IN-STREAM HABITAT COMPLEXING
1988-1990
- PILOT TESTING -

NECHAKO FISHERIES CONSERVATION PROGRAM
Technical Report No. RM90-3

Prepared by:
Triton Environmental Consultants Ltd.

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EXECUTIVE SUMMARY

This report documents the progress of work and physical performance of instream habitat complexes in the Nechako River from the inception of the project in 1988 to the fall of 1990. Habitat complexes were installed in the Nechako River based on recommendations to increase the complexity of juvenile chinook habitat prior to the implementation of the Long-Term Flow Regime, following development of the Kemano Completion Project. The objectives of the pilot habitat complexing project were to determine the hydraulic performance, durability and cost effectiveness of a variety of potential habitat complexes through a series of small scale pilot tests.

The majority of habitat complexes identified for pilot testing in Nechako River were generally of 2 types, structures or instream modifications. Structures consisted of debris bundles and debris catchers, while instream modifications consisted of a side channel developed on the right side of the mainstem Nechako River and 3 point bars constructed on the Nechako River shoreline.

Design criteria utilized in site selection and construction of habitat complex complexes were based on a review of pertinent literature and an assessment of chinook life history data from Nechako River. Selection of habitat complex structure designs was based on Nechako River physical characteristics and natural habitats.

During 1988, the first year of the habitat complex pilot testing, 10 habitat complexes were installed in the mainstem Nechako River. Additionally, a side channel was developed, which included additional complexes and a debris boom installed within the downstream portion of a 735 m side channel excavated on the right margin of the Nechako River. On the mainstem Nechako, debris bundle complexes constructed included 4 rootwad sweepers, 2 floating cribs, and a brush pile. Debris catchers comprised of 3 sets of channel jacks. In 1988, the total cost for the construction of complexes was $58,260. No monitoring of these complexes was done in 1988 as all complexes were installed during the fall.

During 1989, 13 additional habitat complexes were installed in the mainstem Nechako River. Modifications were made to existing and newly constructed complexes based on recommendations from physical monitoring assessments conducted during the spring and fall. New structures included the addition of 1 rootwad sweeper, 7 pseudo beaver lodges, 2 pipe-pile debris catchers, and 3 point bars. Modifications were made to 2 rootwad sweepers, 1 floating crib and all pseudo beaver lodges, channel jacks, and side channel complexes. In 1989, the total cost for the construction of complexes was $26,870.

In 1990, 14 additional habitat complexes were installed in the mainstem Nechako River. Modifications were made to existing and newly constructed complexes based on recommendations from physical monitoring assessments conducted during the spring, summer and fall. New structures included the construction of 7 deep water sweepers and 7 rail debris catchers. All side channel complexes were removed and replaced with smaller complexes and the debris boom was relocated upstream of the side channel to reduce entry of floating debris. Other modifications were made to 1 rootwad sweeper, 3 pseudo beaver lodges, 4 deep water sweepers and 2 rail debris catchers. Four rootwad sweepers, 3 pseudo beaver lodges, 1 deep water sweeper, and 2 channel jacks were removed due to inadequate velocities or design. In 1990, the total cost for the construction of new complexes and side channel remediation was $18,660.

Evaluation of the structural performance of some complexes is in an early stage. Of the debris bundle type habitat complexes installed in 1988 (which included rootwad sweepers, brush piles and floating cribs), rootwad sweepers were oversized. Debris bundles installed in 1989 (which included original and modified pseudo beaver lodges) and in 1990 (deep water sweepers) were subject to stability problems during high flows due to inadequate anchoring. The velocities measured at the debris bundles were generally within the lower portion of the design criteria range or below the design criteria range, either due to oversizing of the complex or placement of the complex in a low velocity area. Recommendations for future installations would be to reduce cover size to approximately 15 m^2, locate the complexes in areas of sufficient velocity to meet criteria, and provide an anchoring system that retains debris yet is flexible enough to adapt to flow fluctuations.

Debris catcher type habitat complexes installed in 1988 (which included original and modified channel jacks) experienced stability problems and lost the majority of their debris. As a result, sufficient cover was lacking, and velocity distributions were within the upper portion of the design criteria range or above the design criteria range. Pipe-pile and rail debris catchers, installed in 1989 and 1990 respectively, were stable and trapped a significant amount of debris. Due to the large amounts of accumulated debris, velocity distributions at the pipe-pile debris catcher sites were within the lower portion of the design criteria range or below the design criteria range. Velocity distributions at the rail debris catcher sites were below, above, or within the design criteria range, depending on their location and the amount of debris caught. Reducing the size of the rail debris catchers resulted in improved velocities, as debris entrapment was reduced.

The full spanning habitat complexes installed in the side channel in 1988, and thinned in 1989, became clogged with small organic debris which acted as a barrier to water flow through the channel. The debris boom, which was installed within the downstream portion of the channel to prevent the loss of seeded debris, also contributed to the lowering of velocities in the side channel. Velocities through the side channel were eventually reduced to below design criteria. In 1990, in an effort to prevent flow blockage due to excessive accumulation of material within the side channel, the debris boom was moved upstream of the side channel entrance to divert floating debris. The full spanning habitat complexes were removed and replaced with smaller complexes more proportional to the size of the side channel, resulting in improved water velocities.

The 3 point bars installed in 1989 experienced some erosion during high flows. The point bars were also found to be oversized as a large area of still water was created downstream of the complexes rather than creating a back-eddy as expected.

With the exclusion of the 1988 channel jack designs, the habitat complexes did not suffer any significant structural damage and/or stability problems over the 1988 and 1989 winter seasons. However, the seasonal conditions observed were relatively mild in comparison to previous years and icing events experienced by most of the complexes were transient and of short duration, since the habitat complex complexes are located upstream of the leading edge of ice cover.

To date, the Nechako Fisheries Conservation Program (NFCP) pilot habitat complexing project has constructed and tested 10 different complex designs in the mainstem Nechako. These designs are categorized below as either “structures” - comprising debris bundles or debris catchers, or “instream modifications”.

Structures

<u>*Debris Bundles*</u>

1. Rootwad Sweepers
2. Brush Pile
3. Floating Cribs
4. Pseudo Beaver Lodges
5. Deep Water Sweepers

<u>*Debris Catchers*</u>

1. Channel Jacks
2. Pipe-Pile Debris Catchers
3. Rail Debris Catchers

Instream Modifications

1. Excavation of a side channel, complexed with debris bundles and a debris boom.
2. Construction of point bars with back eddy pools on the Nechako River shoreline.

All of the debris bundles have good potential with limited modifications required to their designs and placement locations in the future. The pipe-pile and rail debris catcher designs were also successful. The range in unit cost of all habitat complexes identified as successful and / or promising is $470 to $3,300. The least expensive promising design was that of the deep water sweeper, while the most expensive was the rootwad sweeper. Successful debris catcher costs per unit varied from $1,525 for the pipe-pile debris catchers to $1,610 for the rail debris catchers. Modifications that have been recommended to improve the performance of promising complexes could result in increased costs per unit for future installations. Maintenance costs of complexes require several years of data. Therefore, these costs were not presented in this report but may be developed as long term durability is assessed.

The NFCP pilot habitat complexing project has identified several parameters which are important for success in habitat complexing, namely, the provision of required velocities, substrate, appropriate structure sizing, and adequate complex anchoring. The project has also distinguished several successful habitat complex designs from those that were constructed and replicate tested.

INTRODUCTION

The Nechako Fisheries Conservation Program (NFCP) was established as a result of an agreement signed in 1987 by Alcan Aluminium Ltd., the Government of Canada, and the Province of British Columbia (Anon. 1987a). The goal of the NFCP is to ensure conservation of Nechako River chinook salmon population and protection of migrating sockeye salmon populations. An integral component of the program is the testing and implementation of remedial measures including modification of instream habitat and construction of habitat complexes.

This report documents the progress of work on the habitat complexing project from the inception of the project in 1988 to the fall of 1990. The focus of this report is on the physical performance of the habitat complexes. Evaluation of the biological performance of habitat complexes was conducted under separate projects (Triton 1996a, 1996b, and 1996c).

RATIONALE

In August 1987, a working group of technical experts from the Department of Fisheries and Oceans (DFO), Alcan, and the Province of British Columbia was established to assess how to ensure the conservation and protection of the fisheries resource in the Nechako River. The working group recognized that changes in Nechako River flows following development of the Kemano Completion Project, would influence the amount of debris cover habitat available to juvenile chinook that utilize the river. This fact prompted a recommendation to increase the complexity of juvenile chinook habitat in Nechako River prior to implementing the Long-Term Flow Regime (Anon. 1987a). A preliminary assessment of the types of habitat utilized by Nechako River chinook was conducted via snorkelling surveys in early 1988 by NFCP Technical Committee members. Observations from these surveys were used in conjunction with the experience of NFCP Technical Committee members to identify suitable habitat complexing designs for pilot testing. The NFCP pilot habitat complexing project was initiated in 1988 to test these habitat complexing techniques and to assess their utilization by Nechako River chinook.

Subsequent to 1988 pilot testing, information on suitable designs was supplemented by a literature review of instream habitat complexing projects (Appendix A). Results of the literature reviewed indicated that although habitat complexing had been widely used to create fish habitat, most techniques had only been applied to small streams supporting fish species other than chinook. In addition, quantitative assessment of the effectiveness of these techniques was limited. A supplemental menu of potential remedial measures was prepared, and selected techniques appropriate to Nechako River were pilot tested in 1989 and 1990.

OBJECTIVES

The objectives of the pilot habitat complexing project were two-fold. First, to determine the hydraulic performance and durability of a variety of potential habitat complexes through a series of small scale pilot tests. Second, to identify cost effective methods of achieving the habitat complexing goal set out in the Nechako Rvier Working Group Report.

SCOPE

The scope of the NFCP pilot habitat complexing project included the following:

1. Construction of a limited number of habitat complexes that have been demonstrated to work on other river systems for other species of salmon;

2. Construction of a limited number of habitat complexes that could duplicate naturally occurring habitat complexes on the Nechako River;

3. Installation of these habitat complexes at accessible sites downstream of known spawning grounds; and

4. Monitoring of habitat complexes under varying flow and meteorological conditions to determine hydraulic performance and durability.

TYPES OF HABITAT COMPLEXES

Selection of habitat complexing structure designs was based on a review of similar work on other river systems, on Nechako River conditions and on local availability of materials. Woody debris was identified as the preferred cover habitat (Triton 1996b and Lister 1994). Habitat complexes identified for pilot testing in Nechako River were of 2 types, structures and instream modifications. Structures consist of debris bundles and debris catchers placed along the river to provide additional cover habitat for rearing chinook juveniles. Debris bundles consist of trees or root masses cabled to anchors on the river bank. Debris catchers are complexes placed at various locations along the stream margin to intercept and hold any large woody debris (LWD) floating downstream. These complexes trap the river's natural supply of debris to provide fish habitat. Both types of structures provide cover habitat for rearing chinook.

