# KM 34 STREAM CROSSING

# STREAM RESTORATION
# CULVERT OUTLET

# DESIGN

## (W.C. 46 - 700 - 30-130)
## SUSKWA FOREST SERVICE ROAD



Prepared for: Watershed Restoration Program, Kispiox District,
B.C. Ministry of Forests,
Hazelton, B.C.

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March 31, 1999

## Table of Contents

## 1.0 Introduction

At km 34, the Suskwa Forest Service Road (Kispiox Forest District) crosses a 5 to 6 m wide fish-bearing stream. In 1988, a bridge was replaced with a multi-plate pipe arch culvert 3890 x 2690 mm. In WRP reports for 1996 and 1997, prepared by Mike Jacobs and the Suskwa Restoration Society, the culvert on this unnamed tributary to Natlan Creek was identified as a barrier to fish migration. Downcutting at the culvert outlet has left the pipe 1.5 m perched above the present stream bed, with a 0.8 m deep pool. A fish habitat assessment conducted over the summer 1998 by Mike Jacobs identified approximately 2500 m of fish habitat above the culvert. A hydrologic and geomorphic assessment prepared by Irene Weiland in October 1998 identified the culvert slope of 4.6 % to be a primary barrier to fish. A review of flow velocities for an embedded culvert with retrofitted baffles carried out by Don John, P.Eng., Ministry of Forests, Prince Rupert Region, in December 1998 determined that flow velocities would be as low as 1.0 m/s at 0.6 $m^3$/s discharge. During a phone conversation in March 1999, Mike Jacobs stated that juvenile and adult Dolly Varden and Bull Trout would use the fish passage between May and October; spawning would happen in late summer and early fall, when stream temperatures start to drop.

### *1.1 Objectives*

The scope of this report is to present the design for the build-up of the stream bed to gain fish access to the embedded culvert.

## 2.0 Basin Morphology and Site Description

Basin morphology and site description are presented in the hydrologic and geomorphic assessment report (October 1998). To facilitate submission for agency approval, the information was copied into this report.

### *2.1. Drainage Basin Morphology*

The 34 km Creek drains a catchment area of 9.4 $km^2$. Headwaters are non-glaciated and consist of long, mostly uniform, steeply sloping colluvial slopes and sharply defined rock ridges. Snow avalanche tracks are frequent with active debris flow tracks in the avalanche starting and transport zones. Snow avalanches commonly hit the narrow valley floor, but debris flows run-out on mid slope elevations, before debris reaches the valley bottom stream. Near the headwaters, the valley floor consists of partially vegetated, moderately sloping avalanche cones, which have been partially re-worked by stream activity.

The mid-valley section is formed by uniform, steep and long, forested slopes consisting of shallow colluvium overlying bedrock. Snow avalanche tracks running from ridge top to valley bottom are frequent; starting zones are gullied with shallow colluvium failing over bedrock on gully side walls. Debris from the shallow slope failures is transported to the downslope end of the gullies, where it is deposited. Steep, vegetated colluvial cones form the lower part of the valley walls. No valley flat exists. Localized disturbance and widening in the valley bottom stream near the toe of the avalanche tracks was interpreted to be a result of temporary channel damming by snow and avalanche debris during snow melt in late spring.

In the lower section of the valley, within 2000 m upstream of the road, a very narrow alluvial valley flat has developed between steep, uniform valley walls; snow avalanches starting on gullied, somewhat unstable upper slopes on the eastern valley walls run out on moderately sloping, vegetated, colluvial cones which border the stream channel and the alluvial valley flat. Channel gradient in this section ranges from 7 to 12 %. This section is part of the fish habitat identified by Mike Jacobs. Some disturbance of the stream side vegetation pattern (alder and other deciduous trees instead of conifers) is evident on the air photographs, indicating periodic (20 to 50 year) stream bank disturbance during high flows.

Where the tributary valley walls open up into the Natlan Valley, the stream gradient steepens to 10 to 19 % over a length of approximately 500 m upstream of the road. The channel is mostly confined by hummocky terrain and benches (mostly glacial till, some colluvium and glaciofluvial material) along the lower valley walls of Natlan Creek valley. Some scattered, inactive and revegetated landslide scars were identified along the morainal scarp slopes. A few short and narrow alluvial terraces exist along the channel. The stream channel has a step-pool morphology; large woody debris in small log jams is frequent and plays an important role in bedload storage and formation of gradient steps. Fish habitat throughout this section is described by Mike Jacobs, Suskwa Restoration Society.

Below the road, the stream flows over a gently sloping terrace surface parallel to Natlan Creek. The confluence with Natlan Creek is 150 m below the road.

