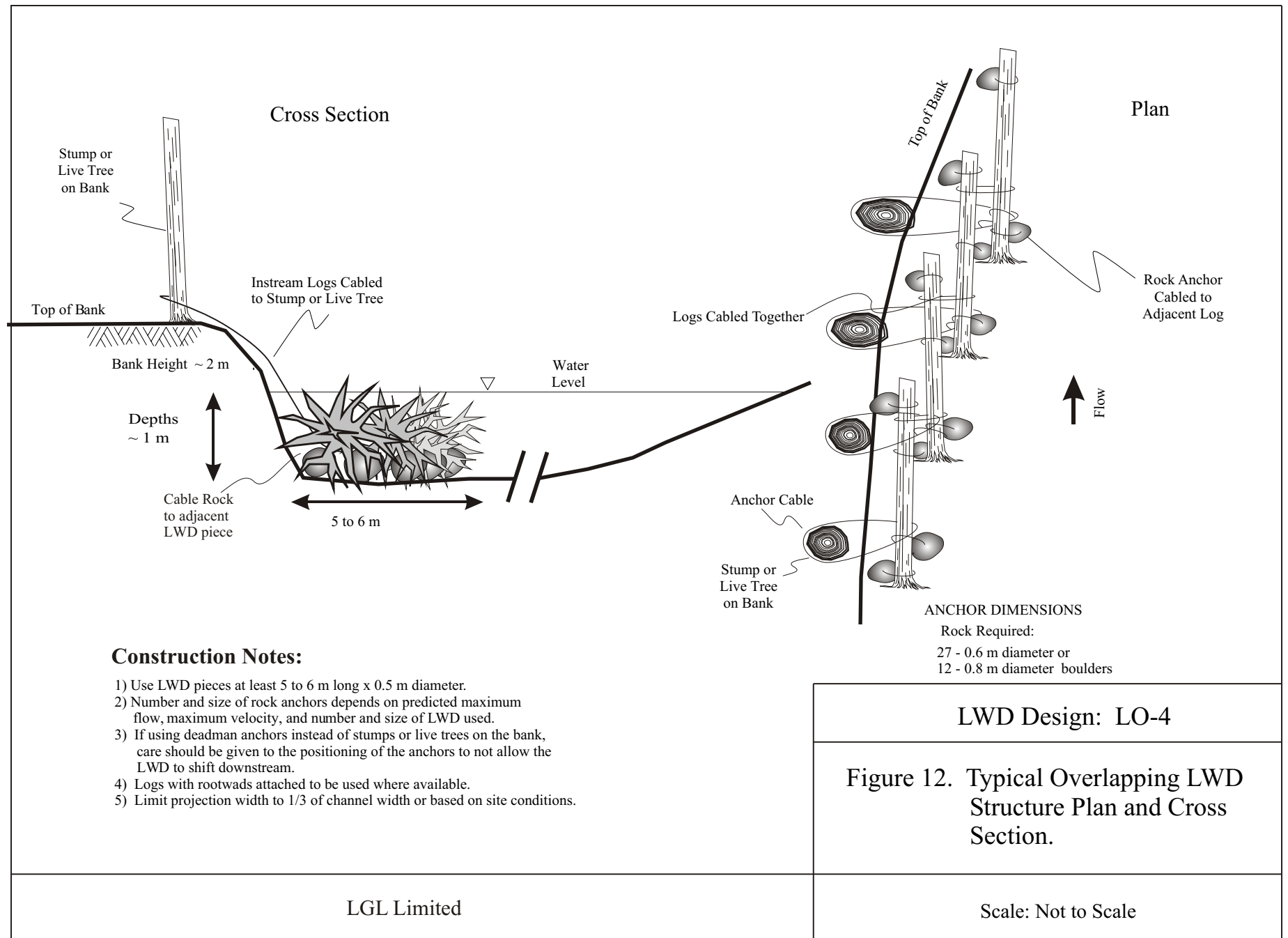


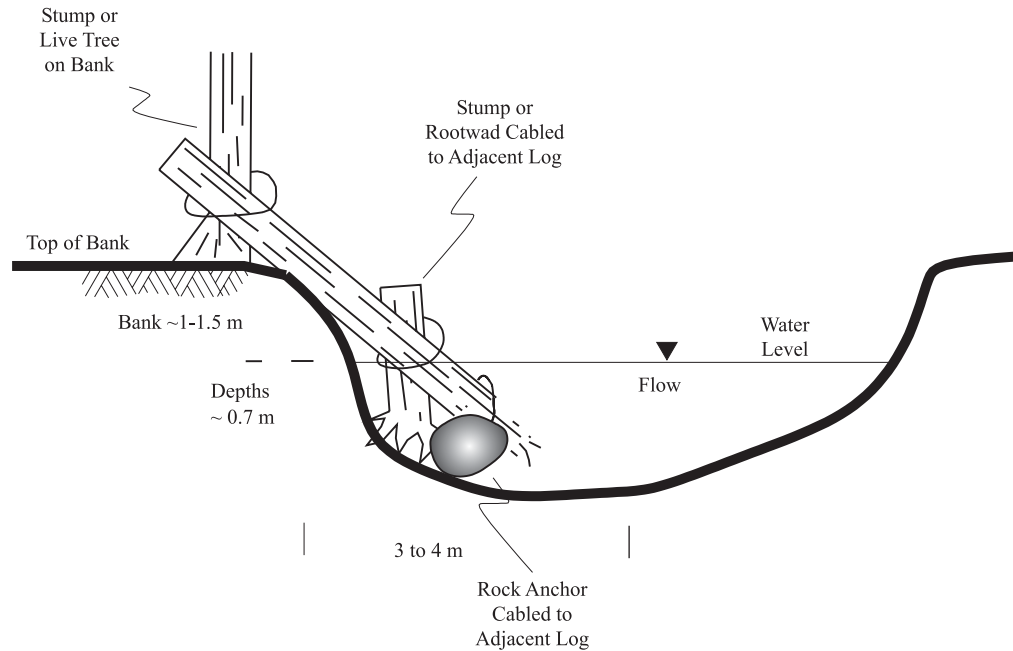
Figure 9. Longitudinal profile of Quinsam River.







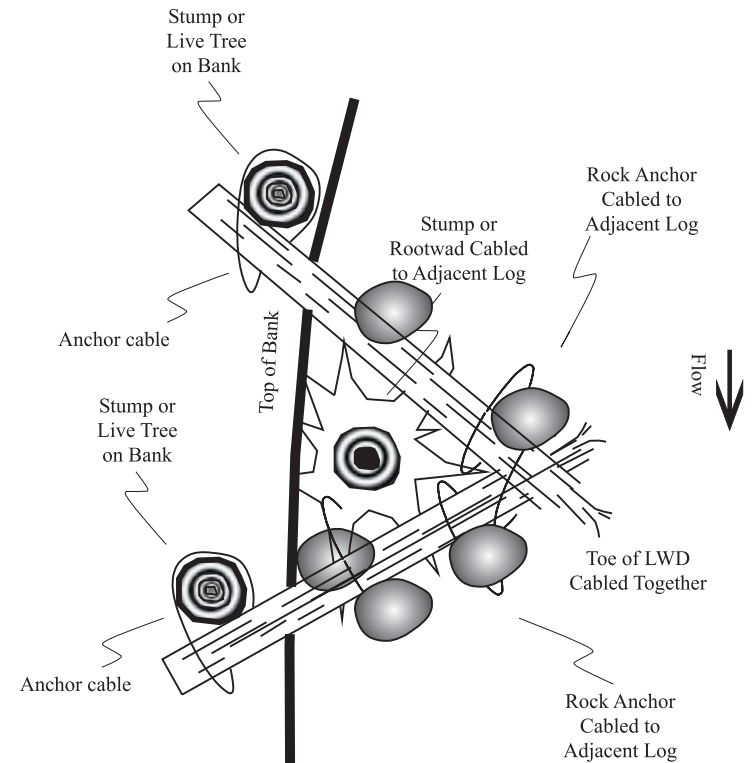
Cross Section



Construction Notes:

- 1) Use LWD pieces 10 to 12 m long x 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) Leave cable anchors slack so that rock anchors scour into stream bed.
- 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 LWD to shift downstream.
- 5) Logs with rootwads attached to be used where available.
- 6) Limit LWD projection width to 30% of channel width or based on site conditions.

Plan



ANCHOR DIMENSIONS

Rock Required (assuming logs with rootwads):
14 - 0.6 m diameter or
6 - 0.8 m diameter boulders

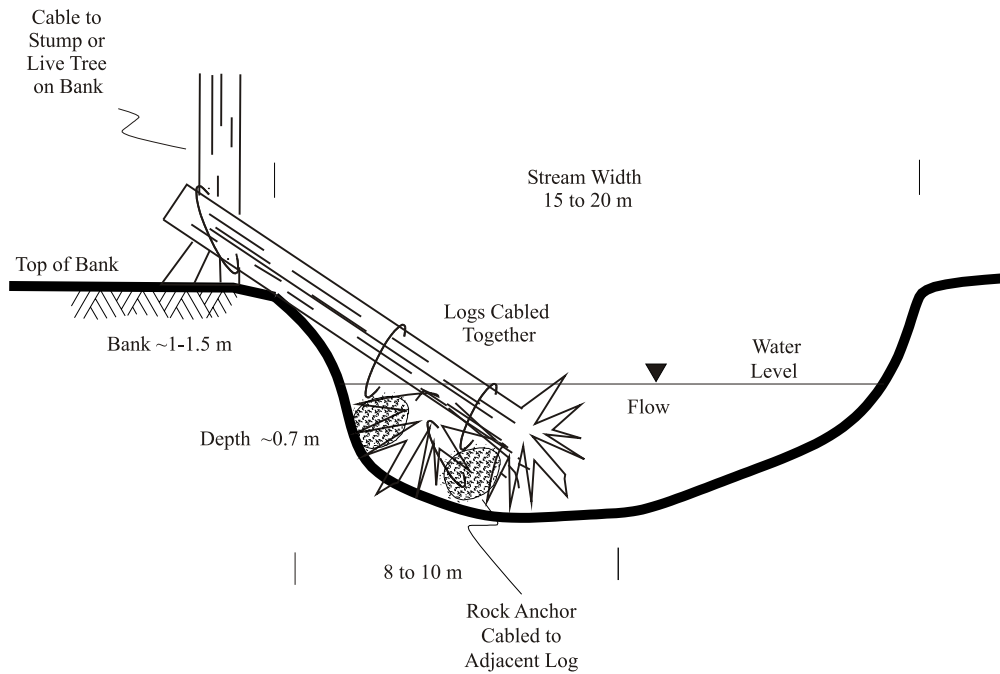
LWD Design: LT-3

**Figure 13. Typical
Triangular LWD Structure
Plan and Cross Section**

LGL Limited

Scale: Not to Scale

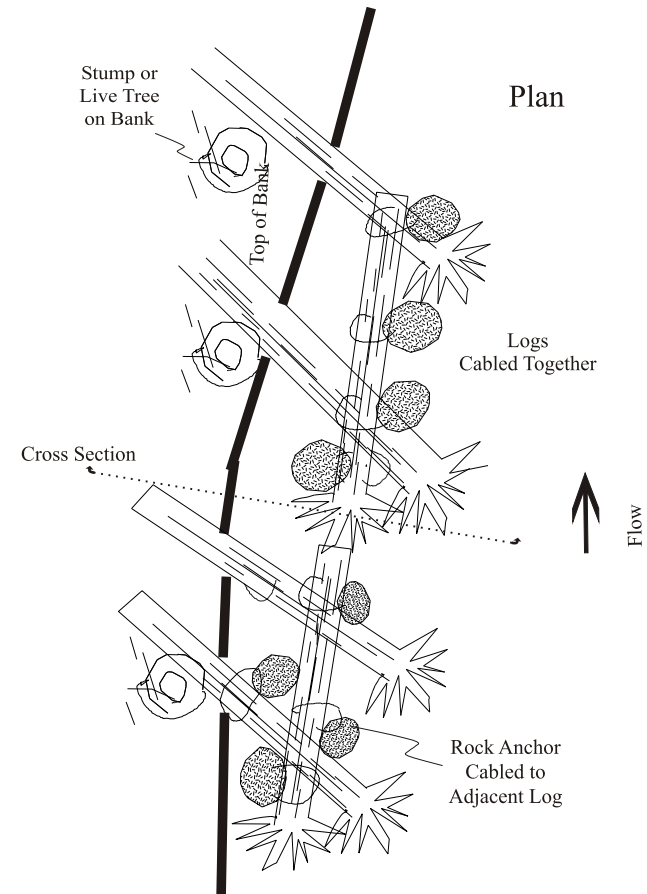
Cross Section



Construction Notes:

- 1) LWD pieces may be between 10 to 12 m long x 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) Leave cable anchors slack so that rock anchors scour into stream bed.
- 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 LWD to shift downstream.
- 5) Logs with rootwads attached to be used where available.
- 6) Limit LWD projection width to 30% of channel width or based on site conditions.