Instream modifications involve the excavation or placement of river bed materials to replicate existing natural morphological features found on the Nechako River. Two types of instream modifications were pilot tested from 1988 to 1990: (i) the excavation of a side channel on the right side of the mainstem Nechako River accompanied by the placement of instream debris bundles; (ii) and the construction of point bars with back-eddy pools on the Nechako River shoreline.

SITE SELECTION AND DESIGN CRITERIA

Design criteria utilized in site selection and construction of habitat complex complexes were based on a review of pertinent literature (Everest and Chapman 1972, Lister and Genoe 1970) and an assessment of chinook life history data from Nechako River (Envirocon 1984a and Russell et al. 1983). Habitat complex designs were based on Nechako River physical characteristics and natural habitats.

Selection of specific sites in the mainstream Nechako River was based on criteria developed by the Department of Fisheries and Oceans (Anon. 1987b) and Envirocon (1984b). The following criteria have been used in the site selection and design of all habitat complexes installed in the mainstem Nechako River since 1988:

Parameter	Criteria Range	Preferred
Velocity (m/s)	0.15 - 0.4	0.3
Depth (m)	not less than 0.4	0.75 - 1.0
Substrate	gravel to cobble	gravel to cobble
Extension (m)	site-specific	5.0

These complexes were intended to operate at the Short-Term Flow Regime (Anon. 1987a) spring and summer rearing flows of 56.6 m^3/s (2,000 cfs). Based on an evaluation of the above criteria, specific sites within Reaches 1 and 2 of the river were selected for the installation of complexes.

Habitat complexes installed in the mainstem Nechako River from 1988 through 1990 were designed to operate at the Short-Term Flow Regime (Anon. 1987a) spring and summer rearing flows of 56.6 m^3/s (2,000 cfs), and fall and winter flows of 31.1 m^3/s (1,100 cfs).

All mainstem habitat complexes were assessed for the design criteria as follows. Velocity and depth were measured upstream and downstream of the complex. The substrate was classified by examining the river bed materials located beneath and along the perimeter of the complex. Data on the following parameters was also collected during physical assessments: cover area, and level of debris entrapment and / or retention.

Design criteria utilized in construction of the side channel in the spring of 1988 were developed by DFO (Anon. 1987b) and Envirocon Ltd. (1984b). The criteria used for the construction of the side channel were developed so that depth and velocity at each complex in the side channel would be similar to the preferred depth and velocity criteria of complexes in the mainstem Nechako River. The following parameters were assigned the indicated values for approximate Nechako River high and low flows of 56.6 m^3/s (2,000 cfs) and 31.1 m^3/s (1,100 cfs), respectively.

Parameter	*Criteria Range*
Maximum Depth (m)	0.6
Average Cross-Sectional Velocity (m / s)	approx. 0.5
Side Channel Flow Range (m^3/s)	1 - 2
Nechako River Flow Range (m^3/s)	31.1 - 56.6

Side channel bank slopes were graded such that the right bank approximated the existing stable slope of 1.5H:1V and the left bank provided shallow habitat for newly emergent fry through a lower slope of 3.5H:1V.

It was expected that installation of a given habitat complex would modify velocities at the site, but that the velocities throughout the complex would remain within the criteria range. Therefore, the criteria ranges apply to both the site selection and the design of the habitat complexes.

Durability of habitat complexes reflects the link between project cost-effectiveness and complex life span. Thus, complexes were fabricated from economical and weather resistant materials suitable for the application.

1988 PROJECT IMPLEMENTATION

In the 1988 fiscal year, habitat complexing preliminary design criteria were provided by the NFCP Technical Committee. Detailed design was provided by the engineering consulting firm Kerr Wood Leidal Associates Ltd. Development of the side channel design was performed by Envirocon Ltd. Habitat complexes were constructed by Nechako Excavating Ltd. and the Carrier Sekani Tribal Council. The side channel development was constructed by Nechako Excavating Ltd. Kerr Wood Leidal Associates Ltd. supervised construction of the habitat complexes while Hay and Company Consultants Inc. supervised the construction of the side channel. Construction of habitat complexes was scheduled in accordance with DFO and Ministry of Environment (MOE) works-in-streams guidelines whenever possible. Construction implemented outside the defined MOE works-in-streams window of mid-July through August was coordinated with DFO and MOE, and was timed to reflect seasonal sensitivities in river ecology. As all 1988 complexes were installed during the fall, no monitoring of the engineering performance of habitat complexes was undertaken during the 1988 fiscal year. A summary of construction activities for the 1988 fiscal year is presented in Table 1. Details are located in Table B1 (Appendix B). Assessment results are presented in Appendix C. Sketches and photos of the habitat complexes are presented in Appendices D and E, respectively.

1988 Habitat Complex Construction Sites

Sites for constuction of habitat complexes were selected on the basis of design criteria, accessibility and sufficient chinook recruitment to assess usage. In 1988, 10 mainstem Nechako River locations were selected in Reach 2 for habitat complexes. An additional location in Reach 2 was designated for side channel development and subsequent habitat complexing on the right bank of the Nechako River between kilometres 17.9 and 18.6. A map of the 1988 NFCP habitat complexing project study area in 1988, including complex locations, is presented in Figure 1.

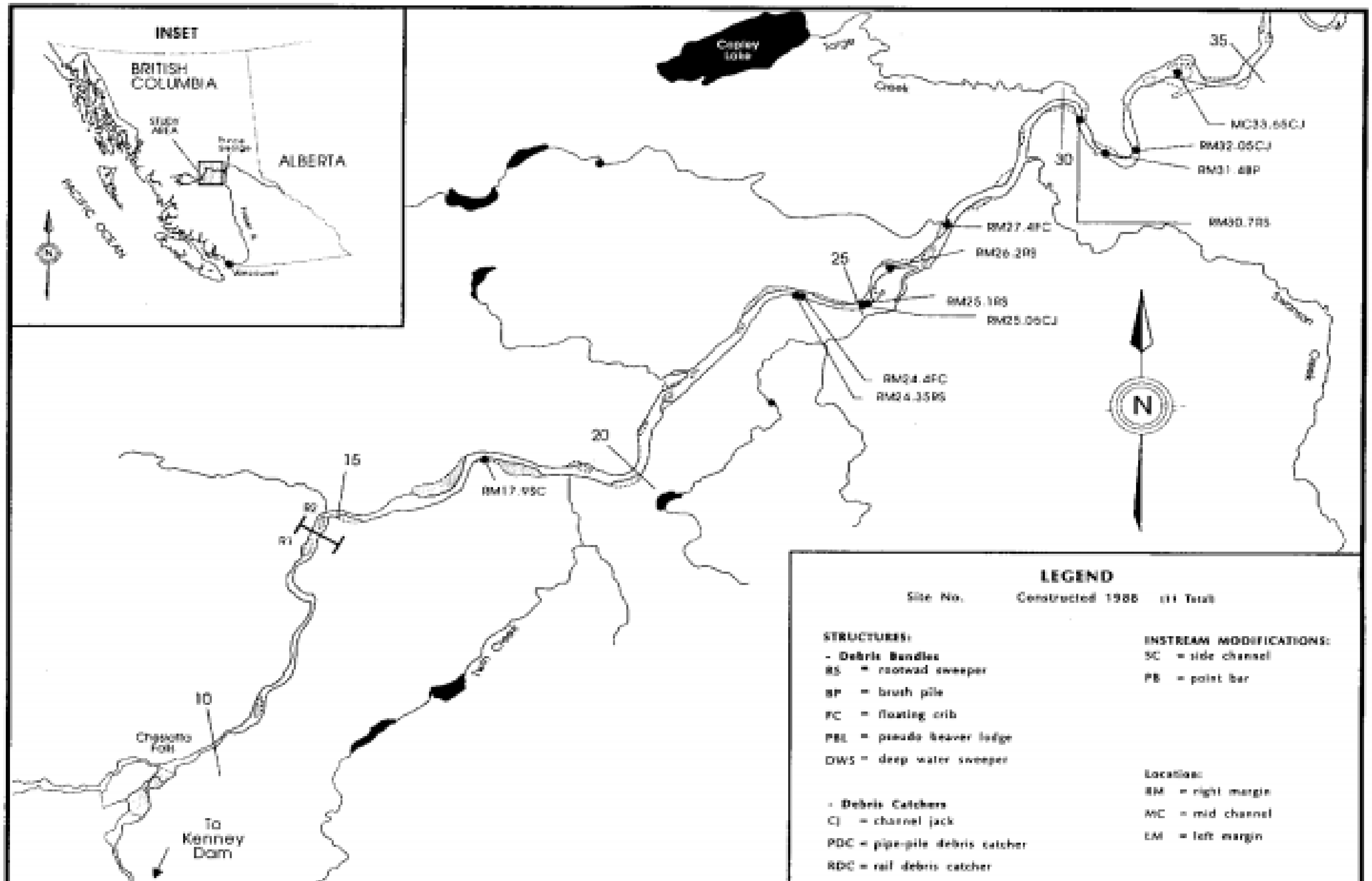
1988 Construction of Habitat Complexes

During the 1988 construction period, 11 complexes were constructed (Table 1 and Table B1 (Appendix B)). Descriptions of the various designs utilized in the NFCP pilot habitat complexing project in 1988 follow.

Table 1
Summary of Habitat Complexing Construction Activities in 1988

Type of Habitat Complex	Abbrev.	Quantity Constructed 1988	Quantity Modified 1988	Quantity Removed 1988	Quantity Remaining 1988
STRUCTURES					
Debris Bundles					
Rootwad Sweepers	RS	4	-	-	4
Brush Pile	BP	1	-	-	1
Floating Cribs	FC	2	-	-	2
Debris Catchers					
Channel Jacks	CJ	3	-	-	3
IN-STREAM MODIFICATIONS					
Side Channel *	SC	1	-	-	1
Totals		11	-	-	11

* 8 brush piles, 12 rootwad sweepers and a debris boom were installed in the side channel. These complexes are not included in the total number of debris bundles or debris catchers installed in the Nechako River as the side channel was assessed as a unique complex.