Bedload input into the stream occurs in the alpine headwaters at a moderate rate and at the toe of snow avalanche tracks at a slow rate. Bedload movement through the system occurs at a moderate rate and in equilibrium with established channel cross sections and channel curvature. Channel banks have dense vegetation with a high percentage of mature conifers providing continuous recruitment of large woody debris as structural elements in the stream bed to aid in bedload storage. It is expected that bedload transport to the crossing site continues at the present rate. At the present rate, it is not expected that bedload movement will have a negative effect on the proposed channel restoration at the culvert outlet.

Table 1: Geomorphic basin characteristics

| | Station Creek above Diversion WSC 08EE028 | 34 KM Creek |
|---|---|---|
| General location | North end of Rocher Deboule Range | North Babine Mountains |
| Size ($km^2$) | 10.8 | 9.4 |
| Size of alpine area ($km^2$) | 5.75 | 4.9 |
| Glacier? | small glacier | none |
| Elevation range (m ASL) | 500 to 2300 | 970 to 1900 |
| Valley length (km) | 6.8 | 5.9 |
| Average slope (%) | 26 % | 16 % |
| Aspect | North | North, West, East |

### *2.2. Stream Crossing Site*

Channel width upstream of the crossing site is 5 to 6 m. Gradients are 8 to 12 % above the road right-of-way, 5 % in the right-of way clearing and 3 to 10 % in the forest below. Mean bed material size ($d_{50}$) measured within 50 m upstream of the culvert in the undisturbed channel bed was 23 cm.

In the 3,890 x 2,690 mm multi plate arch culvert, the natural channel width is reduced to less than 4 m. Flow is accelerated, causing erosion and scour at the outlet of the culvert. Presently, the culvert outlet is .85 m perched above an 0.8 m deep scour pool. Continuing erosion at the outlet slowly enlarges the scour pool, and has caused 0.9 m wide undercutting under the culvert invert. Bedload is mobilized from the 1.5 m high channel banks just below the culvert and is deposited in the gentler channel section in the forest downstream. Two logs were placed perpendicular to the stream flow, 4.5 m downstream of the culvert, spanning the entire channel width. The logs may have been partly embedded in a 5 % channel bed when the culvert outlet was built in 1988. They are now undermined and have approximately 0.7 m clearance above the channel bottom. The down-cut channel section extends over a length of 16 m below the culvert. Downstream of 20 m, the pre-construction channel banks remain intact. Bank height is 30 to 70 cm.

The culvert has a gradient of 4.6 %, over a length of 21.5 m. It is placed level with the stream bed at the inlet. No sediment or woody debris was deposited in the culvert; however, during the second site visit in June, a 66 x 39 x 29 cm boulder was found in the culvert barrel at the outlet. This boulder was not there during the site visit in May. This observation is evidence that large size bedload moved through the culvert, possibly during a flood event on May 26, 1998, which affected other streams in the Suskwa Watershed.

### 2.3 Preliminary Flow Estimate

In the hydrologic and geomorphic assessment (October 1998), bankfull discharge and $Q_{100}$ were estimated to be 4.8 $m^3/s$ and 14.4 $m^3/s$ respectively, extrapolated from a stream survey carried out on June 16, 1998. This was considered a high estimate compared to results from basin comparison with Station Creek (WSC 08EE028) and from calculations using "critical flow velocity" formula (Appendix 1). A large run-off event on May 26, 1998 caused channel widening and bedload mobilization on the Suskwa River main stem and the Harold Price Creek. The event caused no obvious channel disturbance on the 34 km Creek, but may have led to some channel widening resulting in a cross-sectional area larger than the bankfull discharge requires.

## 3.0 Flow

### *3.1. Estimate of Design Flow*

Additional hydrologic information was reviewed in March 1999 (Chapman et al. 1992; Coulson and Obedkoff, 1998). To extrapolate from mean daily discharge to mean instantaneous discharge, an I/D ratio of 1.7 was used to re-calculate design flow. $Q_{50}$ was determined using a $D_{50}$/Mean ratio of 2.5. Design flow ($Q_{50}$) was determined at 7.5 $m^3/s$. (Appendix 1)

### *3.2. Estimate of Fish Passage Flow*

Based on mean, maximum and minimum monthly discharge data from Station Creek (1991 to 1995), flows in KM 34 Creek range between 0.1 $m^3/s$ to > 2 $m^3/s$ in each month between May and October. Small fish (20-30 cm long) are thought to be able to swim against water velocities of 0.8 to 1.4 m/s over a distance of 1.5 m, provided that resting places exist (Poulin et al. 1996, App. 3)

Table 2: Estimated range of flow velocities on the stepped culvert approach.

| Flow Depth (m) | Width (m) | n | Velocity (m/s) | Discharge (m3/s) |
|---|---|---|---|---|
| 0.2 | 5 | 0.137 | 0.8 | 0.8 |
| 0.3 | 5 | 0.130 | 1.05 | 1.6 |
| 0.4 | 5 | 0.125 | 1.3 | 2.6 |
| 0.5 | 6 | 0.11 | 1.7 | 5.1 |
| 0.75 | 4 | 0.11 | 2.0 | 6 |

## 4.0 Design

Seven cross sections were surveyed (December 1, 1998) below the culvert using an automatic level and a 4 m rod, nylon tape and hand compass. Bed material, flow velocity and 3 cross-sections upstream of the road crossing were sampled in June 1998.