Plan



ANCHOR DIMENSIONS

Rock Required:

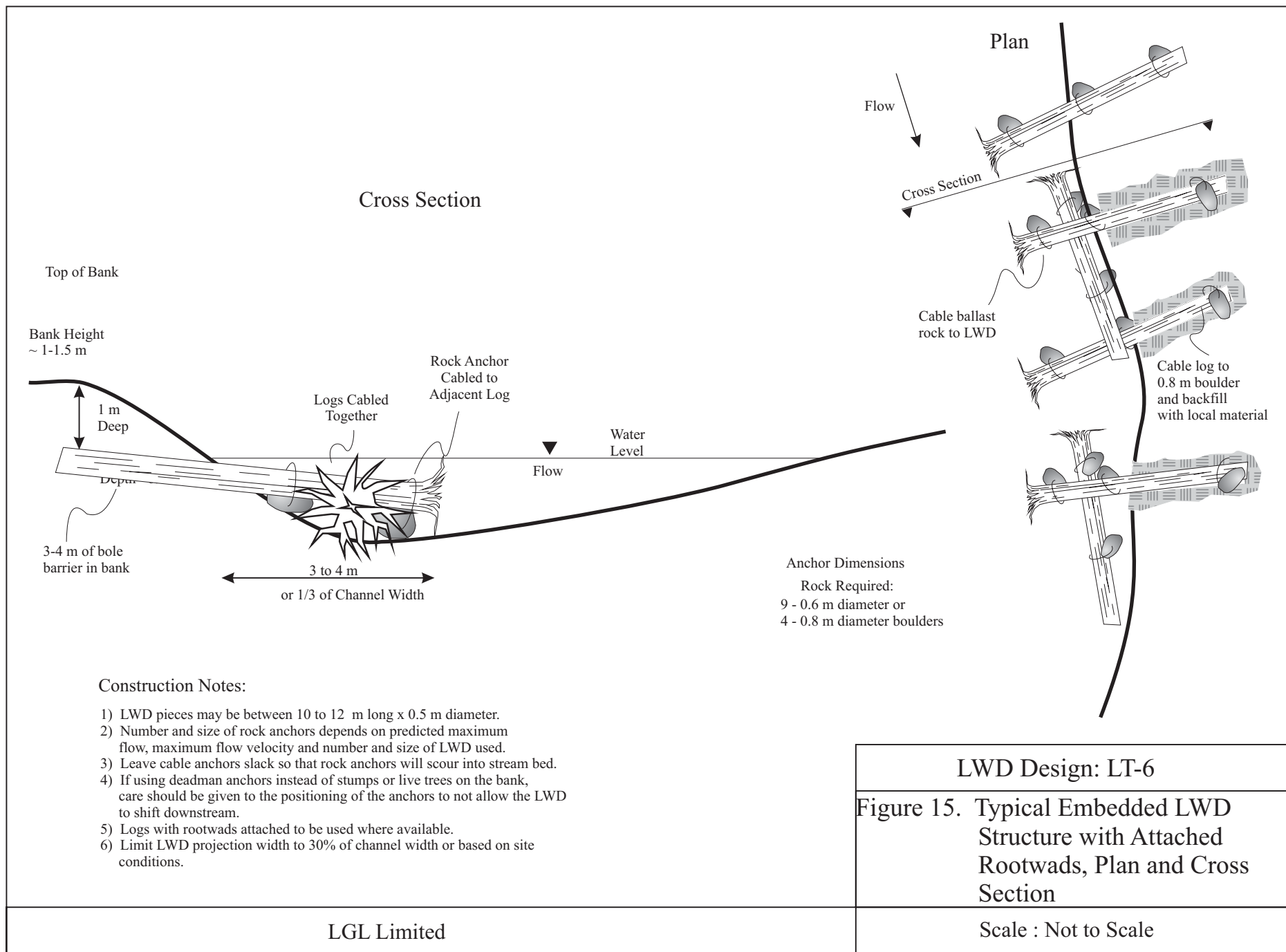
- 23 - 0.6 m diameter or
- 10 - 0.8 m diameter boulders

LWD Design: LT-5

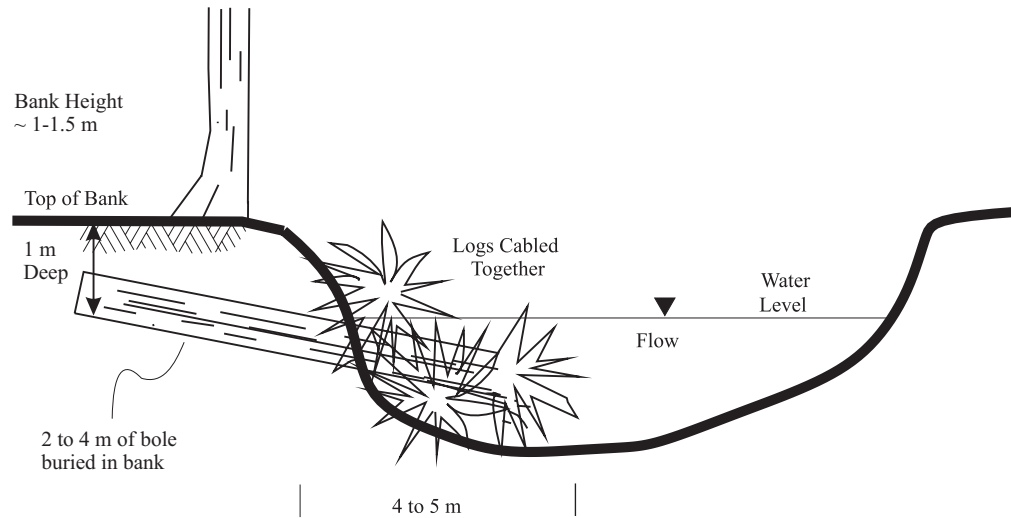
Figure 14. Typical LWD Structure With Attached Rootwads Plan and Cross Section

LGL Limited

Scale: Not to scale



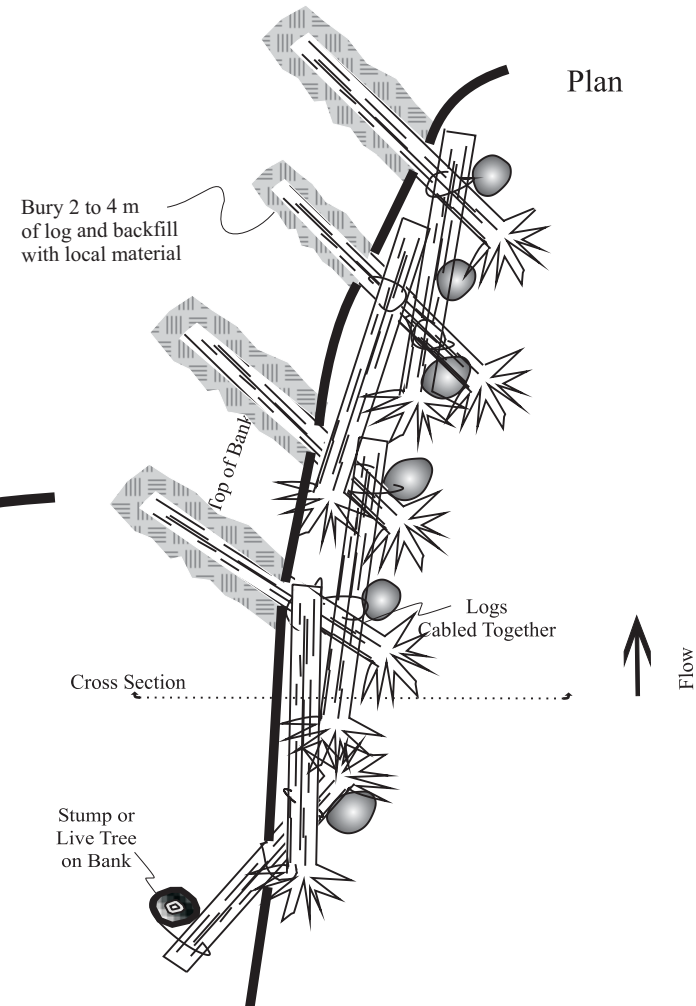
Cross Section



Construction Notes:

- 1) LWD pieces may be between 10 and 12 m long x 0.5 m diameter.
- 2) If using duckbill or deadman anchors care should be given to the positioning of the anchors to not allow the LWD to shift downstream.
- 3) Logs with rootwads attached to be used where available.
- 4) Cable to stumps or live trees on banks where available
- 5) Number and size of rock anchors depends on predicted maximum flow, maximum flow velocity, extent of embedding or anchoring, and number and size of LWD used.

Plan

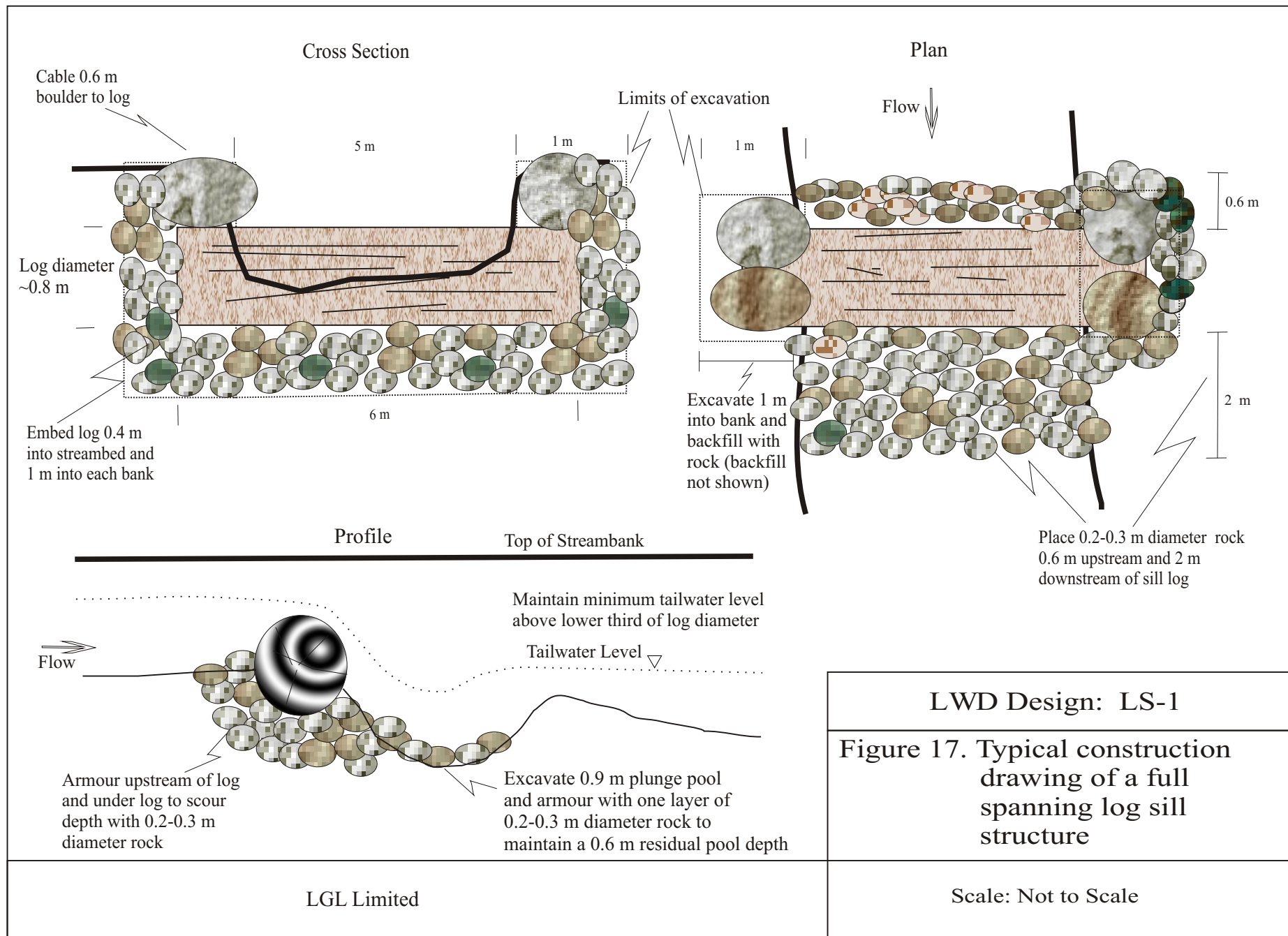


LWD Design: LT-52 Embedded

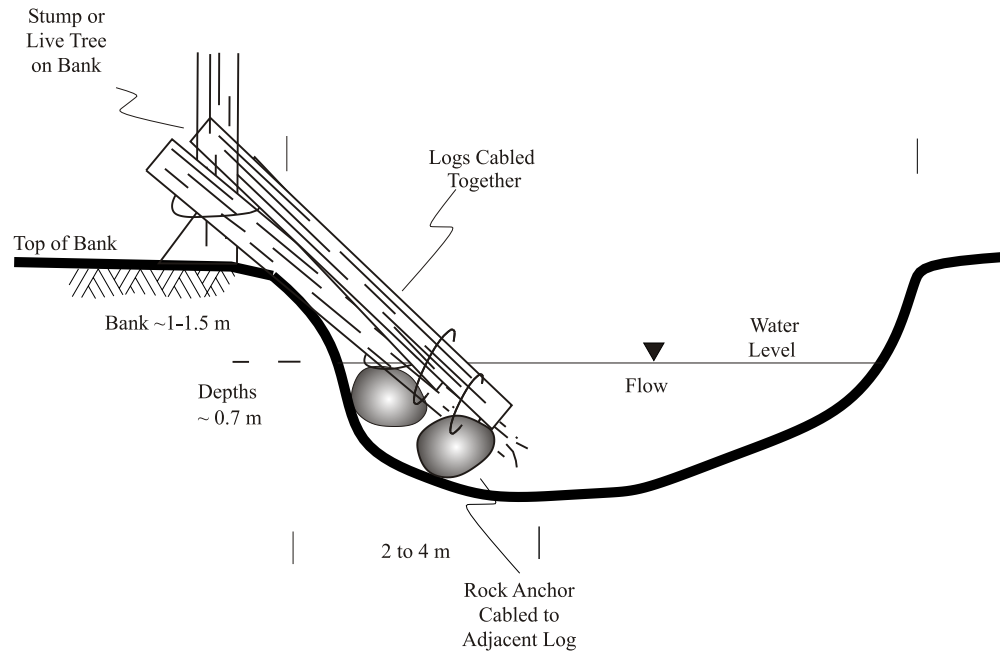
Figure 16. Typical LWD
Structure With Attached Rootwads
Plan and Cross Section

LGL Limited

Scale: Not to scale



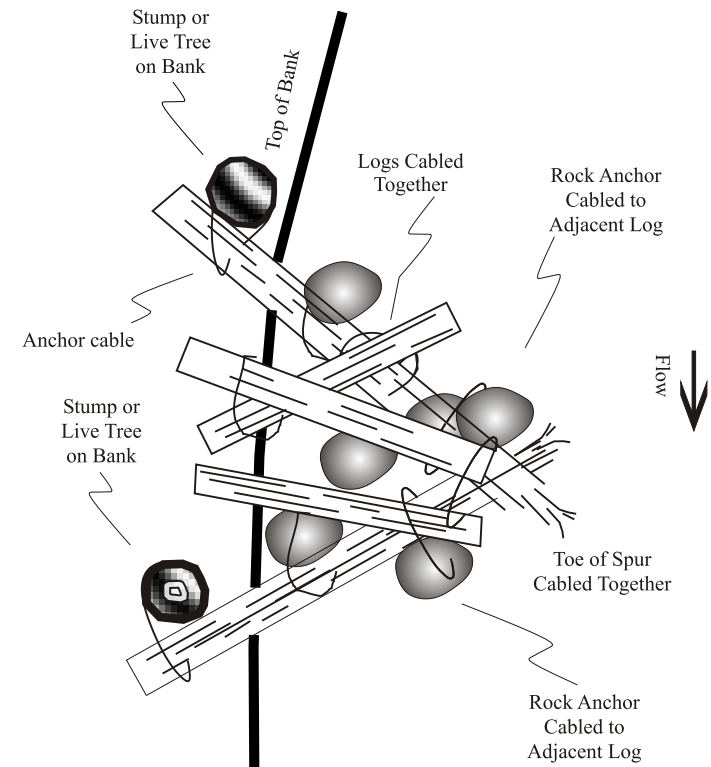
Cross Section



Construction Notes:

- 1) LWD pieces may be between 10 and 12 m long x 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) Leave cable anchors slack so that rock anchors scour into stream bed.
- 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.
- 5) Logs without rootwads attached to be used.
- 6) Limit spur projection width to 30% of channel width or based on site conditions.
- 7) If using more than one spur along the bank, they should be spaced 4 to 6x the projection width apart or based on site conditions.