Nechako Fisheries Conservation Program | Map # RM903FG1

0 5 km

FIGURE 1. NECHAKO RIVER MAINSTEM STUDY AREA 1988

Structures

Debris Bundles

Debris bundle complexes installed in the mainstem Nechako River during fall 1988 consisted of: 4 rootwad sweepers; 1 brush pile; and 2 floating cribs. Rootwad sweepers are cabled bundles of trees, complete with branches, placed such that tree root masses extend approximately 10 m into the watercourse at water depths from 0.4 m to 1.0 m. These complexes spanned approximately 15 - 20 m along the Nechako River shoreline. Brush piles are bundles of tree tops and tree root masses placed along the river margin and cabled to a buried stiff-leg. These complexes extended approximately 10 m into the watercourse. Floating cribs are timber cribs approximately 5 m wide by 12 m long and are seeded with LWD. The crib is secured to shore using 2 stiff-legs cabled to anchors on the bank.

Debris Catchers

Debris catcher designs constructed during the fall of 1988 included 3 sets of 3 to 5 channel jacks placed in the mainstem Nechako River. Each channel jack consisted of a cabled tripod constructed from used steel I-beams. The complexes are placed in the waterway, cabled together in groups to enhance debris entrapment, and are secured to the bank for increased stability under high flow or ice conditions.

In-stream Modifications

Side Channel

A side channel approximately 735 m long was excavated along the right bank of the Nechako River during the spring of 1988 between kilometres 17.9 and 18.6. At the time of construction, depths varied between 0.5 - 1.0 m and the width tapered from 14 m at the upstream end to 6 m at the downstream end.

A total of 8 brush piles and 12 rootwad sweepers were installed in the side channel at 4 test sections during the fall of 1988. Each test section of complexes consisted of brush piles and rootwad sweepers cabled together in bundles of 5. The overall length of each test section was approximately 50 m and these were spaced from 50 to 250 m apart along the length of the side channel.

Additionally, 1 debris boom was placed within the downstream portion of the side channel to trap floating debris within the channel and to prevent the loss of seeded material. The debris boom was constructed using strings of single or paired logs approximately 3 m long cabled end-to-end and anchored into place on the banks of the side channel.

The debris bundle complexes installed in the side channel are not included in the total number of complexes installed in the Nechako River due to the differing design criteria. As a result of lower flows, hydraulic conditions in the side channel were different than at mainstem locations. Additionally, side channel complexes were originally constructed to be full-spanning complexes rather than marginally orientated as in the mainstem designs. Therefore, the side channel, including the 4 test sections of habitat complexes and the debris boom, was assessed as a separate complex.

1988 Methods of Construction

The equipment and methods employed in the construction phases of the NFCP habitat complexing project are documented below. Photos of selected construction operations are presented in Appendix F.

The major piece of equipment used throughout construction operations in 1988 was a UH07 Hitachi backhoe. This type of machinery was used for excavations, placements of habitat complexes and/or materials and the securing of cable. A Cat 966 front end loader was used in the summer of 1988 to move material excavated by backhoe to its final disposal site parallel to the alignment of the side channel.

Excavations were required in the construction of the side channel in 1988 and "deadman" anchor pits. In 1988, a helicopter was required for a particularly difficult channel jack placement.

Fabrication of habitat complexes was completed manually using chain saws, power drills and oxyacetylene cutting torches. Locally available materials used in construction of complexes included river bed cobble, and timber such as pine and spruce. Materials transported to the sites included piping or used rail, chain and cabling. Cables were secured to anchors and/or LWD using large staples.

1988 Construction Costs

In 1988, a total cost of $58,260 was incurred in the construction of habitat complexes and development of the side channel. Table 2 contains a breakdown of the

Table 2
Summary of Habitat Complexing Construction Costs in 1988

Type of Habitat Structure	Quantity Constructed (Units)	Construction Cost ($/Unit)	Total Construction Cost	Comments
Rootwad Sweeper	4	$3,300	$13,200	
Brush Pile	1	$3,300	$3,300	
Floating Crib	2	$2,700	$5,400	
Channel Jacks	3 sets	$3,400/set	$10,200	Installations by backhoe or helicopter. Average cost presented.
Side Channel Construction	735 m	$16/m	$11,760	Excavation and grading (spring).
Side Channel Complexing	200 m	$66/m	$13,200	Installation of brush piles and rootwad sweepers (fall).
Side Channel Debris Boom	1	$1,200	$1,200	
Total Construction Cost - 1988			$58,260	

construction costs associated with each type of habitat complexing structure for 1988. Costs presented include all charges associated with materials, equipment, and labour used in the construction of habitat complex complexes and site access routes. The cost of each complex was variable due to differences in design and other factors such as siting, access, and availability of local materials. Therefore, only the average unit cost is presented in arriving at a total construction cost.

1988 Summary

In summary, during the first year of the habitat complex pilot testing, 10 complexes were installed in the mainstem Nechako River. Additionally, a side channel was developed, which consisted of additional complexes and a debris boom installed within a side channel excavated on the right margin of the Nechako River. On the mainstem Nechako, debris bundle complexes constructed included 4 rootwad sweepers, 2 floating cribs, and a brush pile. Debris catchers included 3 sets of channel jacks. In 1988, the total cost for the construction of complexes was $58,260. No monitoring of these complexes was done in 1988 as all complexes were installed during the fall.

1989 PROJECT IMPLEMENTATION

The 1989 habitat complexing project implementation was as follows. In spring 1989, a thorough physical assessment was performed of all exixting habitat complexes. Construction of new habitat complexes and modification to previously built complexes took place in the spring following the spring assessment. In fall 1989, a thorough physical assessment of all habitat complexes remaining in the Nechako River was performed. Details of the 1989 project implementation are presented below.

In 1989, physical assessment of the engineering performance of all habitat complexes remaining in the Nechako River was undertaken by Triton Environmental Consultants Ltd. in the spring and fall. Field investigations consisted of an inspection of each complex and photographic and video documentation of condition. Physical assessments of habitat complexes were conducted from shore, by boat and by helicopter.

The following features were noted during the inspections at each habitat comples as applicable: local substrate, water velocities, water depths, physical condition and stability of the structure, and level of debris entrapment and/or retention. Substrate composition and hydraulic characteristics of the structure under observed flows were documented as an index of siting and design criteria fulfilment. Physical condition and stability were noted with reference to durability and position in the river. For each complex, a Swoffer (model 2000) flow meter was used to measure water velocity at the locations defined above. Water depths at these locations were determined using the flow meter rod. Principal cover area dimensions of the complexes were measured with a survey tape. Cover areas were then calculated for each complex. Hydraulic characteristics of the complex under observed flows were documented to determine design criteria fulfilment. The amount of debris entrapment and/or retention was recorded to document the function of the habitat complex under prevailing Nechako River conditions. Substrate composition was documented as an index of siting.

In 1989, monitoring of habitat complex structure performance occurred in the spring and fall. The spring assessment included a general evaluation of habitat complexes to identify any structural damage and/or stability problems incurred over the winter period, as well as observations of local substrate, water velocities, water depths and cover area. The fall assessment involved an investigation of structural damage and stability following the summer cooling flows (recorded mean daily flows in Nechako River below Cheslatta Falls ranged from 170 to 277 m^3/s [6,000 to 9,780 cfs]), as well as an evaluation of design criteria fulfilment. Recommendations were made on structure modifications and/or removal where applicable.

Modifications or removal of existing complexes and construction of new complexes were generally based on recommendations from previous physical assessments. Detailed structure design and construction supervision was provided by the engineering consulting firm Hay and Company Consultants Inc. Construction was carried out by Nechako Excavating Ltd. and Wayne Terris Contracting. Construction of in-stream habitat complex complexes in 1989 was scheduled in accordance with DFO and MOE works in streams guidelines whenever possible. Construction implemented outside the defined MOE works-instreams window of mid-July through August was coordinated with DFO and MOE, and was timed to reflect seasonal sensitivities in river ecology. A summary of construction activities is presented in Table 3. Details are located in Table B1 (Appendix B). Results of the 1989 spring and fall assessments are presented in Tables C1 and C2 (Appendix C). Sketches and photos of the habitat complexes constructed in 1989 are presented in Appendices D and E, respectively.

Spring 1989 Physical Assessment

The spring 1989 assessment observations indicated that the rootwad sweepers, brush piles and floating cribs installed in 1988 had sustained minimal disruption during the winter conditions, and that all of these complexes were sound. Habitat complexes installed in the side channel were also observed to be sound.

However, all channel jack complexes had sustained damage by the winter ice, with several of the channel jack tripods being toppled. Minimal debris had therefore been trapped by these complexes. Velocity distributions at channel jack installations were within the upper portion or above the design criteria range.

Recommendations from the spring 1989 assessment were to modify the channel jack design to obtain better long term performance, and leave all remaining complexes in their present form.

Table 3
Summary of Habitat Complexing Construction Activities in 1989

Type of Habitat Complex	Abbrev.	Quantity Remaining 1988	Quantity Constructed 1989	Quantity Modified 1989	Quantity Removed 1989	Quantity Remaining 1989
STRUCTURES						
Debris Bundles						
Rootwad Sweepers	RS	4	1*	2*	-	5
Brush Pile	BP	1	-	-	-	1
Floating Cribs	FC	2	-	1	-	2
Pseudo Beaver Lodges	PBL	-	7	7	-	7
Debris Catchers						
Channel Jacks	CJ	3	-	3	-	3
Pipe-Pile Debris Catchers	PDC	-	2	-	-	2
IN-STREAM MODIFICATIONS						
Side Channel	SC	1	-	1	-	1
Point Bars	PB	-	3	-	-	3
Totals		11	13	14	0	24

* Two structures were modified; one structure was thinned, the other was divided into two smaller structures. This resulted in the addition of one structure in 1989.

1989 Habitat Complex Construction Sites

Sites for in-stream habitat complexing were selected on the basis of design criteria, accessibility and sufficient chinook recruitment to assess usage. In 1989, an additional 13 locations were selected in Reach 2 for the construction of habitat complexes, for a total of 24 locations of complexes on the Nechako River including the side channel development. A summary of all in-stream habitat complexing sites developed in 1989, information on site locations (distances in kilometres downstream from Kenney Dam), and types of habitat complexes are presented in Table B1 (Appendix B). A map of the 1989 NFCP habitat complexing project study area, including complex locations, is presented in Figure 2.