Table 3: Channel characteristics in the designed culvert approach

| | Bankfull discharge (Q2) | Design flood (Q50) |
|---|---|---|
| Anticipated discharge (Q) | 3.0 $m^3/s$ | 7.5 $m^3/s$ |
| Slope (S) | 0.11 | 0.11 |
| Width (W) | 4.0 - 6.0 m | 4.0 - 10.0 m |
| Depth (D) | 0.3 - 0.4 m | 0.5 - 0.9 m |
| Roughness co-efficient (n) | 0.12 | 0.11 |
| Predicted velocity | 1.5 m/s | 1.7 - 2.0 m/s |
| Predicted tractive force | | 55 - 85 $kg/m^2$ |
| Particle size required for boulder steps | | proximal: d90 = 85 cm<br>distal: d90 = 55 cm |

Discharge (Q): based on estimate of instantaneous discharge derived from catchment area comparison.

Slope: Slope was determined as the distance along the thalweg from the culvert to the original/undisturbed channel bank at 20 m below the culvert and the difference in elevation.

Cross-sectional measurements: a bank height (D) of 0.5 m and a width (W) of 6 m was found upstream of the road and adopted as a suitable bank height and channel width; near the culvert outlet (proximal section), the width was reduced to 4 m to tie into the narrow culvert width of 3.~~0~~9 m. Depth was increased to 0.75 m.

Bed material: Incipient diameter (cm) was determined : d90 = t = 1000 x depth x slope. Median material particle size (d 50) in the natural channel was found to be 23.

Roughness coefficient (n) was determined at 0.11 using the composite n approach[1].

[1] n=0.07+0.02+0.001+0.015+0

Velocities in the cross-sectional area were calculated as 1.98 m/s and 1.7 m/s for proximal and distal sections, respectively; discharge was 6 $m^3/s$ and 5.1 $m^3/s$ respectively. While this discharge is larger than the bankfull flow, it is less than the design flow of 7.5 $m^3/s$. To accommodate the design flow, an overbank flow area ( 0.4 m depth x 2 m wide) was designed along each bank top.

At 4 m (proximal section) and 6 m (distal section) channel width, the bankfull flow of 3 $m^3/s$ requires at least a depth of 0.5 and 0.4 m, respectively;

The boulder steps were designed with a 30 cm step height. Seven steps were designed at 3 m intervals to raise the channel bed by 2.2 m. The 3 m spacing between step crests will provide slow velocity resting space for migrating fish.

Flow capacity over top of the boulder steps was determined assuming that flow velocity would be at critical velocity. In the 6 m wide distal channel section, bank height above step crests must be > 0.3 m, in the proximal section with a channel width of 4 m, bank height above step crests must be > 0.4 m to accommodate the mean flow of 3 m3/s.

The channel plan form, cross-sections and longitudinal profile are presented in Appendix 2.

## 5.0 Construction

Direct and easy access exists for equipment (excavator / loader) and trucks to the site on both sides of the creek. There is no riparian vegetation in the clearing width.

Creek flows will have to be diverted during construction using a by-pass pipe.

Construction window should be determined with Ministry of Environment Officials; low stream flows in August and September are preferred times.

Summary of fill material estimates:

- granular fill: 80 $m^3$
- fine-texured fill: 120 $m^3$

### *5.1. Preparation of channel 'subgrade'*

Considerable fill is required to elevate the channel bed to the level of the baffles. Except for the gravelly channel bed, the fill must consist of impervious, compacted material to prevent partial or complete loss of surface flow to sub-surface flow. The current gravelly bed material should be removed from the channel bed and re-installed on the elevated bed.

The depth of the 'active' channel bed was estimated to be 0.4 - 0.7 m. (This number should be field-verified before construction starts.) The 'subgrade' channel elevation equals the designed elevation minus the depth of the gravelly channel bed.

Within 4 m downstream of the culvert, the erodible, impervious fill in the 'sub-grade' should be separated from the granular material in the gravelly channel bed using non-woven geotextile;

- Estimated volume required for sub-grade fill: 45 $m^3$
- Volume excavated for sub-grade construction: 10 $m^3$

Surficial material suitable for channel subgrade fill such as glacial till is available within several km along the Suskwa FSR; possible sources should be discussed with Forest Service Engineering staff. Working with fine-textured impervious fill material requires dry weather. Silt fencing must be available at the construction site to control sediment transfer from short term stock-pile sites near the stream banks.