Plan



ANCHOR DIMENSIONS

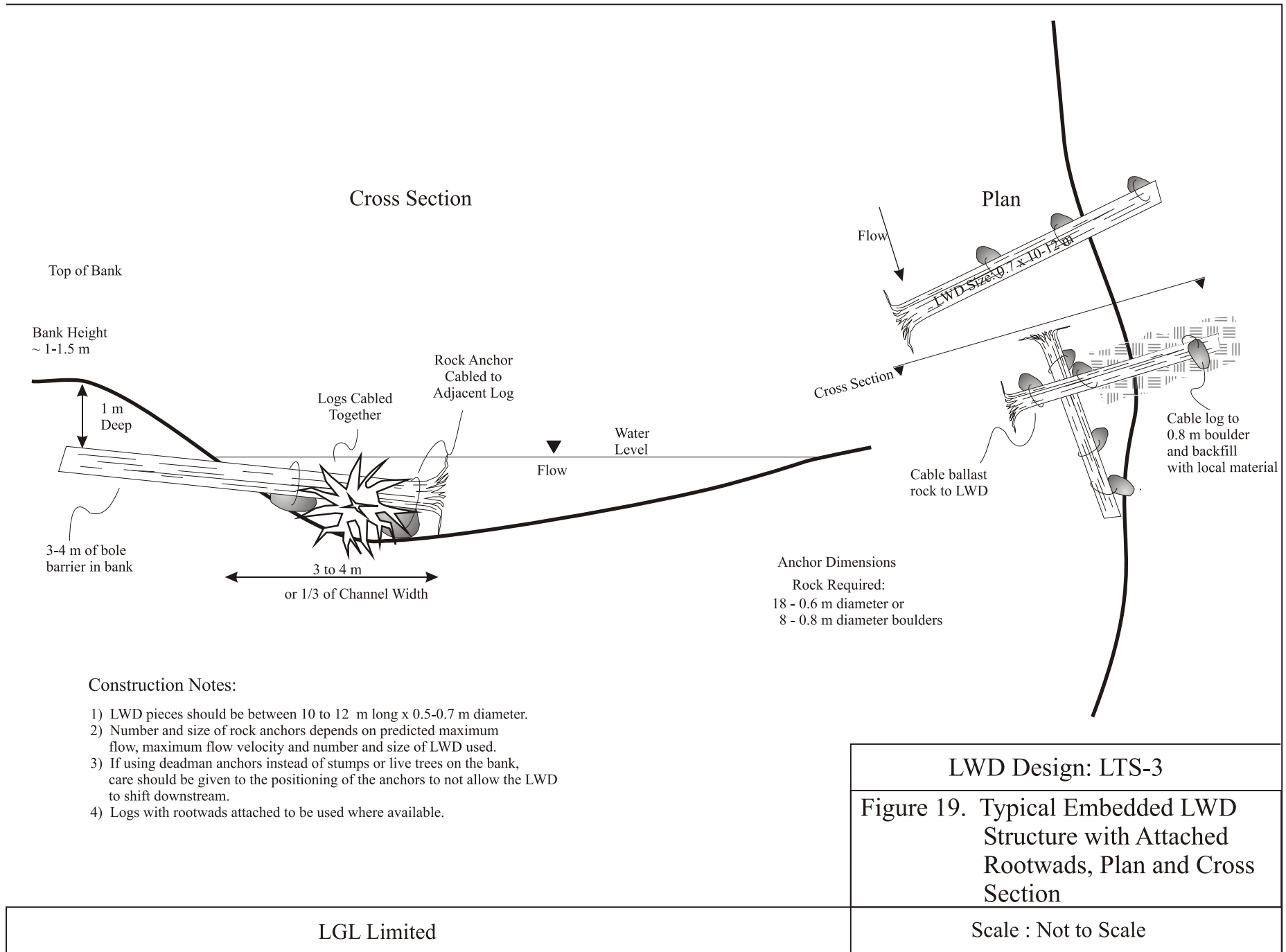
Rock Required:
13- 0.6 m diameter or
6- 0.8 m diameter

LWD Design: LSP-5

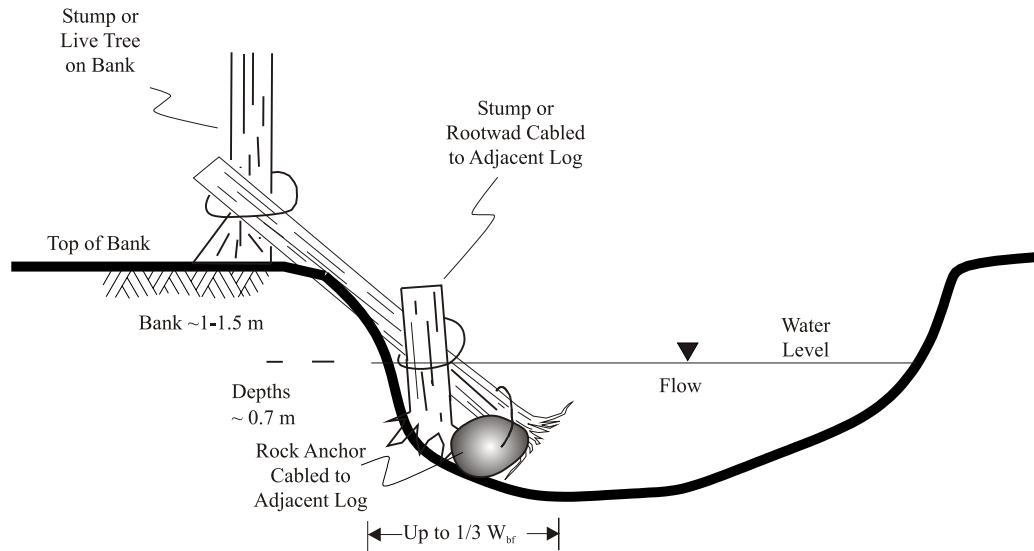
Figure 18. Typical
Triangular LWD Spur
Plan and Cross Section

LGL Limited

Scale: Not to scale



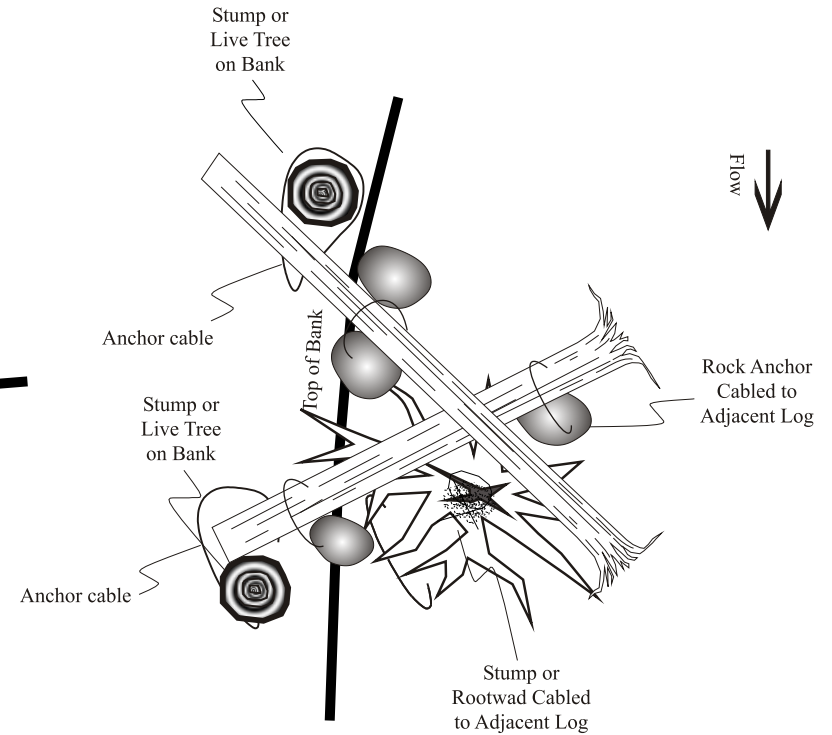
Cross Section



Construction Notes:

- 1) Use LWD pieces 10 to 12 m long x 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) Leave cable anchors slack so that rock anchors scour into streambed.
- 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 LWD to shift downstream.
- 5) Logs with rootwads attached to be used where available.
- 6) Limit LWD projection width to 1/3 of channel width or based on site conditions.

Plan



ANCHOR DIMENSIONS

Rock Required (assuming logs with rootwads):
 16 - 0.6 m diameter or
 7 - 0.8 m diameter boulders

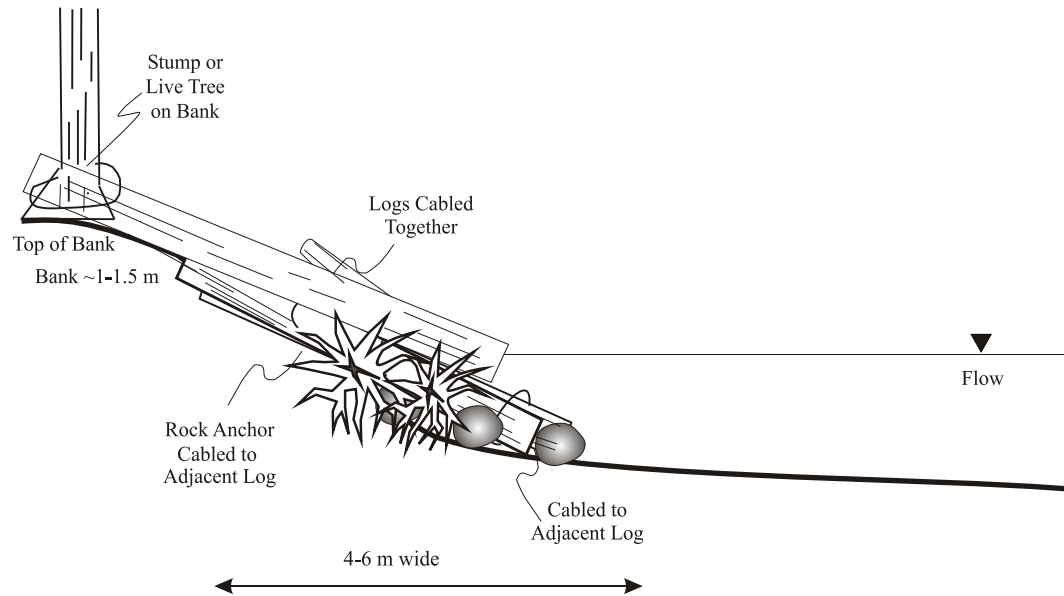
LWD Design: LX-3

Figure 20. Typical Triangular LWD Structure, Plan and Cross Section

LGL Limited

Scale: Not to Scale

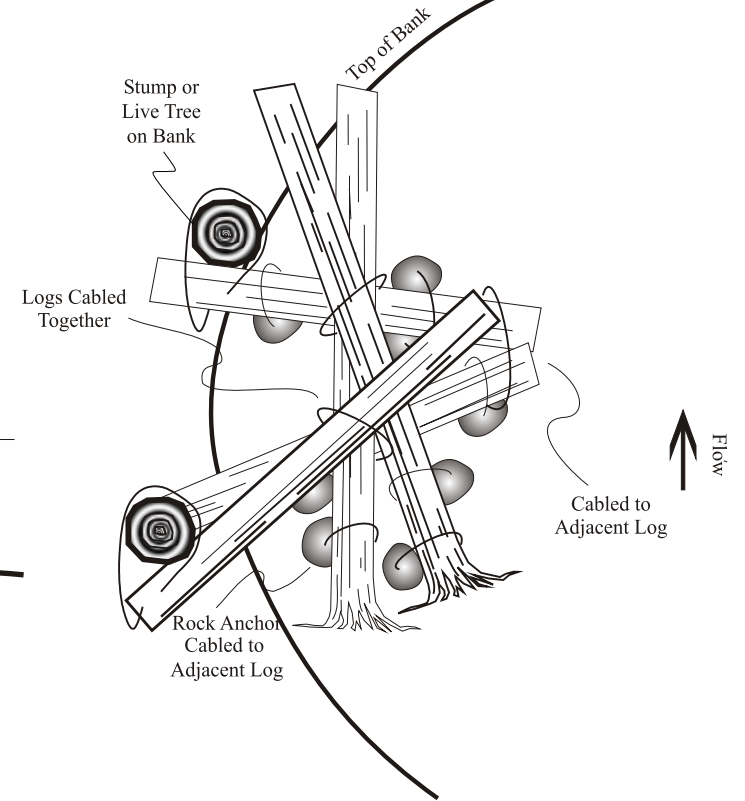
Cross Section



Construction Notes:

- 1) LWD pieces may be between 10 and 12 m long x 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) Leave cable anchors slack so that rock anchors scour into stream bed.
- 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.