Spring 1989 Construction of Habitat Complexes

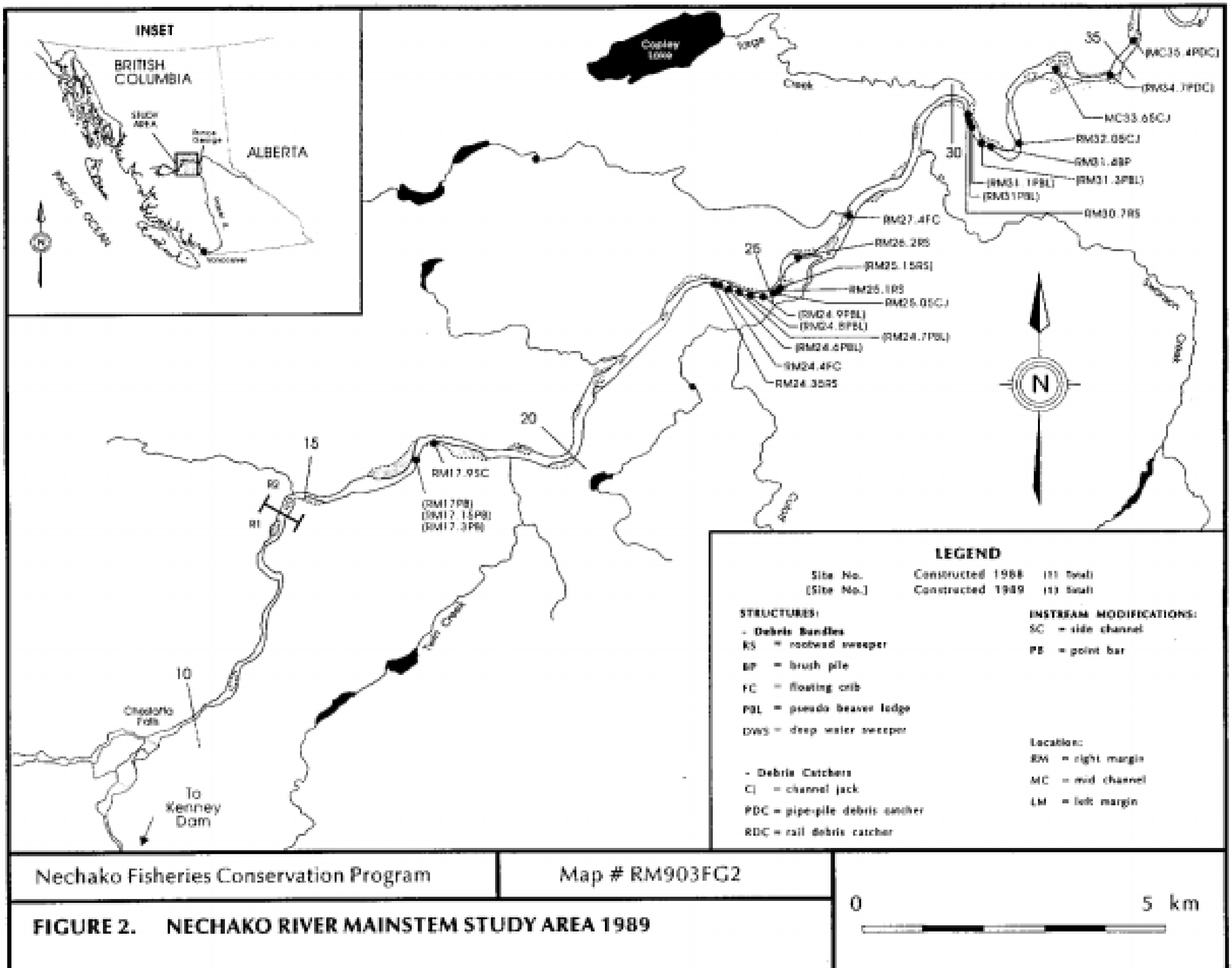
In the spring of 1989, debris bundles installed included 7 pseudo beaver lodges. Two pipe-pile debris catchers were constructed and modifications were made to the existing channel jacks. Additionally, in-stream channel modifications on Nechako River included the construction of 3 point bars.

Descriptions of the various designs utilized in the NFCP pilot habitat complexing project during the spring of 1989 are presented below.

Structures

Debris Bundles

Debris bundle designs that were constructed during the spring of 1989 include 7 pseudo beaver lodges. Pseudo beaver lodges are scaled down variations of the 1988 floating cribs and are constructed of 2 logs 10 m long, separated by 25 m logs, chained together to form a crib. These complexes extend 6 - 8 m from shore and are secured to the bank by cabling the 10 m logs and an additional upstream stiff-leg angled at 45 degrees to buried deadmen on shore.



Nechako Fisheries Conservation Program

Map # RM903FG2

FIGURE 2. NECHAKO RIVER MAINSTEM STUDY AREA 1989

Debris Catchers

Debris catcher designs installed in 1989 included 2 pipe-pile debris catchers. Pipe-pile debris catchers consist of 2 floating logs approximately 10 m long chained between 3 heavy gage steel pipes 6 m long driven approximately 3.5 m into the river bed. The catchers are arranged in a *V* configuration with the open end facing upstream to trap floating debris. The pipes act as supports and the logs are attached in a manner that allows them to rise and fall with changes in the water level.

Modifications to the channel jacks installed during the fall of 1988 were also made based on recommendations from the spring 1989 physical assessment. Modifications included fitting the base of the jacks with wire mesh and ballasting the jacks with river gravel to increase stability during winter ice conditions. Additionally, the channel jack design layout was modified by attaching log booms to increase debris entrapment as noted above for pipe-pile debris catchers.

In-stream Modifications

Point Bars

Channel modifications in the spring of 1989 included the construction of 3 point bars. Point bars consist of a berm extending approximately 10 m out from the river bank at an angle of approximately 45 degrees downstream. These complexes attempt to duplicate shear zones found in the river and are constructed using native river bed materials excavated downstream of the berm. Both the shear zone and the excavated pool are the potential rearing areas for juvenile chinook.

Fall 1989 Physical Assessment

Structures

Debris Bundles

Monitoring of rootwad sweeper installations suggested that 3 of the 4 complexes were oversized. The effective areas of usable habitat in these complexes (which often contained of up to 12 trees in total) were limited as the magnitude of the complexes impeded localized flow and therefore reduced velocities. The upstream ends of the complexes were the only regions where velocities approached criteria. These regions comprised approximately 20% of the total area of the complexes. The remaining regions were characterized by velocities below the design criteria range.

The complexes were also prone to displacement by high flows. Cabling used to bundle the LWD and secure the complexes to deadmen anchors in 1988 was attached to the logs using staples. This method proved inadequate under loading as the cables simply slid through the staples and the complexes moved downstream. Prior to displacement of these habitat complexes; however, chinook utilized the upstream portion (Triton 1996b and 1996c). For the 3 oversized complexes, it was recommended that material be removed from 2, and that the third structure be divided to form 2 smaller complexes. No modifications were recommended for the fourth structure.

The brush pile complex installed in 1988 has remained stable; however, velocities were within the lower portion of the design criteria range. The limited sample number has made conclusions about stability, design performance and durability of this structure inconclusive. No changes were recommended.

The 2 floating cribs installed in 1988 remained structurally sound. Both complexes retained a significant amount of seeded debris although 1 of the complexes provided only surface cover. A beaver lodge covered approximately 75 % of the surface area of 1 of the complexes. It was recommended to cut and place additional debris within the crib of 1 of the complexes and to leave the other 1 in place to avoid disturbing the beavers.

The 7 pseudo beaver lodges constructed during the spring of 1989 experienced stability problems as flows receded. During high flows the complex would shift position. As flows dropped, the stiff-legs would get hung up on the bank and cause the offshore end of the complex to become submerged, resulting in the loss of seeded debris. The recommendation was to modify the stiff-leg anchoring system and re-seed the complexes with debris.

Debris Catchers

Of the debris catchers, 2 channel jack debris catchers modified in the spring of 1989 had their offshore channel jack overturned and had little debris entrapment. A third channel jack debris catcher located in mid-channel had retained significant debris despite a portion of it being overturned due to the load. It was recommended to remove this complex because it was too unstable for placement in mid-channel. For the 2 complexes that had their offshore channel jack overturned, it was recommended to remove the offshore jack and to boom the near-shore jack toward shore. This would bring the complex closer to the margin and make it more stable against ice and debris loading.

The 2 pipe-pile debris catchers entrapped significant debris with the only damage being that the offshore piling on both complexes had become bent and was leaning downstream at 15 to 20 degrees. No repairs were recommended.

In-stream Modifications

Side Channel

Low velocities resulting from flow obstructions at complex locations had caused a deposition of fine materials on the channel bottom. All brush pile / rootwad sweeper complexes had compacted or shifted position. The side channel debris boom was sound and had retained debris lost by the complexes. It was recommended to remove material in each complex to attempt to increase velocities throughout the side channel.

Point Bars

Of the 3 point bars constructed during the spring of 1989, the 2 downstream complexes had their surface washed of fines during high flows but sustained no active erosion of larger structural material. The third point bar was flattened due to increased erosion during high flows. The excavated pool had been filled with eroded sediment and the structure was completely submerged at flows of 56.6 m^3/s (2,000 cfs). No modifications were recommended to the 2 remaining complexes as they were observed to be sound following summer cooling flows.

Fall 1989 Construction of Habitat Complexes

Based on recommendations from the fall 1989 assessment, construction concentrated mainly on modifications to the existing debris bundles and side channel complexes. No modifications were made to existing debris catchers or point bars.

One rootwad sweeper was thinned and another was separated to make 2 complexes to reduce the complex size and increase associated water velocities. Debris from the surface of 1 of the floating cribs was placed within the cribbing of the structure to provide subsurface cover. Pseudo beaver lodges had modifications made to their anchor systems to prevent loss of debris due to submergence of the offshore end of the structure during high flows and subsequent stranding of the complexes on shore as flows receded. Joints were added to the upstream and downstream stiff-legs at their midpoints to allow for a more flexible structure during fluctuating flows. Finally, the side channel complexes were thinned to reduce density and increase associated water velocities.

1989 Methods of Construction

The equipment and methods employed in the construction phases of the NFCP habitat complexing project are documented below. Photos of selected construction operations are presented in Appendix F.

As in 1988, the major piece of equipment used throughout construction operations in 1989 was a UH07 Hitachi backhoe. This type of machinery was used for excavations, installations of pipe-pile debris catcher pilings, placements of habitat complexes and / or materials and the securing of cable.

Excavations were required in the construction of point bars and “deadman” anchor pits. In 1989, pipe-pile debris catcher pilings were physically driven into the river bed through repeated blows of the excavator bucket. All types of complexes were placed using a backhoe.

Fabrication of habitat complexes using locally available materials was performed as in 1988. In 1989, cables were secured to anchors and / or LWD by threading and looping the cable through holes in the timber, and then attaching the 2 ends together with cable clamps.