### *5.2. Build-up of the Right Bank*

The right stream bank must be build-up according to cross-sections. Bank height should be surveyed during construction to ensure sufficient height, in particular over the step crests. Fill material may be gained from a nearby excavation site.

- Estimated volume of fill required: 60 $m^3$

### *5.3. Construction of Boulder Steps*

Boulder steps should be constructed using 85 to 100 cm diameter blocks and boulders for the step crests. The boulders should be buried 1/3 to 1/2 in the 'subgrade' material. Elevation of step crest relative to the embedded culvert invert should be surveyed during construction using a rod and a level to establish a continuous 11% grade. Bouldery and blocky material for the steps and some channel bed material must be hauled in. Possible sources of blast rock in the watershed should be discussed with Forest Service Engineering staff.

In cross-section, boulder steps must be v-shaped to concentrate flow in the centre of the stream; in plan view, boulder steps must be v-shaped with the v pointing downstream; along the longitudinal profile, boulder steps should be steeper on the upstream side and gentler on the downstream side.

Volume estimate for boulder step crests: 7 boulder steps @ 5 $m^3$ = 35 $m^3$;
Boulder size: $d_{50}$ = 0.7 m; $d_{90}$ = 1m

Granular fill required for channel bed: Preferably, the present channel bed material will be available to re-construct the channel bed. Rounded and sub-rounded particles are acceptable except for step crests; additional granular fill d = 23 may have to be trucked in for the overbank flow area.

- Estimate of additional granular fill ($d_{50}$ = 23 cm): 45 $m^3$

### *5.3. Riparian Re-vegetation*

Riparian planting with low shrubs (willow cuttings) is recommended along the distal channel section to improve fish habitat.

Areas with fine-textured material exposed must be grass-seeded (by hand) immediately after construction.

## 6.0. Cost Estimate

| | Professional fees | Technical fees | Contractor |
|---|---|---|---|
| Organization and scheduling, 1 day | $ 500 | | |
| Lay-out, 1 day | $ 500 | $200 | |
| Construction supervision (3 - 4 days) | $ 2000 | | |
| simultaneous survey | | $ 800 | |
| Mileage (750 km + 400 km), miscellaneous expenses ($70) | $400 | $150 | |
| Loader $90 hr: | | | |
| Excavate and load impervious material; (10 hrs) | | | $ 400 |
| Dump Truck: $80/hr | | | |
| Granular material/blast rock (25 hrs) | | | $2000 |
| impervious material (15 hrs) | | | $1200 |
| Excavator $160/hr | | | |
| Low-bedding: | | | $ 600 |
| Fill channel to subgrade level (3 hrs) | | | $ 320 |
| Place boulders to construct boulder riffles (10 hrs excavator) | | | $1600 |
| Build-up of right bank (4 hrs) | | | $640 |
| Revegetation, consultation with ecologist/biologist | $500 | | |
| Planning and organization | | $300 | |
| Planting, Seeding (1 day) | | $300 | |
| Mileage and miscellaneous | $75 | $75 | |
| | $3975 | $1825 | $6760 |
| **Total:** | | | **$ 12,560** |

### *6.1. Additional cost*

By-pass pipe
Non-woven geotextile (Armtec 200 or 300)
Grass seed, willow whips

## 7.0 References:

Chapman, A., D. Reksten, R. Nyhof. 1992. Guide to peak flow estimation for ungauged watersheds in the Skeena Region (Smithers). Hydrology Section, Water Management Division, BC Ministry of Environment, Lands and Parks.

Coulson, C.H. and Obedkoff, W. 1998. British Columbia streamflow inventory. Water Inventory Section, Resources Inventory Branch, BC Ministry of Environment, Lands and Parks.

Environment Canada, 1990. Water Survey of Canada

Ministry of Environment. 1997. Fish habitat rehabilitation procedures. Watershed Restoration Technical Circular No. 9. Watershed Restoration Program, B.C. Ministry of Environment. Lands and Parks and Ministry of Forests.

Ministry of Environment. 1998. Habitat Restoration Prescription Guidebook, Vancouver Island Region 1. Watershed Restoration Program, B.C. Ministry of Environment. Lands and Parks and Ministry of Forests.

Newbury, R. and Gaboury, M.N. 1994. Stream analysis and fish habitat design - a field manual. Newbury Hydraulics, Gibsons, BC.

Poulin, V. and H.W. Argent. 1997. Stream crossing guidebook for fish streams. (Forest Practices Code) Prepared for: BC Ministry of Forests and BC Ministry of Environment, Department of Fisheries and Oceans.