Plan



ANCHOR DIMENSIONS

Rock Required:

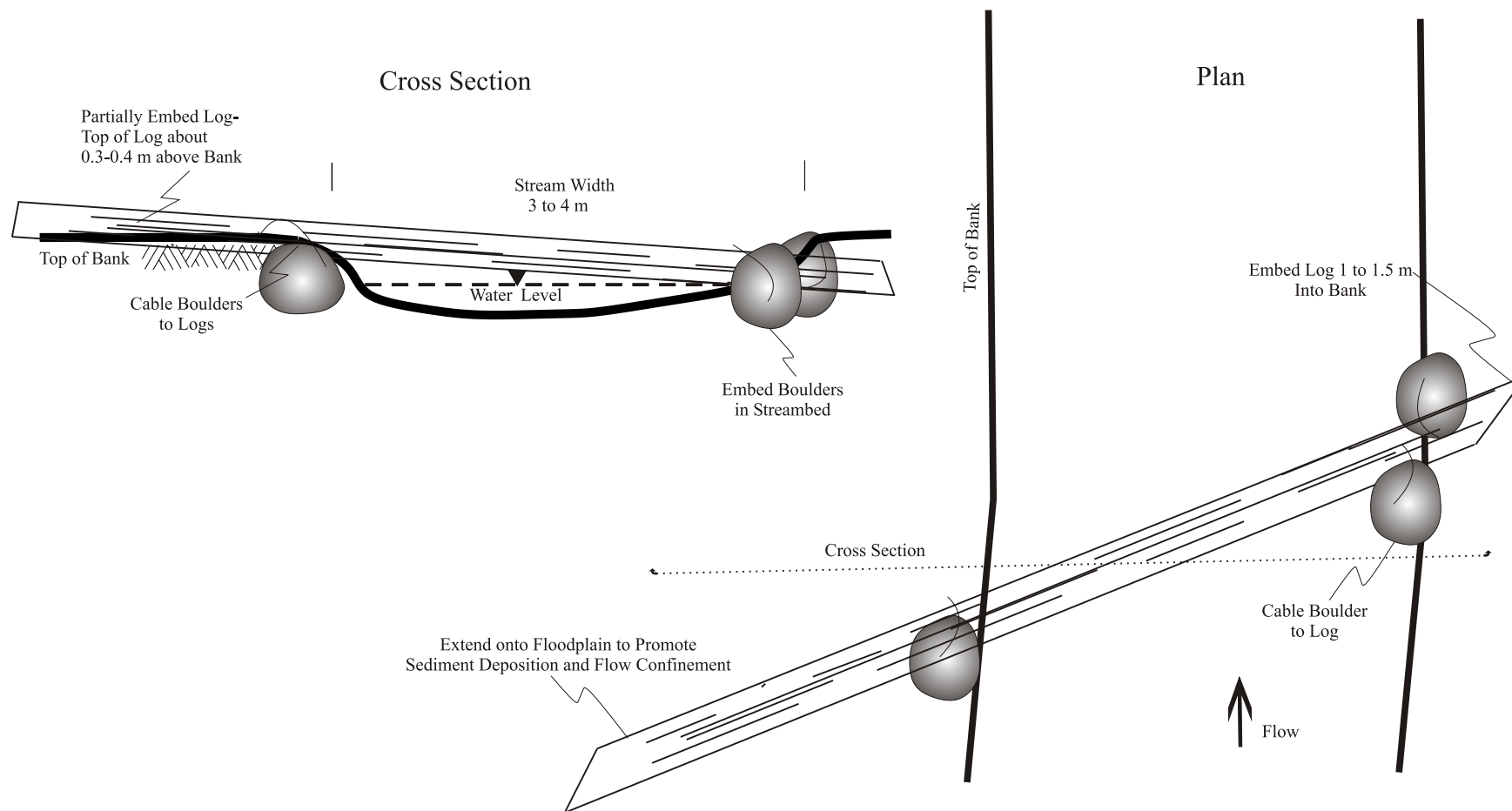
- 17 - 0.6 m diameter or
- 7 - 0.8 m diameter boulders

LWD Design: DJ-5

Figure 21. Typical LWD Jam Structure,
Plan and Cross Section.

LGL Limited

Scale: Not to scale



Construction Notes:

- 1) LWD pieces may be about 10-14 m long and 0.5-0.7 m in diameter and may fully or partially span the channel.
- 2) Log without rootwad attached to be used.
- 3) Log to be embedded into bank a minimum of 1 m, and placed either perpendicular or diagonal, up to 45 degrees off perpendicular.
- 4) Boulders to be embedded into streambed and bank.
- 5) Boulders, log deadmen or 'Duckbill' anchors should be used to secure the log.

LWD Design: DL-1

Figure 22. Typical Fullspanning Diagonal Log Structure, Plan and Cross Section

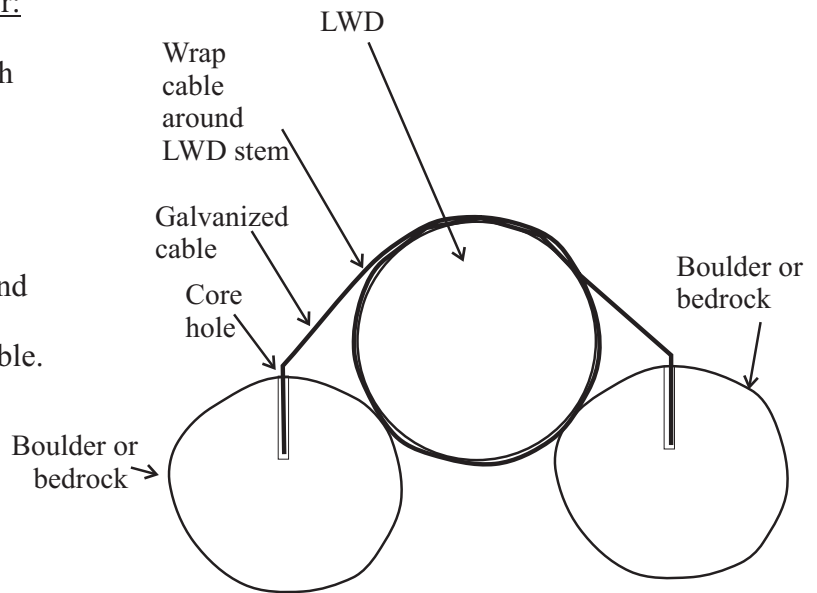
LGL Limited

Scale: Not to scale

Two Cabling Options

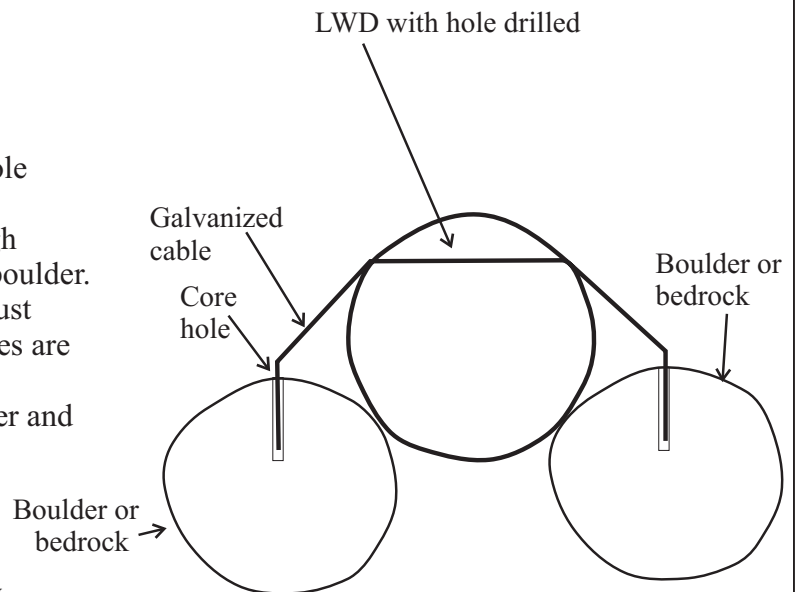
Attach cable to rock in following manner:

- 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.

Figure 23. Detail for attaching boulders to LWD.

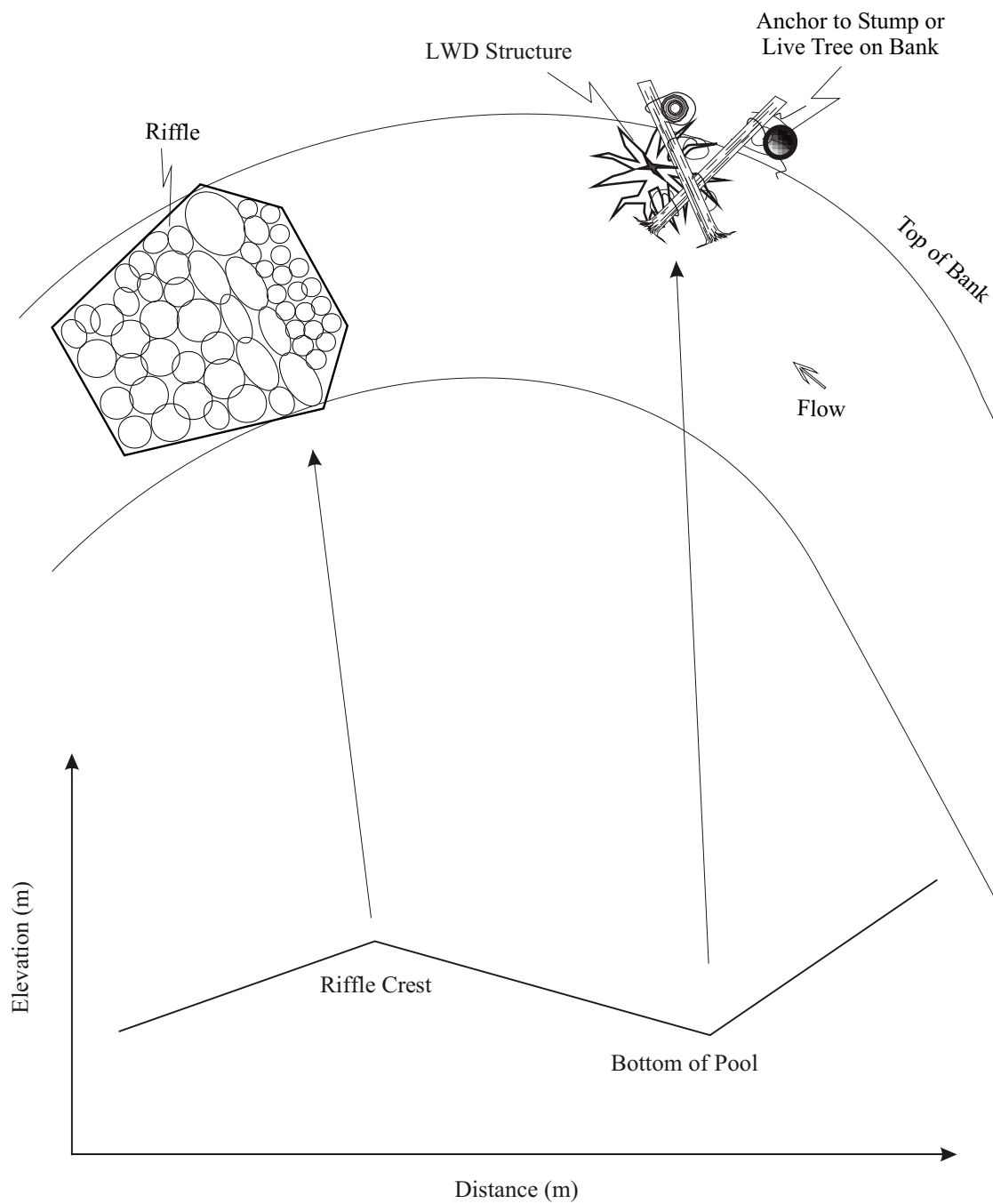
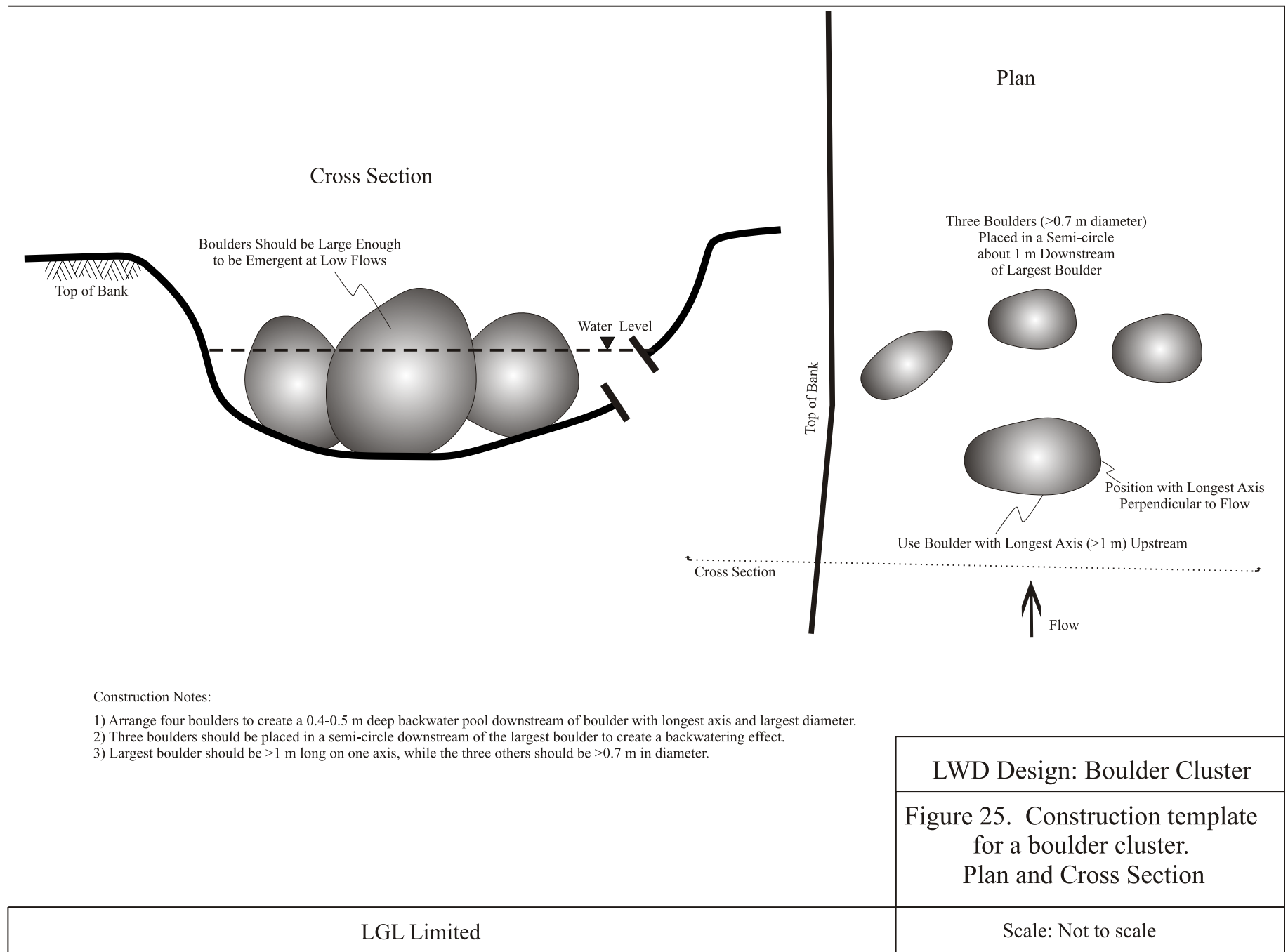
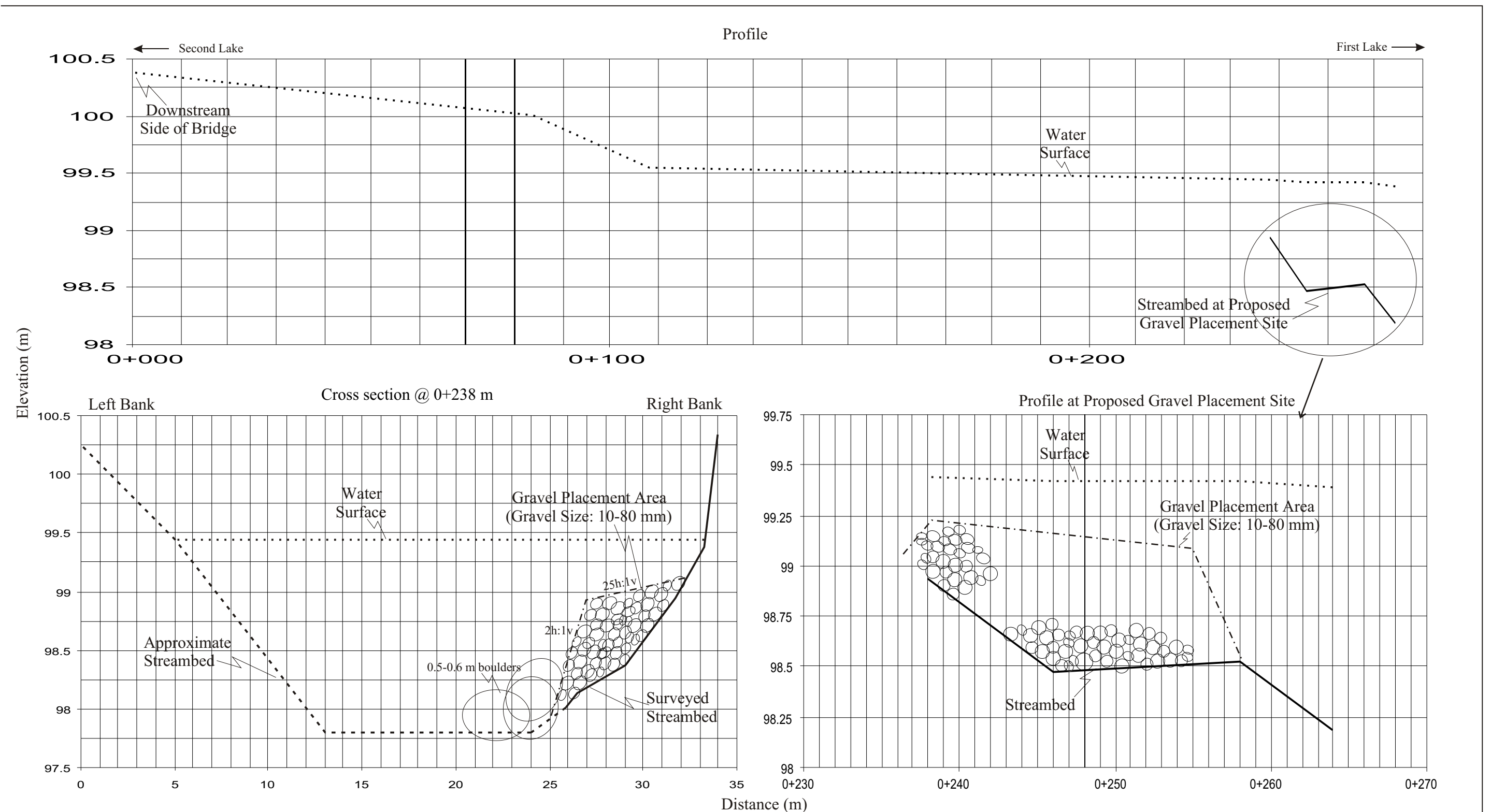