1989 Construction Costs

In 1989, a total cost of $26,870 was incurred in the construction of new habitat complexes and major modifications to existing channel jacks. Table 4 contains a breakdown of the construction costs associated with each type of habitat complexing structure for 1989. Costs presented include all charges associated with materials, equipment, and labour used in the construction of habitat complex complexes and site access routes. The cost of each complex was variable due to differences in design and other factors such as siting, access, and availability of local materials. Therefore, only the average unit cost is presented in arriving at a total construction cost.

Table 4
Summary of Habitat Complexing Construction Costs in 1989

Type of Habitat Complex	Quantity Constructed* (Units)	Construction Cost ($/Unit)	Total Construction Cost	Comments
Pseudo Beaver Lodge	7	$1,740	$12,180	
Channel Jacks**	3 sets	$3,260/set	$9,780	1989 construction includes ballasting jacks and addition of log booms.
Pipe-Pile Debris Catcher	2	$1,525	$3,050	
Point Bar	3	$620	$1,860	Constructed using native river bed materials.
Total Construction Cost - 1989			$26,870	

* Rootwad sweeper added in 1989 considered as modification of another structure. Therefore, cost is not presented.
** Channel jack modification cost presented due to magnitude of remediation.

1989 Summary

In summary, during 1989, 13 additional habitat complex complexes were installed in the mainstem Nechako River. Modifications were made to existing and newly constructed complexes based on recommendations from monitoring assessments conducted during the spring and fall.

New complexes consisted of the addition of 1 rootwad sweeper, 7 pseudo beaver lodges, 2 pipe-pile debris catchers, and 3 point bars. Modifications were made to 2 rootwad sweepers, 1 floating crib and all pseudo beaver lodges, channel jacks, and side channel complexes. In 1989, the total cost for the construction of complexes was $26,870.

In general, the channel jack complexes, rootwad sweepers and pseudo beaver lodge complexes sustained damage or displacement by either ice or high summer flows while the brush pile, floating crib and pipe-pile debris catchers were stable. The side channel complexes shifted, blocking flow and reducing velocities within the channel, and the point bars experienced some surface erosion.

1990 PROJECT IMPLEMENTATION

The 1990 habitat complexing project implementation was as follows. In spring 1990, a physical assessment was performed of all habitat complexes remaining in the Nechako River since the beginning of the pilot testing project in 1988. Construction of new habitat complexes and modification to previously built complexes took place during summer 1990, based on observations from previous physical assessments. Following construction, a physical assessment of the new and modified complexes was performed in summer 1990. In fall 1990, a physical assessment of all habitat complexes remaining in Nechako River was performed. Details of the 1990 project implementation are presented below.

In 1990, physical assessment of the engineering performance of all habitat complexes remaining in the Nechako River was undertaken by Triton Environmental Consultants Ltd. Field investigations consisted of an inspection of each complex and photographic and video documentation of condition. Physical assessments of habitat complexes were conducted from shore by boat and by helicopter. Features noted during the 1989 physical assessments were as described previously for 1988.

In 1990, monitoring of habitat complex structure performance occurred during the spring, summer and fall. There were 2 spring assessments in 1990 due to a forced spill from Skins Lake Spillway. The spill was requested by the Provincial Comptroller of Water Rights and occurred over the period of April 5 to 31 with Skins Lake Spillway releases of up to 255 m^3/s (9,000 cfs). One assessment occurred prior to the spill and a second assessment occurred following the spill.

The first spring assessment of 1990 was a general inspection of habitat complexes to identify any structural damage and / or stability problems incurred over the winter period. The second spring assessment included an evaluation of structural damage and stability following the high flows of the forced spill, as well as observations of water depths, water velocities and cover area. Recommendations were made on structure modifications and / or removal where applicable.

A limited summer inspection of complexes installed in 1990 was conducted in early July, prior to the initiation of the Summer Water Temperature and Flow Management Project. This inspection included limited observations of water depths, water velocities and cover area to determine the status of complexes following a forced spill event during late spring. The fall assessment involved an investigation of structural damage and stability following the summer cooling flows, an evaluation of design criteria fulfilment, and observations of water depths, water velocities and cover area. Recommendations were made on structure modifications and / or removal where applicable.

Modifications or removal of existing complexes and construction of new complexes were generally based on recommendations from previous physical assessments of each year. Detailed design and construction supervision was provided by the engineering consulting firm Hay and Company Consultants Inc. Construction was carried out by Wayne Terris Contracting. Construction of in-stream habitat complex complexes in 1990 was scheduled in accordance with DFO and MOE works-in-streams guidelines whenever possible. Construction implemented outside the defined MOE works-in-streams window of mid-July through August was coordinated with DFO and MOE, and was timed to reflect seasonal sensitivities in river ecology. A summary of construction activities is presented in Table 5. Details are located in Table B1 (Appendix B). Results of the 1990 spring, summer and fall assessments are presented in Tables C3, C4 and C5 (Appendix C). Sketches and photos of the habitat complexes constructed in 1990 are presented in Appendices D and E, respectively.

Spring 1990 Physical Assessment

Structures

<u>*Debris Bundles*</u>

Observations of debris bundles during the spring of 1990 found that in general, the complexes were sound. Review of the 5 rootwad sweepers revealed that 4 complexes were sound and 1 had collapsed. Three of the sound complexes had locations of low velocities, while 1 had shifted out of the main current. It was recommended that only 1 rootwad sweeper be modified by thinning to increase flow-though velocity. The main channel brush pile structure was sound and no modifications were recommended.

The 2 floating cribs were sound and had retained their seeded debris. A beaver lodge now covered all of the area of 1 of the complexes. The recommendation for floating cribs was to leave them in their present form due to their good condition and due to the presence of beavers.

Table 5
Summary of Habitat Complexing Construction Activities in 1990

Type of Habitat Complex	Abbrev.	Quantity Remaining 1989	Quantity Constructed 1990	Quantity Modified 1990	Quantity Removed 1990	Quantity Remaining 1990
STRUCTURES						
Debris Bundles						
Rootwad Sweepers	RS	5	-	1	4	1
Brush Pile	BP	1	-	-	-	1
Floating Cribs	FC	2	-	-	-	2
Pseudo Beaver Lodges	PBL	7	-	3	3	4
Deep Water Sweepers	DWS	-	7	4	1**	6
Debris Catchers						
Channel Jacks	CJ	3	-	-	2	1
Pipe-Pile Debris Catchers	PDC	2	-	-	-	2
Rail Debris Catchers	RDC	-	7	2	-	7
IN-STREAM MODIFICATIONS						
Side Channel	SC	1	-	1	-	1
Point Bars	PB	3	-	-	-	3
Totals		24	14	11	10	28

** Removed by 1990 Summer Cooling Flows.

All but 1 of the pseudo beaver lodges had lost significant amounts of seeded debris despite modifications made to their anchoring systems in 1989. The recommendation for pseudo beaver lodges was to supplement debris on 3 of the 7 lodges. No modifications were recommended for the 4 remaining complexes.

<u>Debris Catchers</u>

Two of the channel jack debris catchers were stable while 1 had its offshore jack overturned and almost all debris removed. Of the 2 sound complexes, 1 had limited debris entrapment while the other had accumulated debris. The 2 pipe-pile debris catchers had significant debris entrapment at both locations.

No modifications were recommended for the channel jack debris catchers. The pipe-pile debris catchers were also left in their present form due to the large amounts of trapped debris.

In-stream Modifications

<u>Side Channel</u>

The side channel had accumulated excess debris as a result of the spring high flows. Existing complexes had compacted and shifted. Due to the low velocities in the side channel created by the dense cover, fines had deposited on the channel bottom. The debris boom was sound and had retained debris.

It was recommended that the side channel be cleared of all existing habitat complex complexes and re-complexed with smaller, partially spanning complexes to allow water velocities to approach design criteria values. It was also recommended that the debris boom be relocated to the upstream end of the side channel to deflect excess river debris from the entrance of the side channel during high flows.

Point Bars

All 3 point bars were structurally sound during the spring 1990 assessment although the upstream complex continued to experience active erosion. The recommendation was to leave all point bars in their present form.

1990 Habitat Complex Construction Sites

Sites for in-stream habitat complexing were selected on the basis of design criteria, accessibility and sufficient chinook recruitment to assess usage. In 1990, an additional 14 locations were selected in Reaches 1 and 2 for the construction of habitat complexes, for a total of 38 locations of complexes on the Nechako River including the side channel development. A summary of all in-stream habitat complexing sites developed in 1990, information on site locations (distances in kilometres downstream from Kenney Dam), and types of habitat complexes are presented in Table B1 (Appendix B). A map of the 1990 NFCP habitat complexing project study area, including complex locations, is presented in Figure 3.

Spring 1990 Construction of Habitat Complexes

Structures

Debris Bundles

Seven deep water sweepers were constructed during the spring of 1990. These complexes consisted of a 7 to 10 m single tree extending into the river flow. The tree was oriented 45 degrees downstream and was secured with cable to a stump or rock on shore.

Debris Catchers

Seven rail debris catchers were constructed during the spring of 1990. These complexes were similar in design to the pipe-pile debris catchers except that the support consisted of a steel rail driven into the river bed. Additionally, these complexes were generally smaller, with a shore-type design utilizing logs measuring 3 m to the offshore anchor and 7 m to the onshore anchor. The standard type in-stream design utilized logs approximately 3 m long.

In-stream Modifications

Side Channel

Based on recommendations from the spring 1990 assessment, all complexes within the side channel were removed and replaced with single logs partially buried at 10 - 50 m intervals along the margins pointing downstream at a 45-degree angle. Small organic debris, trees and rootwads were then cabled to these logs at the margins. Approximately 25 of these complexes were installed in the side channel. The cover area of each habitat complex was approximately 2 m^2. These smaller complexes partially spanned the channel to allow for increased velocities. By angling the logs downstream it was felt that debris accumulation and subsequent blockage would be minimized. The debris boom was relocated to the right bank of Nechako River upstream of the side channel to prevent additional debris from entering the side channel and creating large debris jams which could result in reduced velocities.

Summer 1990 Physical Assessment

A limited assessment of depths, velocities, and cover areas of deep water sweepers and rail debris catchers installed during the spring was completed in early July prior to the initiation of the Summer Water Temperature and Flow Management Project. Results of this assessment showed that velocities measured at the deep water sweepers were generally below the criteria range of 0.15 - 0.4 m/s at the upstream and downstream ends of the complexes and above the criteria range at the outside shear zone. The velocities measured at the rail debris catchers were generally within the criteria range at the upstream and downstream ends of the complexes but exceeded the criteria at the outside shear zone.