## Appendix 1: Flow Calculations

Table A1.1 Cross sectional area method

| | Cross-section 3 | Cross-section 2 | Cross-section 1 |
|---|---|---|---|
| Distance above culvert | 15 m | 25 m | 40 m |
| Survey date | 16/06/98 | 16/06/98 | 16/06/98 |
| $A_w$ | 1.25 m2 | 1.06 m2 | 0.816 m2 |
| $W_w \times D_w$ | 4.9m x 0.25m | 4.6m x 0.23m | 4.8 x 0.17m |
| $V_w$ | (0.82 m/s) | 0.82 m/s | (0.82 m/s) |
| $Q_w$ | (1.025) | 0.87 m3/s | (0.67 m3/s) |
| Slope | 10.5 % | 11.5 % | N/D |
| Manning's $n_w$[2] | | 0.137 | |
| d50 | | 0.23 m | |
| $W_2 \times D_2$ | 5.5 m x 0.45m | 5.2 m x 0.51m | 5.4 m x 0.45m |
| $A_2$ | 2.48 m2 | 2.65 m2 | 2.43 m2 |
| $n_2$[3] | | 0.093 | |
| $V_2$ | | 1.92 m/s | |
| $Q_2$ | 4.76 m3/s | 5.09 | 4.67 |
| $Q_2$ (mean) | | 4.8 $m^3/s$ | |
| $Q_{100}$ ($3 \times Q_2$) | | 14.4 $m^3/s$ | |

Table A1.2 Basin comparison approach

| | Station Creek above Diversion WSC 08EE028 | 34 KM Creek |
|---|---|---|
| Years of flow records (maximum daily discharge) | 1985 to 1995 | none |
| $Q_{d2}$ ($m^3/s$) (2 year return discharge) | 2.05 | 9.4 * 0.189 = 1.78 |
| $Q_{d2}$ unit discharge ($m^3/s/km^2$) | 0.189 | |
| $Q_{i2}$ (estim. $=1.7 \times Q_{d2}$) $m^3/s$ extrapolated for instantaneous Q[4] | | **3.00 $m^3/s$** |
| Q 50 =2.5 x Qi2 | | **7.5 m3/s** |
| Q100 = 3 x Qi2 | | 9 m3/s |

Table A1.3 "Critical Flow Formula" Approach[5]

| | |
|---|---|
| Bankfull discharge | $Q_{bf} = 2.5\,(A^3\,W_{bf}^{-1})^{.5} = 2.5\,(2.52^3\,5.36^{-1})^{.5} = 4.3\ m^3/s$ |
| 100 year flood | $Q_{100}$ = 12.9 m3/s |

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[2] Calculated from Manning's formula

[3] Determined from composite n-approach (Stream Crossing Guidebook, 1997)

[4] Chapman et al. 1992; Appendix 5

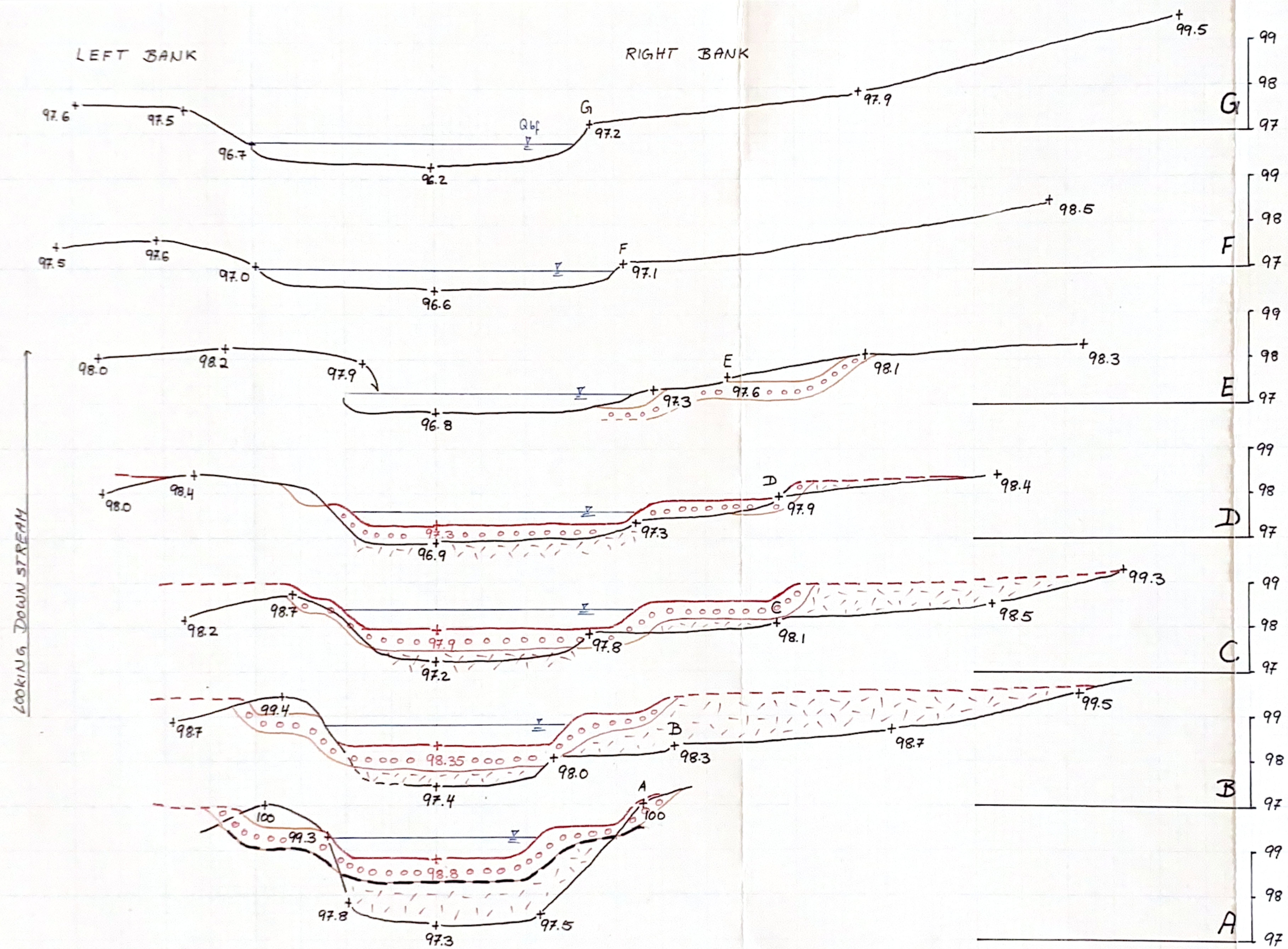
[5] Presented by Dennis Russell, Professor emeritus, UBC, During FCSN course, spring 1998