Figure 24. LWD structure placement - the preferred location in plan and profile views.





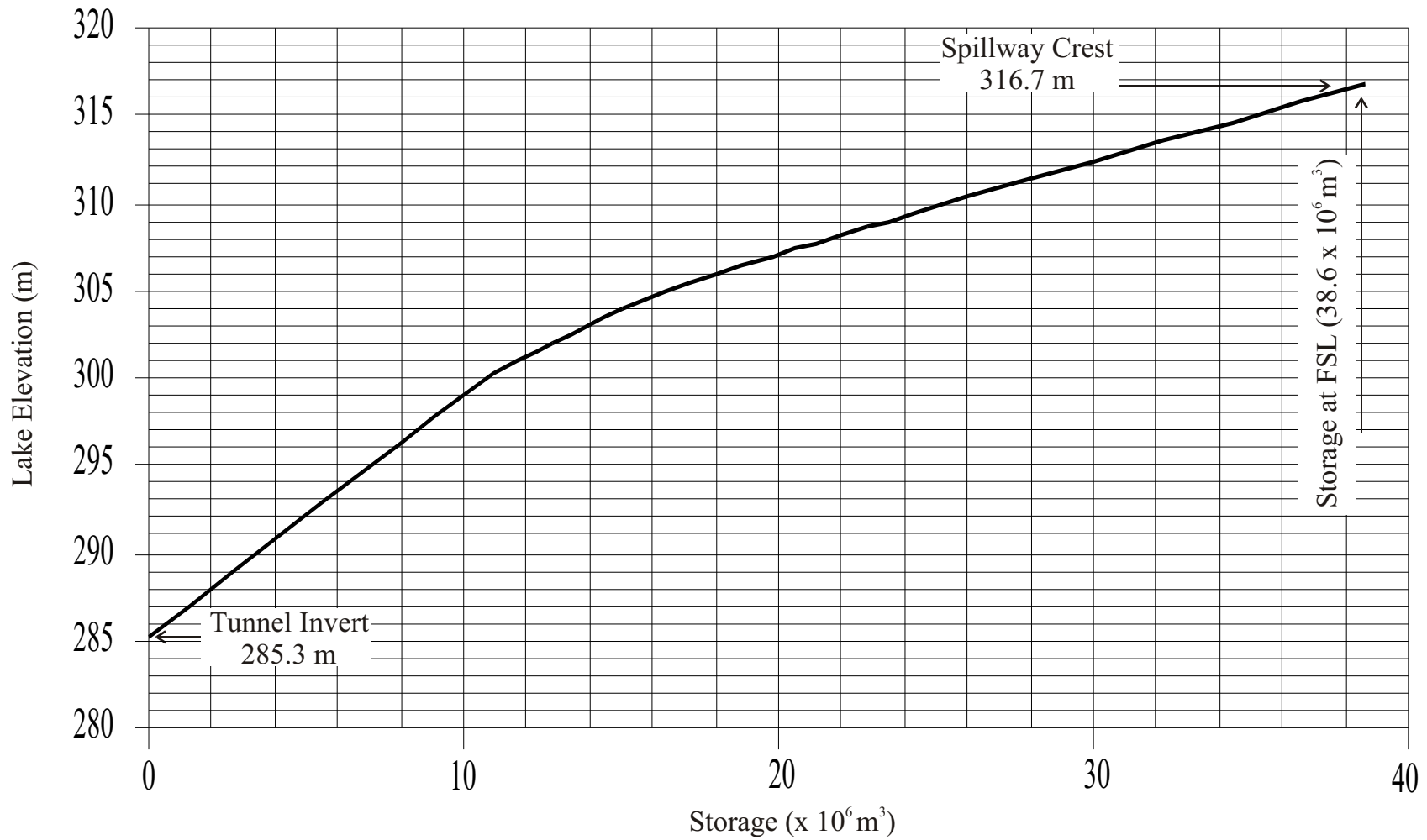


Figure 27. Fourth Lake reservoir volume versus lake stage. Modified from Kerr, Priestman & Assoc. Ltd. July, 1986.

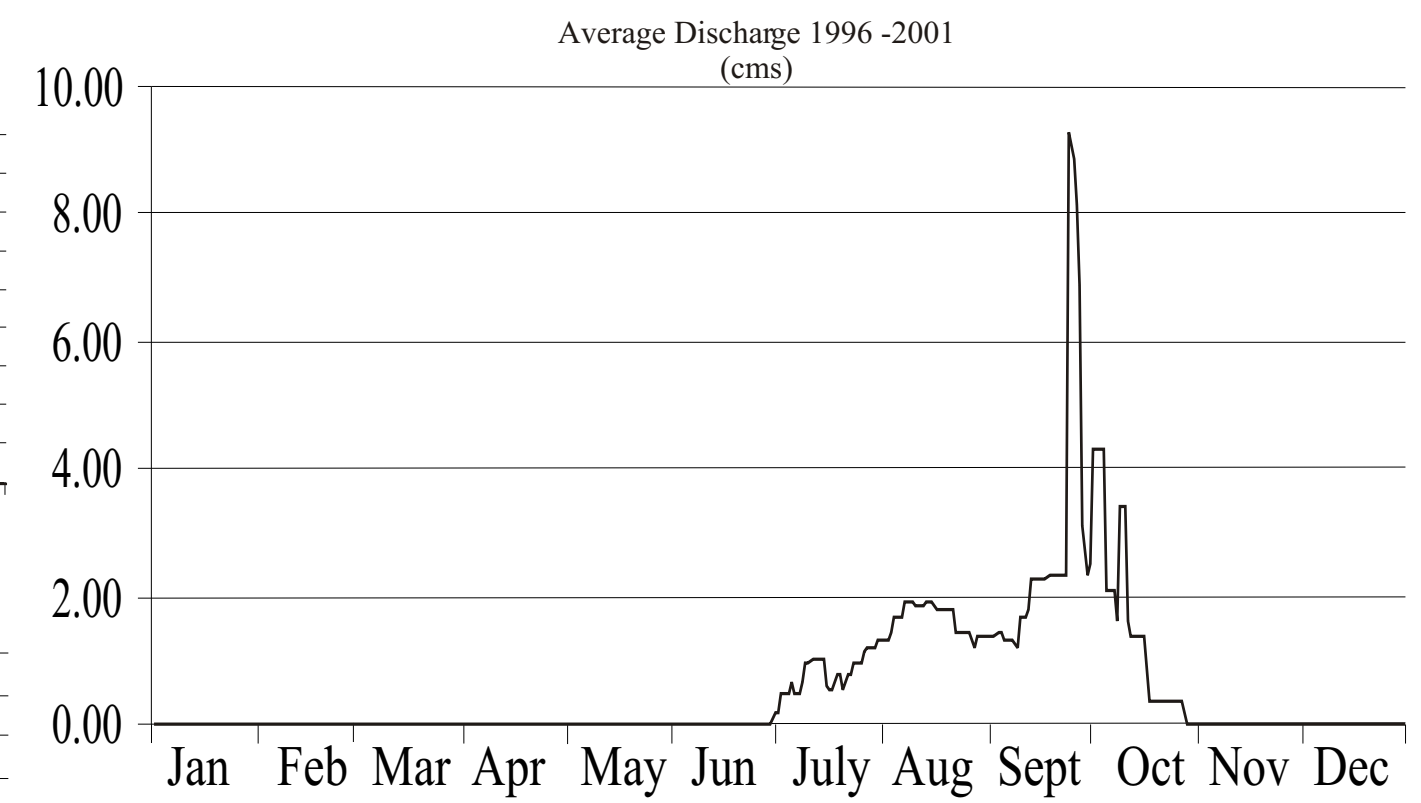
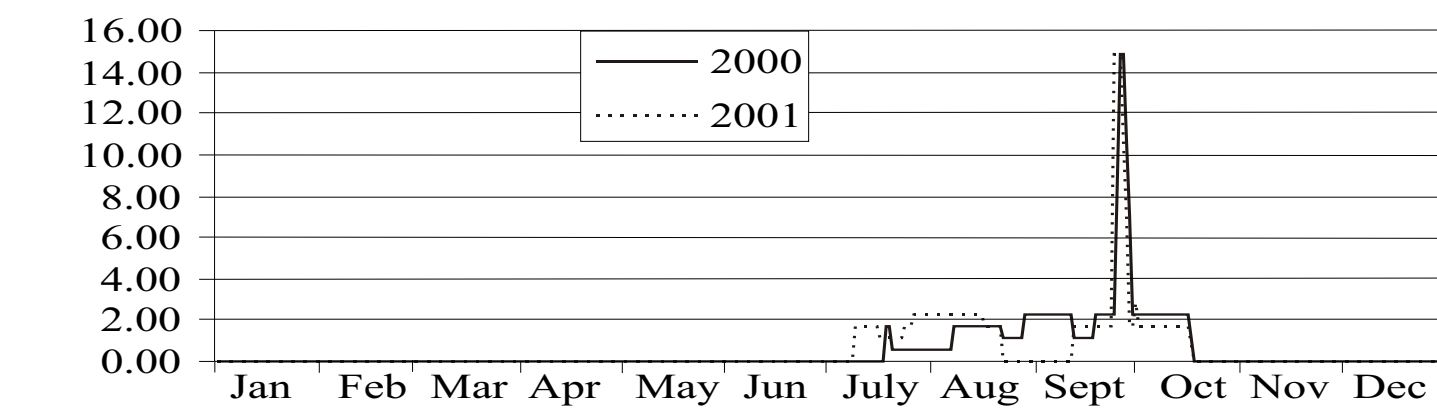
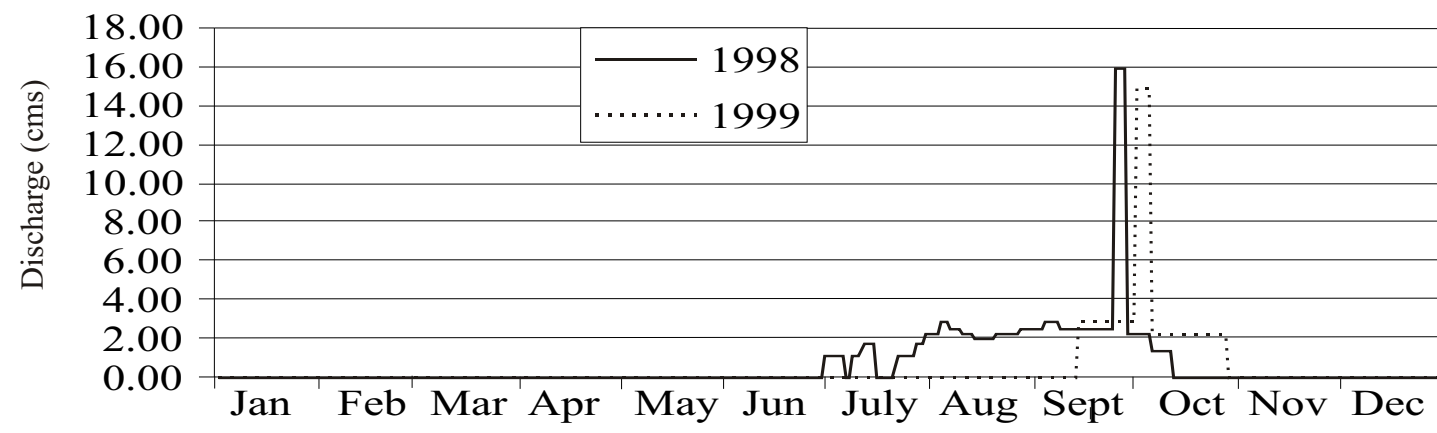
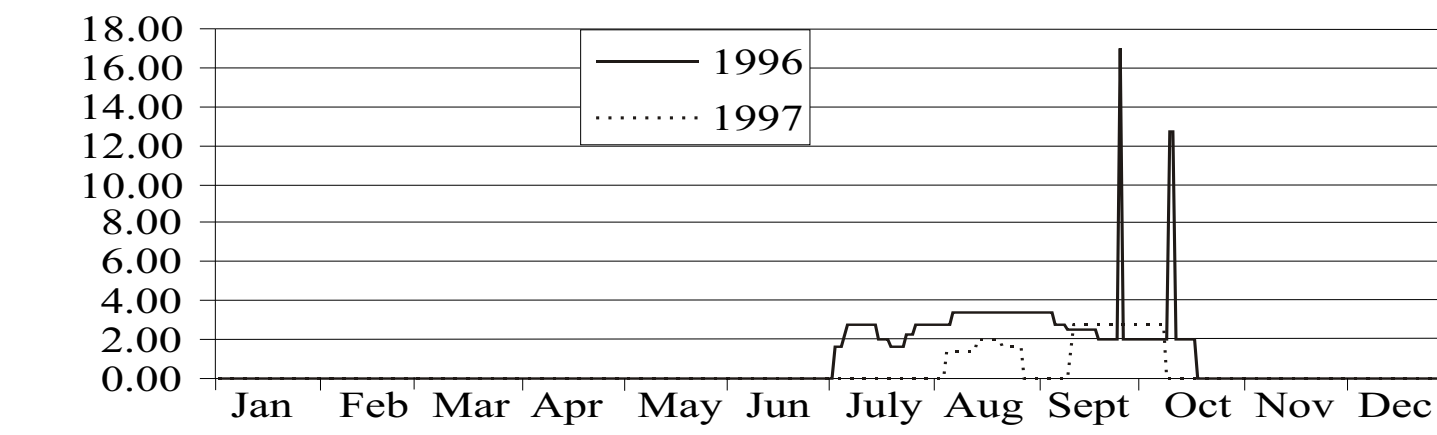