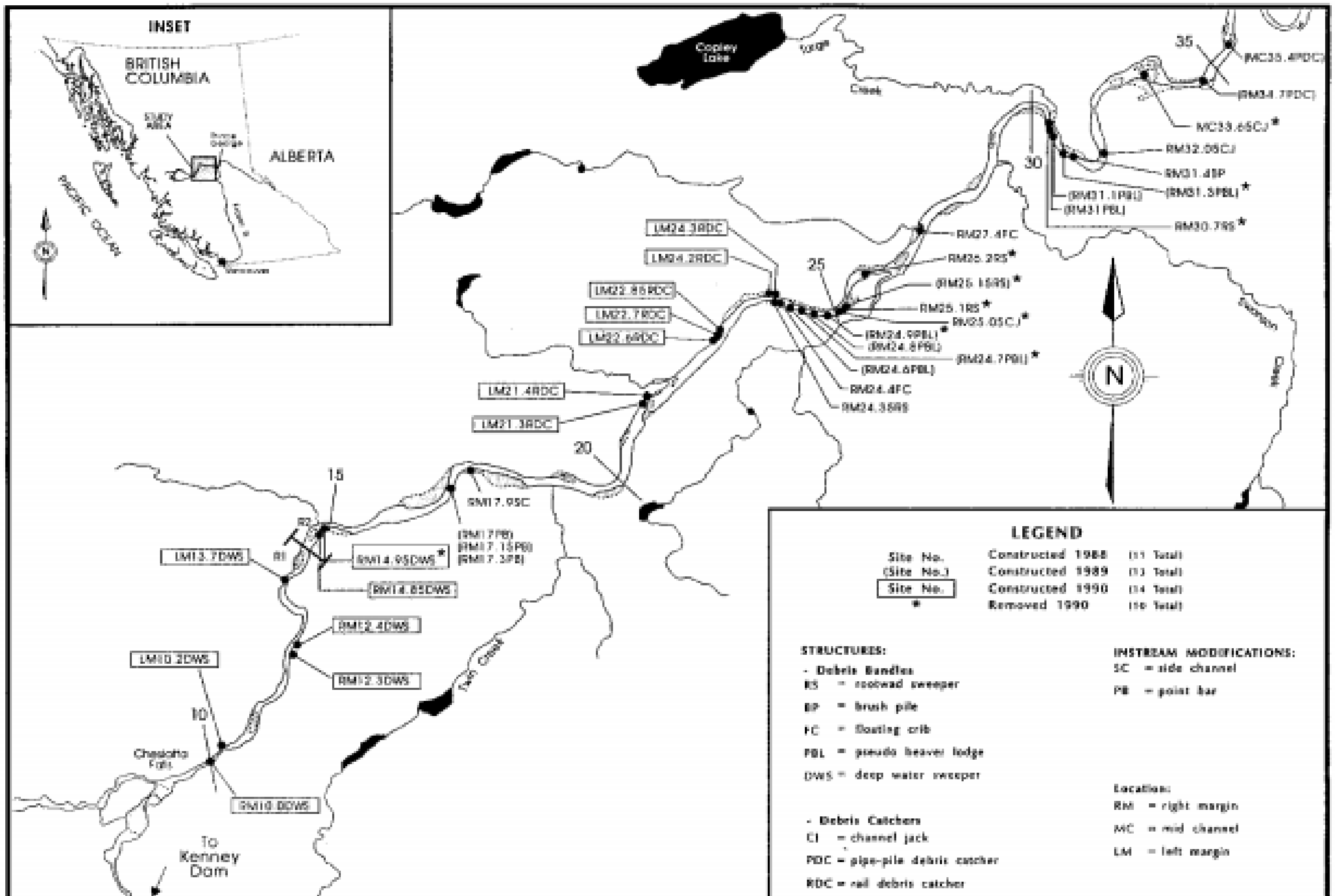
Depths measured at all rail debris catchers were above the criteria of 0.4 m at the outside and downstream ends. Cover area of the deep water sweepers and rail debris catchers ranged from approximately 11 to 36 m^2. Results of the summer assessment were combined with fall assessment results and used to determine recommendations for the modification of habitat complexes.

Fall 1990 Physical Assessment

Structures

Debris Bundles

Review of the 5 rootwad sweepers revealed that 4 of the complexes remained sound and stable, and 1 structure had remained shifted and collapsed from 1989. Inadequate velocities were again measured at these complexes. As a result of the 1990 assessment it was recommended that 1 rootwad sweeper be thinned and 4 be removed due to inadequate velocities. The brush pile was sound and stable and no modifications were recommended.



Nechako Fisheries Conservation Program

Map # RM903FG3

FIGURE 3. NECHAKO RIVER MAINSTEM STUDY AREA 1990

The 2 floating cribs were sound. One of the cribs continued to be used by beavers. Low velocities had again been measured at the second crib. The recommendation was to leave the first structure as to avoid disturbing the beavers and to re-orient the second structure 90 degrees to improve velocities.

All 7 pseudo beaver lodges were structurally sound. Six of 7 complexes had lost a significant portion of their seeded debris yet 3 of these complexes still had inadequately low velocities. The low velocities were possibly a result of placement just upstream of a hydraulic constriction at km 25.4. The recommendation was to remove the 3 complexes with low velocities and to add debris to the 3 remaining complexes. The complex that had significant debris entrapment was left in its present form.

Five of the 7 deep water sweepers constructed in the spring of 1990 had their offshore end shifted inshore, and had been either partially or totally de-watered. Of the other 2 complexes, 1 had been reduced in size and had shifted downstream and the other had been removed by the summer cooling flows. The fall recommendation was to relocate all 6 remaining complexes in the current.

<u>Debris Catchers</u>

Two of the 3 channel jack debris catchers were structurally sound. One of the 2 had virtually no debris entrapment while the other had created a debris jam. The third structure located in mid-channel had been overturned, and had not trapped debris. It was recommended that the 2 channel jack complexes with no debris entrapment be removed. The 2 pipe-pile debris catchers had significant debris entrapment. No modifications were recommended.

All 7 rail debris catchers appeared structurally sound with all but 2 not trapping debris. Therefore the recommendation was to supplement debris on these 2 complexes.

In-stream Modifications

<u>Side Channel</u>

The re-complexed side channel complexes were sound, although velocities were in the lower part of the design criteria range and insufficient cover area existed. The recommendation was to supplement the re-complexed regions with debris. The relocated side channel debris boom was sound and effectively retained seeded debris and deflected river debris from entering the side channel. No modifications were recommended.

<u>Point Bars</u>

The 3 point bars remained structurally sound despite being submerged during peak cooling flows. No modifications were recommended.

Fall 1990 Construction of Habitat Complexes

No new complexes were constructed during the fall of 1990. Based on spring and fall recommendations, several complexes were either thinned, removed or relocated due to inadequate velocities or design. Some complexes required debris to be added to allow for adequate cover.

Structures

<u>Debris Bundles</u>

Four of the 5 rootwad sweepers were removed due to inadequate velocities. The remaining complex was thinned again in the fall of 1990 to increase velocities.

Three of the 7 pseudo beaver lodges were removed due to inadequate velocities within the complex. Debris was added to 3 of the remaining complexes to fully seed the traps. No modifications were performed to the seventh complex.

Four of the remaining 6 deep water sweepers were relocated in the river current to enable a biological assessment of chinook utilization during the early life history period. The other 2 remaining complexes were left alone.

<u>Debris Catchers</u>

Two of the 3 channel jack debris catchers were removed due to continuing stability problems during winter ice flows.

Debris was added to 2 of the 7 rail debris catchers to fully seed them. The remaining rail debris catchers had trapped a significant amount of debris.

1990 Methods of Construction

The equipment and methods employed in the construction phases of the NFCP Habitat Complexing Project are documented below. Photos of selected construction operations are presented in Appendix F.

The major piece of equipment used throughout construction operations in 1990 was a Caterpillar EL200B backhoe. This type of machinery was used for excavations, installations of rail debris catcher pilings, placement and removal of habitat complexes and / or materials, and the securing of cable.

In 1990, rail debris catcher pilings were driven into the river bed using the excavator and a vibratory attachment. This operation required minor modifications to the excavator arm but proved highly successful as driving each rail took approximately 20 to 30 seconds. Rails were driven to depths ranging from 3.0 to 5.0 m into the substrate with 2.0 to 3.0 m remaining above the river bed. All types of complexes were placed and removed using a backhoe.

Fabrication of habitat complexes was completed manually using chain saws, power drills and oxyacetylene cutting torches. Locally available materials used in construction of complexes included river bed cobble, and timber such as pine and spruce. Materials transported to the sites included piping, used rail, chain and cabling. Cables were secured to anchors and / or LWD by threading and looping the cable through holes in the timber, and then attaching the 2 ends together with cable clamps.

1990 Construction Costs

In 1990, a total cost of $18,660 was incurred in the construction of new habitat complexes and side channel remediation. Table 6 contains a breakdown of the construction costs associated with each type of habitat complexing structure for 1990. Costs presented include all charges associated with materials, equipment, and labour used in the construction of habitat complexes and site access routes. The cost of each complex was variable due to differences in design and other factors such as siting, access, and availability of local materials. Therefore, only the average unit cost is presented in arriving at a total construction cost.

1990 Summary

In summary, during 1990, 14 additional habitat complexes were installed in the mainstem Nechako River. Modifications were made to existing and newly constructed complexes based on recommendations from monitoring assessments conducted during the spring, summer and fall.

New complexes consisted of construction of 7 deep water sweepers and 7 rail debris catchers. All side channel complexes were removed and replaced with smaller complexes and the debris boom was relocated upstream of the side channel to reduce entry of floating debris. Other modifications were made to 1 rootwad sweeper, 3 pseudo beaver lodges, 4 deep water sweepers and 2 rail debris catchers. Four rootwad sweepers, 3 pseudo beaver lodges, 1 deep water sweeper, and 2 channel jacks were removed due to inadequate velocities or design. In 1990, the total cost for the construction of new complexes and side channel remediation was $18,660.

In general, the rootwad sweepers, floating cribs, rail debris catchers, pipe-pile debris catchers and brush piles were stable in 1990. Most of the deep water sweepers were displaced to the shore and the channel jack debris catchers had not collected any debris. The pseudo beaver lodges also lost debris, but were stable while the modified side channel still experienced slow velocities despite the reducted size of the complexes. Point bars continued to be eroded but were stable following summer flows.