## Appendix 2: Channel Design Drawings

***Figure A2-1: Site Plan***

***Figure A2-2: Longitudinal Profile***

***Figure A2-3: Cross-sections***




**KM 34 SUSKWA FSR**
**STREAM RESTORATION**
**CULVERT OUTLET**
CROSS SECTIONS

MARCH, 1999

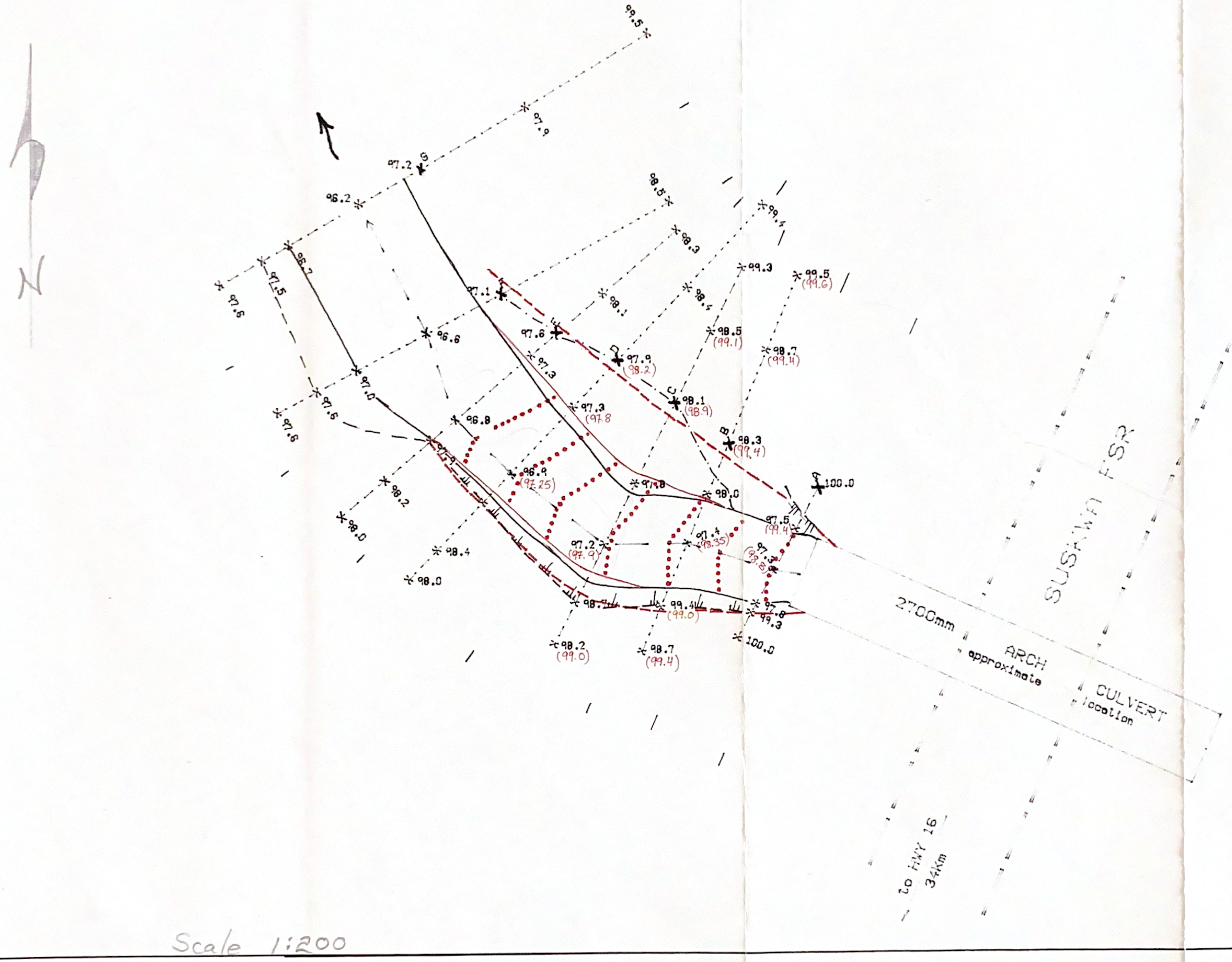
**LEGEND:**

| | |
|---|---|
| SURVEYED CROSS SECTION | |
| DESIGNED CROSS SECTION | |
| IMPERVIOUS FILL | |
| GRANULAR FILL | |
| GEO FABRIC | |
| VERTICAL SCALE: | 1:100 |
| HORIZONTAL SCALE | 1:100 |

| | |
|---|---|
| DATE OF SURVEY: | 01/12/98 |
| SURVEYED BY: | Ted Turner, Irene Weiland |