Figure 28. Daily discharges out of Fourth Lake, Nanaimo River from 1996 to 2001. Data provided by Pope and Talbot Ltd., Harmac Pulp Operations, Nanaimo.

LGL Limited

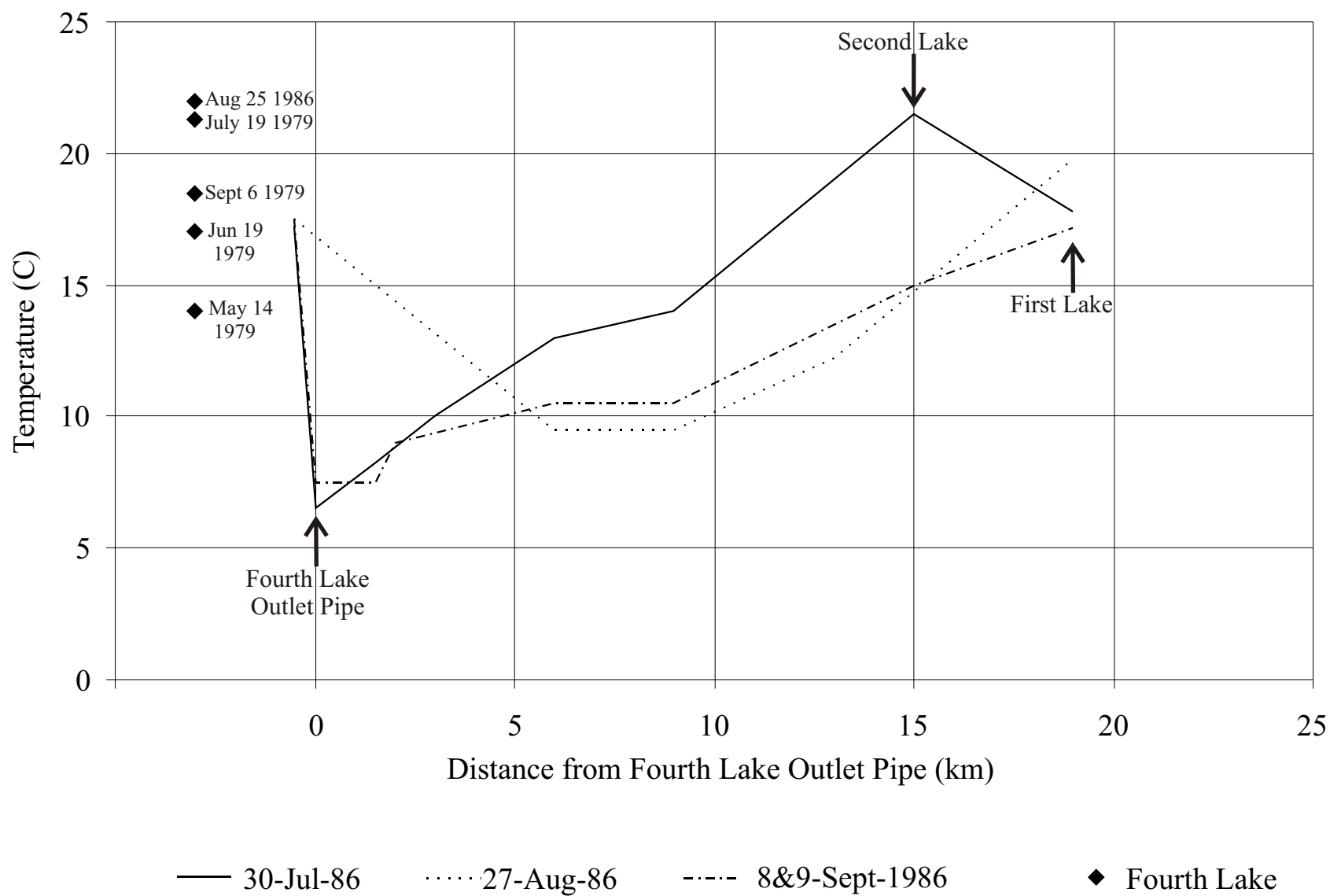


Figure 29. Water temperatures in Nanaimo River from Fourth Lake to First Lake.
 Unpublished data from BC Ministry of Water, Land and Air Protection, Nanaimo.

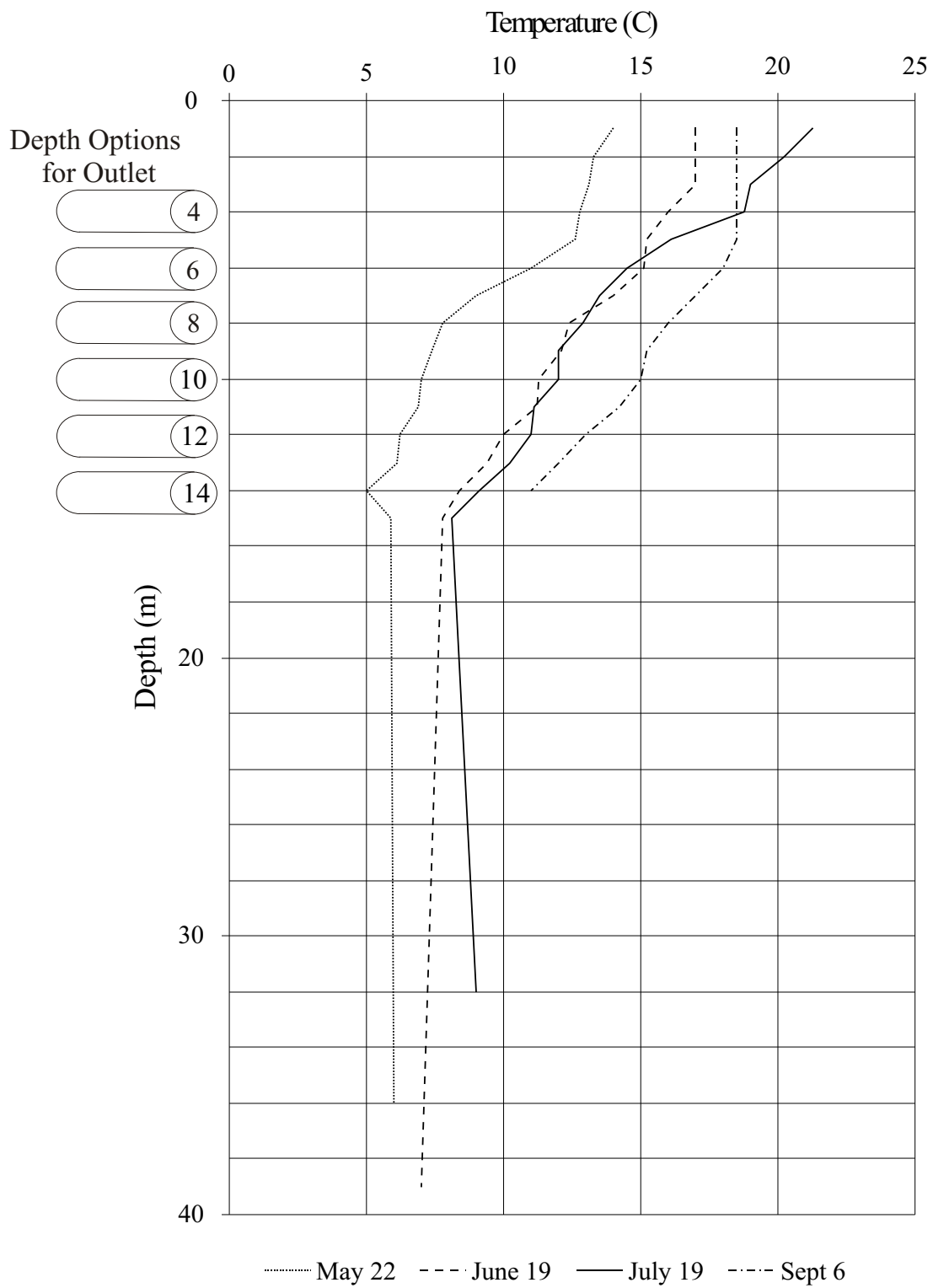


Figure 30. Temperature profile for Fourth Lake, May to September, 1979. Unpublished data from BC Ministry of Water, Land and Air Protection, Nanaimo.

MAPS

APPENDICES

Appendix 1

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. Appendix 2 contains information on the species-specific freshwater FSZ timing windows. 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.

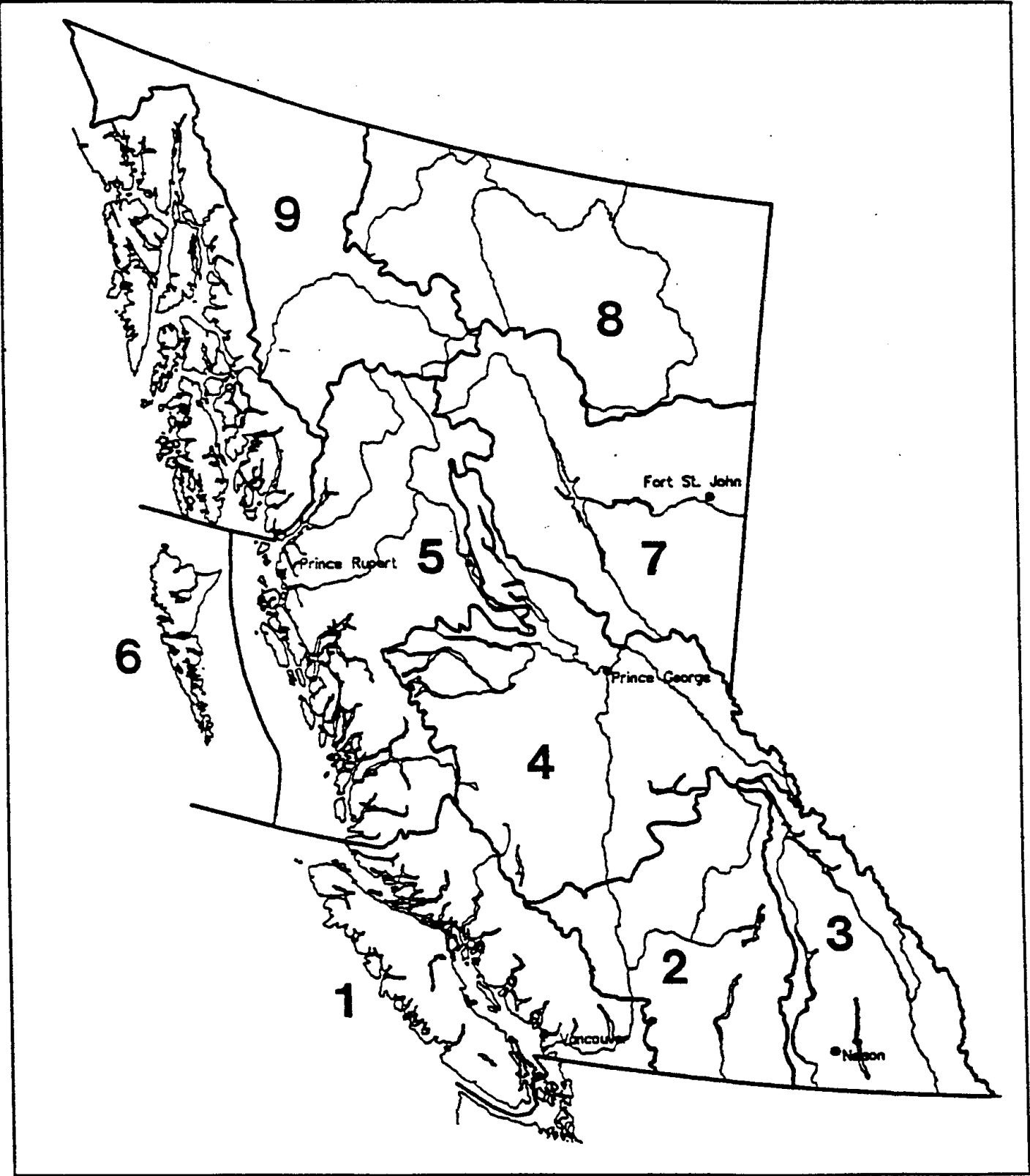
Maintenance of Instream Structures

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 2

Fishery Construction Windows for BC (Chilibeck 1992)