Table 6
Summary of Habitat Complexing Constuction Costs in 1990

Type of Habitat Complex	Quantity Constructed (Units)	Construction Cost ($/Unit)	Total Construction Cost	Comments
Deep Water Sweeper	7	$470	$3,290	Excludes cost of fall relocation of offshore end structure.
Rail Debris Catcher	7	$1,610	$11,270	Excludes cost of modification of excavator for vibratory attachment ($7,190).
Side Channel Remediation*	100 m	$41 / m	$4,100	Removal of existing structures and recomplexing (Spring).
Total Construction Cost - 1990			$18,660	

* Side channel remediation presented due to cost magnitude

SUMMARY OF OBSERVATIONS ON HABITAT COMPLEX PERFORMANCE

Evaluation of the structural performance of some complexes is in an early stage. The long term durability of items used in the anchoring of complexes (cable, chain, clamps etc.) is also in an early stage as these items may fail within 1 to 10 years or more due to decay from corrosion. However, it is instructive to examine the performance of the habitat complexes constructed to date to develop some understanding of the factors affecting structure durability and/or performance. These observations can be used to further evaluate the criteria used in the design and siting of the complexes.

A summary of observations on habitat complex structure design performance from 1988 to 1990 is presented below.

Structures

Debris Bundles

<u>General Observations</u>

Of the debris bundle type habitat complexes installed in 1988 (which included rootwad sweepers, brush piles and floating cribs), rootwad sweepers were oversized. This resulted in reduction of velocities through the complexes below the specific design criteria. In addition, anchoring systems used at these sites proved to be inadequate to hold complexes in place.

Debris bundles installed in 1989 (which included original and modified pseudo beaver lodges) experienced stability problems and were unable to retain a significant amount of seeded debris. The velocities characterizing pseudo beaver lodge sites were within the lower portion of the design criteria range or below the design criteria range.

Debris bundle habitat complexes installed in 1990 (deep water sweepers) were subject to stability problems. The complexes were not adequately secured into place and were displaced from areas of active current during high flows. Velocity distributions assessed prior to displacement by 1990 cooling flows were generally within the lower portion of the design criteria range or below the design criteria range.

<u>Rootwad Sweepers</u>

All 1988 rootwad sweeper installations were oversized. The effective areas of usable habitat in the complexes (which often contained up to 12 trees in total) were limited. The size of the complexes impeded localized flow and reduced velocities. The upstream ends of the complexes were the only regions characterized by flow-through velocities approaching criteria. The complexes were also prone to displacement by high flows. Cabling used to secure the complexes to anchors was attached to the logs using staples. This method proved inadequate under loading as the cables simply slid through the staples and the complexes moved downstream. Prior to displacement; however, chinook utilized the upstream portion of these complexes (Triton 1996b and 1996c). All but 1 of the rootwad sweepers were removed in 1990 due to inadequate velocities.

<u>Brush Pile</u>

The brush pile complex installed in 1988 has remained stable; however, velocities are within the lower portion of the design criteria range due to placement location. The limited sample number (1) has made conclusions about stability, design performance and durability of this structure difficult.

<u>Floating Cribs</u>

The 2 floating cribs installed in 1988 have remained structurally sound. Both complexes retained a significant amount of seeded debris. In 1989, the amount of subsurface cover provided by the downstream complex was supplemented through modifications in the placement of seeded debris within the crib. The upstream floating crib was colonized by beavers in the fall of 1989 and has not been modified. Velocities measured at both locations were within the lower portion of the design criteria range.

<u>Pseudo Beaver Lodges</u>

The pseudo beaver lodges constructed in the spring of 1989 experienced stability problems which occurred as Nechako River flows receded. During high flows the complexes shifted position. As the flow dropped the stiff-legs got hung up on the bank and caused the outside corner of the complexes to become submerged. This design was modified in the fall of 1989 to include an anchoring system in which the stiff-legs were jointed at the midpoints to enhance complex stability. This prevented the complex from being hung up on the river bank and thus enabled it to better maintain its position following flow recession. The majority of the modified installations still suffered loss of seeded debris. Velocity distributions at the upstream pseudo beaver lodge installations (km 24.6 to 24.9) were within the lower portion or below the design criteria range. This may have been a result of the placement of the complexes just upstream of a hydraulic constriction (km 25.4). Three of these complexes were removed in 1990 due to measurement of insufficient velocities. The velocity distributions which characterized the remaining installations were generally within the design criteria range.

Deep Water Sweepers

The deep water sweepers installed in 1990 were of adequate size but only anchoring at the butt end was utilized, which made them unstable. Deep water sweepers were positioned along the shoreline with the outermost ends extending into the water at an angle of approximately 45 degrees downstream. However the butt of the tree was placed such that at high flows the entire tree was floating and the tip was easily displaced towards shore. As flows receded, the sweepers were left de-watered. Relocation of these complexes was required in the fall of 1990. Velocity distributions assessed prior to structure displacement by 1990 cooling flows were generally within the lower portion of the design criteria range or below the design criteria range.

Debris Catchers

General Observations

Debris catcher type habitat complexes installed in 1988 (which included original and modified channel jacks) experienced stability problems and lost the majority of their debris. Velocity distributions at channel jack installations were within the upper portion of the design criteria range or above the design criteria range.

Pipe-pile and rail debris catchers, installed in 1989 and 1990 respectively, were stable and trapped a significant amount of debris. Velocity distributions at the pipe-pile debris catcher sites were within the lower portion of the design criteria range or below the design criteria range. Velocity distributions at the rail debris catcher sites were below, above, or within the design criteria range. One general comment with all of the debris catcher designs was over the aesthetics of the steel members protruding above the water surface during low flows.

Channel Jacks

The original channel jack design installed in 1988 did not successfully trap significant amounts of debris and individual tripods proved unstable under winter icing conditions. The following spring, the 1988 channel jack design was modified to include the weighting of the channel jack bases and the booming of channel jack groups. These adaptations produced complexes which achieved greater success at debris entrapment but stability problems were still evident. Debris buildup on boomed channel jack groups often resulted in the toppling of the tripods. The complexes that had not trapped debris were removed in the fall of 1990. Velocity distributions at channel jack installations were within the design criteria range.

Pipe-Pile and Rail Debris Catchers

The pipe-pile and rail debris catcher designs maintained position and configuration under variable flow conditions and were generally not displaced or damaged during periods of high flow. There was evidence of piling displacement under heavy debris loading at some of the early installations. At these sites, the outermost pilings were leaning at angles of 10 to 15 degrees. Overall, the complexes successfully trapped and retained significant amounts of debris. Velocity distributions at the pipe-pile debris catcher sites were within the lower portion of the design criteria range or below the design criteria range. Velocity distributions at the rail debris catcher sites were within the upper portion of the design criteria range or above the design criteria range. Modifications to the original design, which included changes in piling materials and the length of log booms, were initiated in response to material cost and to smaller cover area requirements as indicated through biological assessment. The boom lengths used in the various installations ranged between 3 and 10 m.

In-stream Modifications

Side Channel

The original complexes installed in the side channel in 1988 were found to be oversized. The full spanning complexes eventually became clogged with small organic debris after which they acted as barriers to water flow through the channel, even after being thinned in 1989. The debris boom, which was installed within the downstream portion of the channel to prevent the loss of seeded debris performed well; however it also contributed to the lowering of velocities in the side channel. Velocities through the side channel were eventually reduced to below design criteria.

In an attempt to remedy these problems the side channel was modified in 1990. In an effort to prevent flow blockage due to excessive accumulation of material within the side channel, the debris boom was moved upstream of the side channel entrance to divert floating debris. Full spanning habitat complexes were removed and replaced with single logs buried at intervals along the margin pointing downstream at a 45-degree angle. Smaller organic debris was then cabled to these logs in an effort to create smaller complexes more proportional to the size of the side channel. By angling the logs downstream it was felt that debris accumulation and side channel blockage could be avoided.

Point Bars

The 3 point bars installed in 1989 were generally stable under high flows. The first post-construction high flow event caused active erosion of the most upstream structure and removed fines from the 2 other complexes. Subsequently the 2 downstream point bars proved to be stable under high flow conditions, although the most upstream complex continued to be severely degraded. The point bars were also found to be oversized as a large area of still water was created downstream of the complexes rather than creating a back-eddy as expected.

Resistance to Winter Physical Conditions

With the exclusion of the 1988 channel jack designs, the habitat complexes did not suffer any significant structural damage and / or stability problems over the 1988 and 1989 winter seasons. However, this fact does not indicate that the complexes are necessarily immune to damage or displacement under winter physical conditions. The seasonal conditions observed over the first 2 years of the project (1988 and 1989) were relatively mild in comparison to previous years and icing events experienced by most of the complexes were transient and of short duration. Under average winter conditions, the current siting of the majority of the habitat complex complexes precludes their exposure to long periods of severe ice cover. All existing sites are located in the upper 35 km of the Nechako River and records indicate that the mean location of the leading edge for the period of record ranges from km 59.5 to km 80.8 (Blanchut 1988; Wilkins and Faulkner 1996a, 1996b).

CONCLUSIONS AND RECOMMENDATIONS

To date, the NFCP pilot habitat complexing project has constructed and tested 10 different complex structure designs in the mainstem Nechako. These consist of:

Structures

Debris Bundles

1. Rootwad Sweepers
2. Brush Pile
3. Floating Cribs
4. Pseudo Beaver Lodges
5. Deep Water Sweepers

Debris Catchers

1. Channel Jacks
2. Pipe-Pile Debris Catchers
3. Rail Debris Catchers

In-stream Modifications

1. Excavation of a side channel, complexed with debris bundles and a debris boom.
2. Construction of point bars with back eddy pools on the Nechako River shoreline.

Specifics on the success or failure of a certain design's performance and functionality, as well as general conclusions on habitat complexing are presented below. Also included are recommendations on modifications to improve design performance. A summary of all the habitat complexes constructed to date, observations and modifications of each over the duration of the project and the rationale upon which modifications and / or removal were based is presented in Appendices B and C.

Structures

Debris Bundles

All the debris bundles have good potential with limited modifications required to their designs and placement locations in the future.

The modified pseudo beaver lodge design constructed in the fall of 1989 proved successful in maintaining position under variable flow conditions; however, further modifications are required to ensure the retention of seeded debris. This could be remedied by cabling or securing the debris to the timber crib, or by increasing floatation of the outermost boom.

Deep water sweepers constructed in 1990 could not be adequately assessed for performance as the majority of the installations were subjected to displacement by high flows. Modifications to the anchoring systems of the complexes are required to secure positioning of the off-shore ends of the sweepers. Installations modified in this manner could then be assessed for physical and biological performance. A possible option is the use of a downstream stiff-leg to secure the tip of the sweeper in place.