| DESIGNED BY: | Irene Weiland, P Geo Smithers, BC |

PREPARED FOR:

WATERSHED RESTORATION PROGRAM
KISPIOX FOREST DISTRICT
HAZELTON, BC




Scale 1:200

**KM 34 SUSKWA FSR**
**STREAM RESTORATION**
**CULVERT OUTLET**

PLAN VIEW

MARCH, 1999

**LEGEND:**

BASELINE STATIONS

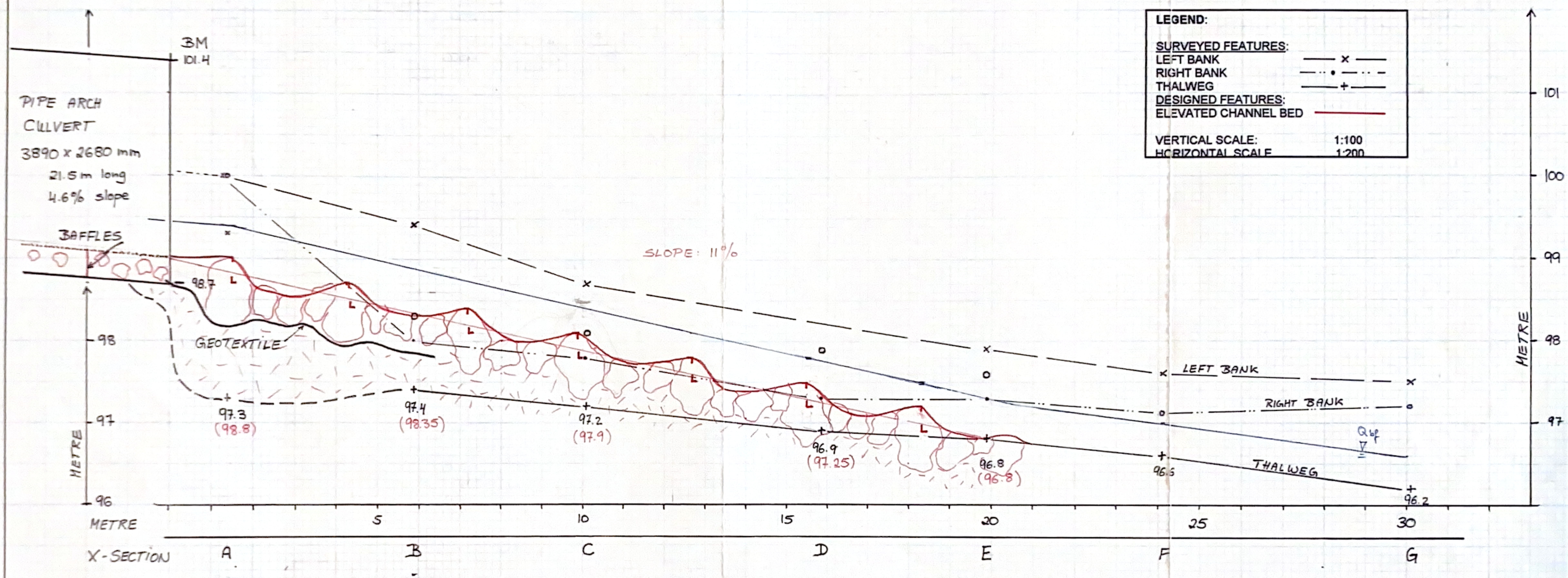
SURVEYED FEATURES:
EDGE OF WATER
TOP OF BANK
FAILING BANK
GRAVEL BAR

DESIGNED FEATURES:
EDGE OF WATER
EDGE OF OVERBANK CHANNEL
CREST OF BOULDER STEPS

| | |
|---|---|
| SCALE: | 1:200 |
| DATE OF SURVEY: | 01/12/98 |
| SURVEYED BY: | Ted Turner, Irene Weiland |
| DESIGN BY: | Irene Weiland, P.Geo<br>Smithers, BC |