Figure A3.1 Fisheries Sensitive Zone Areas of British Columbia



BC Fisheries Zones (from Chilibeck, 1992 and FPC 1996)

Species**	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9
Chinook salmon	Jul 15-Sep 15	Jun 15-Jul 31	N/A	Jun 15-Jul 15	Jun 15-Jul 31	Jun 01-Jul 31	N/A	N/A	May 01-Jul 31
Coho salmon	Jun 15-Sep 15	Jul 01-Sep 30	N/A	Jun 15-Sep 30	Jul 01-Aug 31	Jun 15-Aug 15	N/A	N/A	Apr 01-Aug 15
Pink salmon	May 01-Aug 15	Jun 01-Aug 31	N/A	Jun 15-Aug 31	May 15-Aug 15	May 15-Aug 15	N/A	N/A	Mar 15-Jul 31
Chum salmon	May 15-Sep 15	N/A	N/A	N/A	May 15-Aug 31	May 15-Aug 31	N/A	Jul 01-Aug 15	Apr 01-Sep 15
Sockeye salmon	Jun 01-Sep 15	Jun 01-Jul 31	N/A	Jun 15-Jul 15	Jun 15-Jul 15	Jun 15-Jul 31	N/A	N/A	Apr 01-May 31
Kokanee	Jun 15-Jul 31	May 15-Aug 31	Jun 15-Aug 15	Jun 01-Aug 31	Jun 15-Jul 15	Jun 15-Jul 31	Jun 01-Aug 31	N/A	N/A
Steelhead	Aug 01-Nov 15	Jul 15-Oct 30	N/A	Aug 01-Apr 30	Aug 15-Dec 31	Aug 15-Nov 15	N/A	N/A	Aug 15-Nov 15
Rainbow trout	Aug 15-Nov 15	Aug 15-Sep 30	Jul 15-Mar 31	Jul 15-Apr 15	Aug 15-Jan 31	Aug 15-Jan 31	Jul 15-Mar 31	Jul 15-Mar 31	Sep 01-Apr 30
Cutthroat trout	Aug 01-Sep 30	Aug 15-Apr 15	Sep 15-Apr 30	N/A	Aug 15-Dec 31	Aug 15-Dec 31	N/A	N/A	Sep 01-Apr 30
Dolly Varden	Jun 01-Sep 15	N/A	Jun 15-Aug 15	Jul 15-Aug 31	Jun 15-Aug 31	May 15-Aug 31	Jun 01-Aug 31	Jun 01-Aug 31	Jun 15-Aug 31
Whitefish	Jun 01-Sep 15	Jun 01-Sep 15	Apr 01-Oct 31	Jun 01-Sep 15	Jun 01-Sep 15	N/A	Jun 15-Aug 31	Jun 15-Aug 31	Jun 01-Aug 31
Arctic grayling	N/A	N/A	N/A	N/A	N/A	N/A	Jul 15-Mar 31	Jul 15-Mar 31	Jul 15-Mar 31
Walleye	N/A	Jul 30-Apr 01	N/A	N/A	N/A	N/A	Jul 01-Apr 30	Jul 01-Apr 30	N/A
Pike	N/A	N/A	N/A	N/A	N/A	N/A	Jul 01-Apr 30	Jul 01-Apr 30	N/A
Bull trout	N/A	Jul 01-Jul 31	Jun 15-Aug 15	Jun 15-Aug 15	Jun 15-Aug 31	N/A	Jun 15-Aug 15	Jun 15-Aug 15	Jun 15-Aug 31

* Instream work windows are approximations for a particular species over an entire specified area and should be considered time periods of reduced risk only

** Not a complete list of species of concern. Proponent should consult regional fisheries staff with regard to species not listed here.

Appendix 3

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

Guidelines for Construction Practices within the Fisheries Sensitive Zone

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.

Appendix 4. Assessment, restoration and acquisition projects completed in five East Vancouver Island watersheds.

Watershed	Project Title	Date	Project Type	Funding Source	Organization	Estimated Cost
Chemainus	Westholme Side Channel		Side Channel Dev.	DFO	Note: Estimated Costs	\$50,000.00
	Total Projects	1			Total Expenditures	\$50,000.00
Nanaimo	Thatcher Creek	1995	Assessment	USHP	Nanaimo Fish and Game Protective Assn.	\$10,000.00
	Watershed Planning	1995	Planning	USHP	Nanaimo First Nations	\$10,000.00
	Haslam Creek	2001	Assessment	USHP	Nanaimo Fish and Game Protective Assn.	\$10,000.00
	Thatcher Creek	1996	Restoration	USHP	Nanaimo Fish and Game Protective Assn.	\$24,087.00
	Thatcher Creek	1997	Restoration	USHP	Nanaimo Fish and Game Protective Assn.	\$21,500.00
	Thatcher Creek	1998	Restoration	USHP	Nanaimo Fish and Game Protective Assn.	\$22,135.00
	Nanaimo River Land Acquisitions	1999	Land Acquisitions	Victoria	Nature Conservancy of Canada	\$100,000.00
	White Rapids Fish Passage Improvement	1995	Instream Construction	SEP	DFO	\$15,000.00
	Nanaimo River Land Acquisitions	2000	Land Acquisitions	HRSEP	DFO	\$325,000.00
	Nanaimo River Land Acquisitions	1999	Land Acquisitions	HRSEP	DFO	\$50,000.00
	Nanaimo River Water Management Plan	1992	Assessment	MoELP	R.P. Griffith and Assoc.	\$25,000.00
	Total Projects	11			Total Expenditures	\$587,722.00
Little Qualicum	Storage Weir at the Outlet of Cameron Lake	1979	Instream Construction	DFO	Note: Estimated Cost	\$50,000.00
	Kinkade Creek Clay Bank Restoration	1996	Instream Construction	MoELP / M&B	Note: Estimated Cost	\$50,000.00
	Total Projects	2			Total Expenditures	\$100,000.00
Oyster	Assessment of streams in the Oyster R.	1996	Assessments	USHP	Oyster River Watershed Management Committee	\$24,500.00
	Assessment of streams in the Oyster R.	1997	Assessments	USHP	Oyster Bay Streamkeepers	\$6,780.00
	Assessment of streams in the Oyster R.	1997	Assessments/Restoration	USHP	Oyster Bay Streamkeepers	\$5,530.00
	Bear Creek Assessment	1998	Assessments	USHP	Oyster River Watershed Management Committee	\$10,080.00
	Assessments of Artificial Channels	1999	Assessments	HRSEP	Oyster River Enhancement Society	\$31,040.00
	Rehabilitation of Side Channel #2	1999	Restoration/Maintenance	USHP	Oyster River Enhancement Society	\$13,150.00
	Off Channel Construction	1999	Construction	FsRBC	Oyster River Enhancement Society	\$6,400.00
	Water Quality Monitoring	1999	Assessments	USHP	Oyster River Watershed Management Committee	\$4,300.00
	Instream Construction	2000	Instream Construction	WRP	Interfor	\$60,000.00
	Oyster River Water Management Plan	1991?	Assessment	MoELP		\$15,000.00
	Total Projects	10			Total Expenditures	\$176,780.00
Quinsam	Biophysical Assessment	1999	Assessment	BC Hydro	Contractors	\$60,000.00
	Total Projects	1			Total Expenditures	\$60,000.00

Appendix 5. Average salmon escapement records over five time periods for the five study watersheds.

Data obtained from nuSEDS V1.0 Fisheries and Oceans Canada.

	Chemainus						Nanaimo				
	57-65	66-75	76-85	86-95	96-99		57-65	66-75	76-85	86-95	96-99
Sockeye	0	0	1	0	-		6	0	2	2	0
Pink	0	0	0	1	4		167	0	10	61	0
Chum	10944	14725	23280	12420	7163		18833	35550	41820	53800	43750
Chinook	18	60	451	681	302		2500	1373	1834	434	1700
Coho	1067	590	387	372	175		3361	3055	2740	1781	2279

	Oyster						Quinsam				
	57-65	66-75	76-85	86-95	96-99		57-65	66-75	76-85	86-95	96-99
Sockeye	0	0	0	0	-		0	55	38	49	199
Pink	10022	1410	743	24889	32000		3056	4890	14455	137217	83126
Chum	1697	365	329	567	6000		917	670	530	273	230
Chinook	13	0	0	160	375		17	47	753	4627	1797
Coho	10833	5700	1730	1978	5500		5778	2350	12100	15972	13862

	Little Qualicum				
	57-65	66-75	76-85	86-95	96-99
Sockeye	38	66	89	60	-
Pink	361	34	3	78	-
Chum	32778	59500	47947	71052	68250
Chinook	633	393	1361	787	1288
Coho	4167	2650	3150	1436	1604

Appendix 6. Juvenile and adult steelhead stock status for the five study watersheds.
(Unpublished data from MWLAP and BCCF).

River	Juvenile Standing Stock			Adult Snorkel Survey Indices				Stock Status	
	% of Predicted Fry/Unit (# Sites)			Peak Adult Counts (fish/km)				Classification based on Ptolemy (1998)	Classification based on Wightman et al. (1998)
	1998	1999	2000	1998	1999	2000	2001		
Chemainus	n/a	n/a	n/a	1.38 ^a	18.4	6.4	12.4	Scarce / Moderate Risk	High Risk
Nanaimo	13.9 (7)	13.8 (7)	20.0 (7)	3.25	0.46	2.4	12	Rare / High Risk	Moderate Risk
Little Qualicum	20 (8)	33 (8)	31 (8)	1.86	6.47	3.1	6.6	Scarce / Moderate Risk	High Risk
Oyster	24 (8)	N/A	53 (8)	2.50	0.53	1.3	2.2	Rare / High Risk	High Risk
Quinsam	4 (2)	26 (10)	29 (10)	1.14	6.59	7.7	7.9	Scarce / Moderate Risk	Moderate Risk

Note: a - this section was not deemed to be an accurate indicator of stock abundance

Appendix 7. Lake elevations (m) and discharges (cms) at Fourth Lake, Nanaimo River from 1996 to 2001. Discharges from Harmac's outlet pipe; data provided by Pope & Talbot Ltd., Harmac Pulp Operations.

Month-Day	1996		1997		1998		1999		2000		2001		Mean	Mean	Max
	Lake		Lake		Lake		Lake		Lake		Lake		Water	Discharge	Discharge
	Elevation	Discharge	Elevation	Discharge	Elevation	Discharge	Elevation	Discharge	Elevation	Discharge	Elevation	Discharge	Level		
6-30		0.00		0.00	316.70	1.13		0.00		0.00		0.00	316.70	0.19	1.13
7-1		0.00	316.75	0.00		1.13		0.00		0.00		0.00	316.75	0.19	1.13
7-2	316.70	1.70		0.00		1.13		0.00		0.00		0.00	316.70	0.47	1.70
7-3		1.70		0.00		1.13		0.00		0.00		0.00		0.47	1.70
7-4		1.70		0.00		1.13		0.00	316.75	0.00	316.72	0.00	316.73	0.47	1.70
7-5	316.50	2.83		0.00		1.13		0.00		0.00		0.00	316.50	0.66	2.83
7-6		2.83		0.00	316.84	0.00		0.00		0.00		0.00	316.84	0.47	2.83
7-7		2.83		0.00		0.00		0.00		0.00		0.00		0.47	2.83
7-8		2.83		0.00	316.53	1.13		0.00		0.00		0.00	316.53	0.66	2.83
7-9		2.83		0.00		1.13		0.00		0.00	316.70	1.70	316.70	0.94	2.83
7-10	315.75	2.83	316.78	0.00		1.13		0.00		0.00		1.70	316.27	0.94	2.83
7-11		2.83		0.00	316.38	1.70		0.00	316.75	0.00		1.70	316.57	1.04	2.83
7-12		2.83		0.00		1.70		0.00		0.00	316.53	1.70	316.53	1.04	2.83
7-13		2.83		0.00		1.70		0.00		0.00		1.70		1.04	2.83
7-14		2.83		0.00		1.70	316.78	0.00		0.00		1.70	316.78	1.04	2.83
7-15	315.32	1.98		0.00	316.41	0.00		0.00		0.00		1.70	315.87	0.61	1.98
7-16		1.98		0.00		0.00		0.00		0.00	316.38	1.13	316.38	0.52	1.98
7-17		1.98	316.72	0.00		0.00		0.00		0.00		1.13	316.72	0.52	1.98
7-18	314.99	1.70		0.00		0.00		0.00	316.70	1.70		1.13	315.85	0.76	1.70
7-19		1.70		0.00		0.00		0.00		1.70	316.06	1.13	316.06	0.76	1.70
7-20		1.70		0.00		0.00		0.00	316.64	0.57		1.13	316.64	0.57	1.70
7-21		1.70		0.00	316.70	1.13	316.81	0.00		0.57		1.13	316.76	0.76	1.70
7-22		1.70		0.00		1.13		0.00		0.57		1.13		0.76	1.70
7-23	314.72	2.27	316.72	0.00	316.63	1.13		0.00		0.57	315.86	1.70	315.98	0.94	2.27
7-24		2.27		0.00		1.13		0.00		0.57		1.70		0.94	2.27
7-25		2.27		0.00		1.13		0.00		0.57		1.70		0.94	2.27
7-26	314.40	2.83		0.00		1.13		0.00		0.57	315.60	2.27	315.00	1.13	2.83
7-27		2.83		0.00	316.46	1.70		0.00	316.69	0.57		2.27	316.57	1.23	2.83
7-28		2.83		0.00		1.70		0.00		0.57		2.27		1.23	2.83
7-29		2.83		0.00		1.70	316.78	0.00		0.57		2.27	316.78	1.23	2.83
7-30		2.83		0.00	316.23	2.27		0.00		0.57		2.27	316.23	1.32	2.83
7-31		2.83		0.00		2.27		0.00		0.57		2.27		1.32	2.83

Appendix 7. Lake elevations (m) and discharges (cms) at Fourth Lake, Nanaimo River from 1996 to 2001. Discharges from Harmac's outlet pipe; data provided by Pope & Talbot Ltd., Harmac Pulp Operations.

Month-Day	1996		1997		1998		1999		2000		2001		Mean Water Level	Mean Discharge	Max Discharge
	Lake Elevation	Lake Discharge	Lake Elevation	Lake Discharge	Lake Elevation	Lake Discharge	Lake Elevation	Lake Discharge	Lake Elevation	Lake Discharge	Lake Elevation	Lake Discharge			
8-1		2.83	316.72	0.00		2.27	316.75	0.00		0.57		2.27	316.73	1.32	2.83
8-2		2.83		0.00		2.27		0.00	316.69	0.57	314.99	2.27	315.84	1.32	2.83
8-3		2.83		0.00	316.05	2.83		0.00		0.57		2.27	316.05	1.42	2.83
8-4		2.83	316.69	1.44		2.83		0.00		0.57		2.27	316.69	1.66	2.83
8-5		2.83		1.44		2.83		0.00		0.57		2.27		1.66	2.83
8-6	313.18	3.40		1.44	315.80	2.55		0.00		0.57		2.27	314.49	1.70	3.40
8-7		3.40		1.44		2.55		0.00	316.69	1.70		2.27	316.69	1.89	3.40
8-8		3.40		1.44		2.55		0.00		1.70	315.20	2.27	315.20	1.89	3.40
8-9		3.40		1.44		2.55		0.00		1.70		2.27		1.89	3.40
8-10		3.40		1.44	315.70	2.27		0.00		1.70		2.27	315.70	1.85	3.40
8-11		3.40		1.44		2.27		0.00		1.70		2.27		1.85	3.40
8-12		3.40		1.44		2.27		0.00		1.70		2.27		1.85	3.40
8-13		3.40	315.86	1.98	315.13	1.98	316.75	0.00		1.70		2.27	315.92	1.89	3.40
8-14		3.40		1.98		1.98		0.00		1.70		2.27		1.89	3.40
8-15		3.40		1.98		1.98		0.00	316.23	1.70		2.27	316.23	1.89	3.40
8-16	311.55	3.40		1.98		1.98		0.00		1.70	314.58	1.70	313.07	1.79	3.40
8-17		3.40		1.98		1.98		0.00		1.70		1.70		1.79	3.40
8-18		3.40		1.98		1.98		0.00		1.70		1.70		1.79	3.40
8-19		3.40		1.98		1.98		0.00		1.70		1.70		1.79	3.40
8-20		3.40	315.32	1.70	314.10	2.27		0.00		1.70		1.70	314.71	1.79	3.40
8-21		3.40		1.70		2.27		0.00	315.41	1.70		1.70	315.41	1.79	3.40
8-22		3.40		1.70		2.27		0.00		1.13	314.86	0.00	314.86	1.42	3.40
8-23	310.58	3.40		1.70		2.27		0.00		1.13		0.00	310.58	1.42	3.40
8-24		3.40		1.70		2.27		0.00	315.25	1.13		0.00	315.25	1.42	3.40
8-25		3.40		1.70		2.27		0.00		1.13		0.00		1.42	3.40
8-26		3.40		1.70		2.27		0.00		1.13		0.00		1.42	3.40
8-27	310.02	3.40	315.32	0.00	313.27	2.55		0.00		1.13		0.00	312.87	1.18	3.40
8-28		3.40		0.00		2.55		0.00	314.98	2.27	316.26	0.00	315.62	1.37	3.40
8-29		3.40		0.00		2.55		0.00		2.27		0.00		1.37	3.40
8-30		3.40		0.00		2.55		0.00		2.27		0.00		1.37	3.40
8-31		3.40		0.00		2.55		0.00		2.27		0.00		1.37	3.40

Appendix 7. Lake elevations (m) and discharges (cms) at Fourth Lake, Nanaimo River from 1996 to 2001. Discharges from Harmac's outlet pipe; data provided by Pope & Talbot Ltd., Harmac Pulp Operations.

Month-Day	1996		1997		1998		1999		2000		2001		Mean	Mean	Max
	Lake		Lake		Lake		Lake		Lake		Lake		Water	Discharge	Discharge
	Elevation	Discharge	Elevation	Discharge	Elevation	Discharge	Elevation	Discharge	Elevation	Discharge	Elevation	Discharge	Level		
9-1		3.40		0.00		2.55	316.72	0.00		2.27		0.00	316.72	1.37	3.40
9-2		3.40		0.00		2.55		0.00		2.27		0.00		1.37	3.40
9-3	308.99	3.40	315.71	0.00	312.48	2.83		0.00		2.27		0.00	312.39	1.42	3.40
9-4		3.40		0.00		2.83		0.00		2.27	316.72	0.00	316.72	1.42	3.40
9-5	308.98	2.83		0.00		2.83		0.00		2.27		0.00	308.98	1.32	2.83
9-6		2.83		0.00		2.83		0.00	314.07	2.27		0.00	314.07	1.32	2.83
9-7		2.83		0.00		2.83		0.00		2.27		0.00		1.32	2.83
9-8		2.83	315.77	0.00	311.96	2.55		0.00		2.27		0.00	313.87	1.27	2.83
9-9	308.36	2.55		0.00		2.55		0.00		2.27		0.00	308.36	1.23	2.55
9-10		2.55	315.80	2.83		2.55		0.00		2.27		0.00	315.80	1.70	2.83
9-11	308.41	2.55		2.83		2.55		0.00		2.27		0.00	308.41	1.70	2.83
9-12		2.55		2.83		2.55		0.00	313.87	1.13	316.70	1.70	315.29	1.79	2.83
9-13	307.88	2.55		2.83		2.55	316.70	2.83		1.13		1.70	312.29	2.27	2.83
9-14		2.55		2.83		2.55		2.83		1.13		1.70		2.27	2.83
9-15		2.55		2.83		2.55		2.83		1.13		1.70		2.27	2.83
9-16		2.55		2.83	311.02	2.55		2.83		1.13		1.70	311.02	2.27	2.83
9-17		2.55	315.56	2.83		2.55		2.83		1.13		1.70	315.56	2.27	2.83
9-18	307.65	1.98		2.83		2.55		2.83	313.47	2.27		1.70	310.56	2.36	2.83
9-19		1.98		2.83		2.55		2.83		2.27		1.70		2.36	2.83
9-20		1.98		2.83		2.55		2.83		2.27	316.02	1.70	316.02	2.36	2.83
9-21		1.98		2.83		2.55		2.83		2.27		1.70		2.36	2.83
9-22		1.98		2.83		2.55	315.44	2.83		2.27		1.70	315.44	2.36	2.83
9-23	307.47	1.98		2.83		2.55		2.83		2.27		1.70	307.47	2.36	2.83
9-24	306.58	16.99		2.83	310.18	15.89		2.83		2.27	315.89	14.87	310.88	9.28	16.99
9-25		1.98	315.04	2.83		15.89		2.83	312.63	14.87		14.87	313.84	8.88	15.89
9-26		1.98		2.83		15.89		2.83		14.87		10.62		8.17	15.89
9-27		1.98		2.83		15.89		2.83		10.62		7.08		6.87	15.89
9-28		1.98		2.83	307.70	2.27		2.83		7.08	314.07	1.70	310.88	3.11	7.08
9-29		1.98		2.83		2.27		2.83	310.90	2.27	314.07	1.70	312.48	2.31	2.83
9-30		1.98		2.83		2.27		2.83		2.27		2.83		2.50	2.83

Appendix 7. Lake elevations (m) and discharges (cms) at Fourth Lake, Nanaimo River from 1996 to 2001. Discharges from Harmac's outlet pipe; data provided by Pope & Talbot Ltd., Harmac Pulp Operations.

Month-Day	1996		1997		1998		1999		2000		2001		Mean Water Level	Mean Discharge	Max Discharge
	Lake Elevation	Lake Discharge	Lake Elevation	Lake Discharge	Lake Elevation	Lake Discharge	Lake Elevation	Lake Discharge	Lake Elevation	Lake Discharge	Lake Elevation	Lake Discharge			
10-1		1.98		2.83		2.27	314.40	14.87	310.90	2.27	314.07	1.70	313.12	4.32	14.87
10-2	305.60	1.98	316.93	2.83		2.27		14.87		2.27		1.70	311.27	4.32	14.87
10-3		1.98		2.83		2.27		14.87		2.27	314.08	1.70	314.08	4.32	14.87
10-4		1.98		2.83		2.27		14.87	310.42	2.27		1.70	310.42	4.32	14.87
10-5		1.98		2.83	306.99	1.42	313.03	2.27		2.27		1.70	310.01	2.08	2.83
10-6		1.98		2.83		1.42		2.27		2.27		1.70		2.08	2.83
10-7	305.91	1.98		2.83		1.42		2.27		2.27		1.70	305.91	2.08	2.83
10-8	305.67	1.98	316.78	0.00		1.42		2.27		2.27		1.70	311.22	1.60	2.27
10-9		12.74		0.00		1.42		2.27		2.27		1.70		3.40	12.74
10-10	304.39	12.74		0.00		1.42		2.27		2.27	313.62	1.70	309.00	3.40	12.74
10-11		1.98		0.00		1.42		2.27	309.57	2.27		1.70	309.57	1.60	2.27
10-12		1.98		0.00	306.78	0.00		2.27		2.27		1.70	306.78	1.37	2.27
10-13		1.98		0.00		0.00	312.13	2.27		2.27		1.70	312.13	1.37	2.27
10-14		1.98		0.00		0.00		2.27		2.27		1.70		1.37	2.27
10-15		1.98		0.00		0.00		2.27		2.27		1.70		1.37	2.27
10-16	305.15	1.98	316.78	0.00		0.00		2.27		2.27		1.70	310.96	1.37	2.27
10-17		0.00		0.00		0.00		2.27	309.51	0.00	314.07	0.00	311.79	0.38	2.27
10-18		0.00		0.00		0.00		2.27		0.00		0.00		0.38	2.27
10-19		0.00		0.00		0.00		2.27		0.00		0.00		0.38	2.27
10-20		0.00		0.00	308.38	0.00		2.27		0.00		0.00	308.38	0.38	2.27
10-21		0.00	316.75	0.00		0.00		2.27		0.00		0.00	316.75	0.38	2.27
10-22		0.00		0.00		0.00		2.27		0.00		0.00		0.38	2.27
10-23		0.00		0.00		0.00		2.27		0.00		0.00		0.38	2.27
10-24		0.00		0.00		0.00		2.27		0.00		0.00		0.38	2.27
10-25		0.00		0.00		0.00		2.27	313.40	0.00	314.93	0.00	314.16	0.38	2.27
10-26		0.00		0.00		0.00	310.90	2.27		0.00		0.00	310.90	0.38	2.27
10-27		0.00		0.00		0.00		2.27		0.00		0.00		0.38	2.27

Appendix 8

Notification for Proposed Works and Changes In and About a Stream under Water Act Regulation 204/88.

Appendix 8. Notification for Proposed Works and Changes In and About a Stream under Water Act Regulation 204/88

Please refer to the application guidelines (attached), and the Regulation (Users Guide) when completing this Notification Form

1. Applicant Name:
Mailing Address: _____
City: _____ Postal Code: _____

Phone: (____) _____ - _____ Cell Ph: (____) _____ - _____ Fax: (____) _____ - _____

2. Location of Works:
Stream Name: _____
Location on Stream (Property Address): _____
What stream\river\lake\water body does it flow into?: _____
Legal description of property where work proposed _____

3. Drawing, Plan & Site Map: attach an accurate drawing showing lot boundaries, location of proposed works/structures with cross-section, stream direction and flow and location of buildings; photos of existing site. Design drawing of structure.
Also include a key map showing location of site.

4. Proposed Timing for work in/ about a stream:
Start (day/month/year): _____
Finish (day/month/year): _____

5. Type of Works. Check appropriate box - - circle whether installation or removal, where applicable:
(Also refer to attached sheet of definitions)

☐ (a) Road crossing culvert	(I) installation (give details of type and dimensions below*)	(ii) removal
☐ (b) Clear span bridge	(I) installation	(ii) removal
☐ (c) Pipeline crossing		
☐ (d) Pier or wharf	(I) installation	(ii) removal
☐ (e) Flow or water level measuring device	by Federal or Provincial government	(I) installation (ii) removal
☐ (f) Fish fences or screens, fish or game guards	by Federal or Prov. Government	(I) installation (ii) removal
☐ (g & h) Stream channel restoration or maintenance	by a municipality or the Province	
☐ (i) Cutting annual vegetation in a stream channel		
☐ (j) Fish habitat restoration or maintenance	by Federal or Provincial government	
☐ (k) Repair or maintenance to existing dike or erosion protection works		
☐ (l) Construction or maintenance of storm sewer outfalls		
☐ (m) Control of Eurasian Watermilfoil or other aquatic vegetation		
☐ (n) Construction or maintenance of ice bridges, winter fords or snowfills		
☐ (o) Construction/placement of erosion protection	at direction of the Crown during flood emergency	
☐ (p) Clearing obstruction from bridge or culvert	by the Crown or a municipality during a flood event	
☐ (u) Maintenance of a minor and routine nature	by a public utility	
☐ (v) Beaver dam removal		
☐ (w) Construction of a temporary ford		

Dimensions: Length _____ Width _____ Diameter _____
***Detailed Description of Work to be Performed:** (attach appropriate drawings)

6. Land Ownership:
Do you own the land on which the work is to occur? Yes ☐ No ☐
IF NOT, who owns the land?
Private:_____ Crown:_____
Landowner Name:_____
Mailing Address: _____

Phone: (____) _____ - _____
Landowner's Signature:
(Attach tenure document for Crown land)

. Who is Doing the Work?
Contractor: if different from applicant:
Company Name: _____
Contact Name: _____
Address: _____

Postal Code: _____
Phone: (____) _____ - _____
Fax: (____) _____ - _____

8. Statement of Intent:
I declare that the information contained on this form is complete and accurate. **I have read, understood and will meet the requirements** for construction of works and changes in and about a stream in accordance with **Section 9 of the Water Act and the Regulation.**

Signed: _____ **Date:** _____

The information relative to this application will become part of the public record.

Ministry Use Only:	
_____ Meets the requirements to proceed under regulation	_____:Approval required
Notification Form Reviewed by: _____	Date: _____