PREPARED FOR:

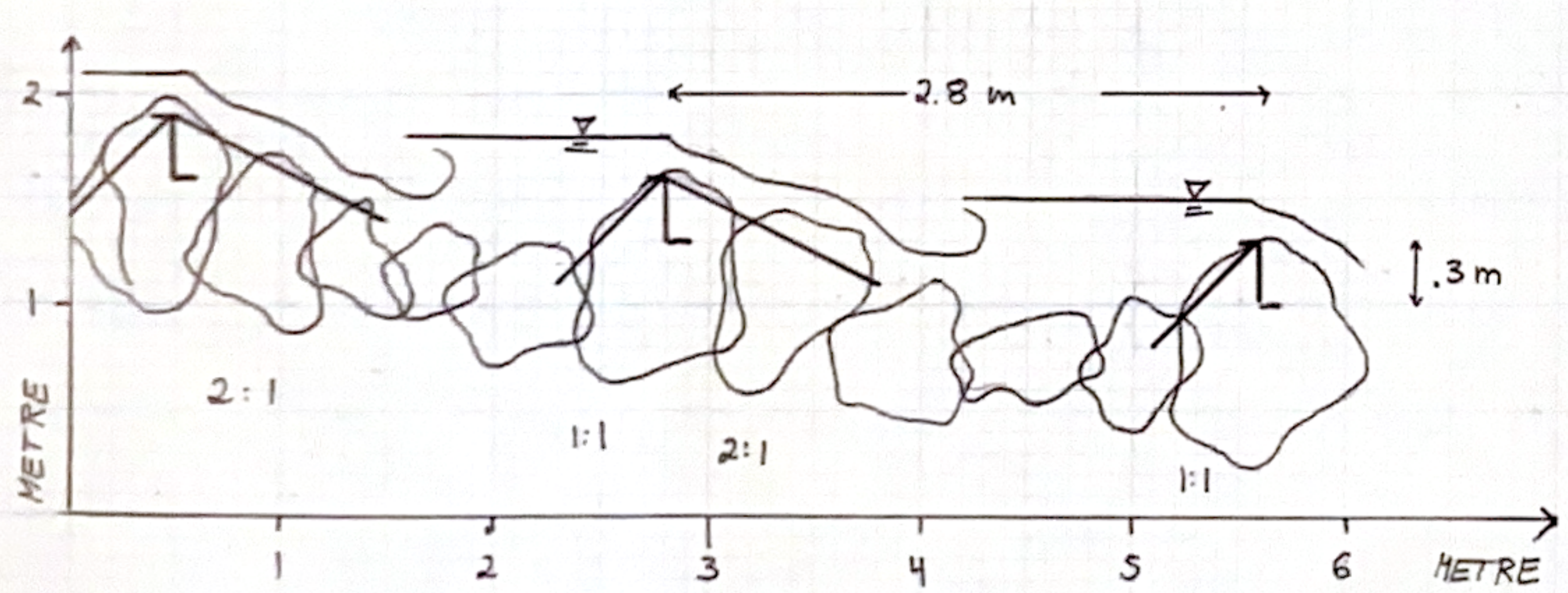
WATERSHED RESTORATION PROGRAM
KISPIOX FOREST DISTRICT
HAZELTON, BC




**LEGEND:**

SURVEYED FEATURES:
LEFT BANK
RIGHT BANK
THALWEG
DESIGNED FEATURES:
ELEVATED CHANNEL BED

VERTICAL SCALE: 1:100
HORIZONTAL SCALE 1:200




**BOULDER STEP**
DESIGN DETAIL

VERTICAL SCALE: 1:100; HORIZONTAL SCALE 1:100

| | |
|---|---|
| DATE OF SURVEY: | 01/12/98 |
| SURVEYED BY: | Ted Turner, Irene Weiland |
| DESIGNED BY: | Irene Weiland, P.Geo Smithers, BC |

PREPARED FOR:
WATERSHED RESTORATION PROGRAM
KISPIOX FOREST DISTRICT
HAZELTON, BC

**KM 34 SUSKWA FSR**
**STREAM RESTORATION**
**CULVERT OUTLET**
LONGITUDINAL PROFILE

MARCH, 1999

Photo 1: Culvert outlet; looking upstream; 17/05/98

Photo 2: Transition from scoured high channel bank to lower undisturbed pre-construction; looking downstream; 16/06/98