Other debris bundle type designs which had marginal success included rootwad sweepers, brush pile and floating cribs. The rootwad sweepers constructed in 1988 were not successful in maintaining their position due to the fact that they were oversized and lacked sufficient anchoring. These complexes impeded localized flow and were incapable of providing velocities within the design criteria range. The unsuitable conditions resulted in limited areas of usable habitat. Future installations of rootwad sweepers must be considerably smaller in size. It is recommended that complexes of this type be limited to 1 to 3 trees, and the threading and looping method of attaching cable be used.

The brush pile constructed in 1988 has remained relatively stable; however its location in a low velocity area as well as a limited sample size of 1 has prevented an accurate assessment of the structure's durability. It is recommended that these complexes be properly assessed for velocity criteria fulfilment prior to installation.

The floating crib designs installed in 1988 were also placed in areas where water velocity is near the lower end of the design criteria value. These complexes were successful in maintaining position under variable flows. However, the size of the complexes made construction labour-intensive given the area of usable habitat produced. Pseudo beaver lodges are a smaller scale reproduction of this design, and are much less labour intensive to construct. Therefore, it is recommended that this design be further tested and modified before returning to the original floating crib design.

Debris Catchers

The pipe-pile and rail debris catcher designs were successful. These complexes were stable under high flow conditions, caught significant amounts of debris and were able to maintain their configuration and debris under variable flow conditions. This type of design functioned very well and provided significant cover area within the design criteria range. The only apparent negative aspect of these complexes is one of unpleasant aesthetics. This aspect could be significant when considering the number of complexes that may be installed over the duration of the project. However, perhaps over time debris accumulation will be sufficient to obscure the piles or rails from view.

The channel jack designs were not successful due to stability problems. By design, the stability of a channel jack is dependant on its own mass. Icing conditions or heavy debris loading exerts a lateral force to the top of the structure. This force creates a high moment arm which topples the tripod. Design aesthetics were also a concern with the channel jacks. Therefore, it is recommended that no future channel jack complexes be constructed.

In-stream Modifications

Side Channel

The long term effects of icing and sedimentation for the side channel complex modified in 1990 are in an early stage of assessment. However, the current design provides improved water velocities over the original configuration.

Point Bars

Point bars proved to be stable complexes capable of withstanding high flows with limited erosion. However, further assessment is required as the hydraulic performance has not been fully evaluated. Currently, point bars extend too far into the current impeding velocities in the area downstream of the point bar, instead of creating a back-eddy.

It is recommended that future point bar installations consider the size of complexes suitable to Nechako River conditions. Point bars should be modified to be shorter and higher to create a back-eddy and to function at larger range of flows. Designs that mimic naturally occurring scallops would be less disruptive to local stream flow.

General Conclusions and Recommendations

The most critical factor in the biological success of habitat complexes is the provision of required velocities. Site selection is integral to establishing a complex which fulfils velocity design criteria over the full range of flows. Size is also important. Based on the initial results of biological and physical monitoring and earlier studies on the Nechako River (Lister 1994, and Triton 1996b and 1996c), it is suggested that habitat complexes be approximately 15 m^2 in area. Flexibility in the application of the cover area design range depends on the type of complex and the target species of fish. For chinook salmon, habitat complex complexes which impede velocities due to increased cover area (typically LWD placements), should be avoided. Ultimately, it is important to ensure that all habitat complexes, regardless of size, meet target species requirements.

Anchoring systems of habitat complexes must be secured adequately to maintain complex placement. The deadman anchoring system used in the NFCP pilot habitat complexing project has been successful. The suggested method of attaching cable to anchors and LWD is the looping and threading method described previously. Stapling of cable proved to be unsuccessful. It is also necessary that anchoring systems be designed to function under variable and transient flow conditions. The adaptability of habitat complex anchoring systems to changing flow conditions and site-specific conditions is particularly important for maintaining structure position and stability following flow recession.

The average cost per unit of each of the various habitat complexing designs constructed and tested in the NFCP pilot habitat complexing project was presented in Tables 2, 4, and 6 for complexes constructed in 1988, 1989, and 1990, respectively. The range in unit cost of all habitat complexes identified as successful and / or promising is \$470 to \$3,300. The least expensive promising design was that of the deep water sweeper, while the most expensive was the rootwad sweeper. Successful debris catcher costs per unit varied from \$1,525 for the pipe-pile debris catchers to \$1,610 for the rail debris catchers. Modifications that have been recommended to improve the performance of promising complexes could result in increased costs per unit for future installations. Maintenance costs of complexes require several years of data. Therefore, these costs were not presented in this report but may be developed as long term durability is assessed.

To date, the NFCP pilot habitat complexing project has identified several parameters which are important for success in habitat complexing, namely, the provision of required velocities; substrate; appropriate complex sizing; and adequate complex anchoring. The project has also distinguished several successful habitat complex designs from those that were constructed and replicate tested.

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APPENDIX A

Literature Review of Remedial Measures Used to Provide Increased Habitat Complexity to Rearing Juvenile Salmonids

INTRODUCTION

A major element of the Nechako Fisheries Conservation Program (NFCP) is the testing and implementation of remedial measures including in-stream habitat modifications. This appendix summarizes information acquired through a literature review of the in-stream habitat complexing programs.

RESULTS

Assessment of the in-stream habitat complexing techniques is particularly difficult due to the fact that few programs are fully evaluated and documented. However, several authors have conducted reviews of available studies (Buell 1986; Hall and Baker 1982; Reeves and Roeffs 1982; Parkinson and Slaney 1975). Generally in-stream habitat modification projects have focused on small streams characterized by normal peak flows of 5.7 m^3/s to 56.6 m^3/s (200 to 2000 cfs) which support fish species other than chinook.

Applications of in-stream habitat complexing measures in the Pacific Northwest have met with both great success and failure. This can be attributed to a number of factors including, but not limited to the following:

1. Lack of current state-of-the-art knowledge in the application of in-stream habitat complexing techniques to variable field conditions.
2. Inadequate knowledge of river response to in-stream habitat complexing installations.
3. A lack of documented procedural guidelines.
4. Insufficient consultation and pre-project research due to economic and time constraints.

All of these factors have served to promote pilot testing methods of application. This approach has been adopted by the NFCP pilot habitat complexing program due to the limited availability of published work on similar programs applied to systems comparable to Nechako River.

Currently there are some programs within the Pacific Northwest which are applying in-stream habitat complexing techniques to larger streams. However, these projects have yet to be evaluated on their physical and/or biological merits. Generally, the types of structures being installed in these streams are clusters of materials placed at stream margins. Installations of full-spanning structures are limited. Typical large stream structures include boulder, whole tree or log deflectors placed at the bank, boulder clusters in the riffles, secured log jams and angle logs sloping down on the banks. In Washington State, commissioning plans to install in-stream habitat complexing structures in larger streams are being considered. Study members emphasize the need to assess prevailing system dynamics and locate structures to enhance existing characteristics and magnify optimum features. When working with larger rivers it is important to work with stream energy rather than against it.

Buell (1982) suggests that in-stream habitat complexing installations should utilize structural material which mimics a system's naturally occurring habitat. If LWD is the dominant factor, emphasize log structures; whereas if bedrock outcrops or boulders predominate, emphasize boulder structures. Limitations such as the availability of materials, site accessibility an personal preference also dictate the type of structural material which is used.

A summary of regional projects utilizing in-stream habitat complexing structures to increase rearing habitat for salmonids and particularly juvenile chinook is presented in Table A1. Each program reference includes the name of the stream, stream location, literature citation, program year, a description of the technique and/or structure used, level of program evaluation and results. The focus of the projects is application to small rivers and creeks, a fact which reflects the emphasis of programs implemented to date. Techniques of in-stream habitat complexing employed in these programs are generally of 2 types; rock structures and LWD structures. Applications include boulder berms, boulder clusters or groups, gabions and rock weirs, as well as K dams, log weirs, rootwads, whole trees and logs.

A particularly extensive and well documented study is the Coldwater River juvenile salmonid monitoring study (Beniston et al. 1987). This program primarily utilized rock mitigation structures, particularly boulders, in addition to cabled pine trees. Choices of in-stream habitat complexing techniques were based on river characteristics and the availability of materials. Results focused on biological performance and indicated that mitigative measures appeared to increase chinook and coho rearing capability by 19 to 25%.

The Fish Creek basin fisheries enhancement study is one in which in-stream habitat complexing was applied to a larger system. Techniques utilized include boulder berms and LWD placed at channel margins. Although evaluation of the program is still in progress, preliminary assessments indicate that log and boulder accumulations have performed well in flows of up to 142 m^3/s (5,000 cfs) (Hohler et al. 1986).

Some of the most successful programs involve the improvement of overwintering salmon and steelhead habitat in streams characterized by winter flows. In these studies in-stream habitat complexing techniques were applied to stream margins (King et al. 1985).

Review of in-stream habitat complexing programs clearly indicates that when considering techniques applicable to a given system, system size and natural habitat features are of utmost importance. An additional factor in the assessment of suitable techniques is the availability of materials and cost effectiveness. When considering program execution the literature suggests that an experimental / incremental approach is best for the implementation and evaluation of large scale projects. Once a program proposal has been adopted and potential for effective treatment has been confirmed, initial activities should be viewed as "test treatments" to be followed by preliminary post-treatment evaluation and (if warranted by initial results) by a program of step-wise augmentation / evaluation in subsequent years (Griffith 1982).

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Appendix A

Table A1: Summary of Habitat Complexing on Some Small Streams in the Pacific Northwest

STREAM/ LOCATION	REFERENCES/ YEAR OF STUDY	STRUCTURES/ METHODS USED/PURPOSE	EVALUATION/ RESULTS
1 **Red Cap Creek, California** - Tributary to the Klamath River. - Drains 166 km2, 33 km in length.	Brock (1988) / - - - -	Boulder placement. - Create habitat for spawning chinook salmon and rearing of steelhead trout.	- Boulders placed in clusters received no adverse impact. Increase in population of age 1+ steelhead (parr) of 300% while control site showed a decrease of 20%. - A cost-benefit analysis calculates break-even point ten years after boulder placement.
2 **Sauk and Suiattle Rivers, Washington** - Tributaries to the Skagit River. - Wide active channels are characteristic.	Longenbaugh (1987) / - - - -	Placement of logs and rootwards (pinned) to provide habitat for chinook, coho, chum, and pink salmon. - Create deep pools, provide cover, and generally increase complexity of flows.	- Pinned logs and rootwads remained in original position. - Scour under a pinned log or pair of logs provided deep cover and encouraged deposition along part of the upstream length. - Single logs placed perpendicular to flow to maximise channel response.
3 **John Day River, Oregon** - Tributary to the Columbia River. - Mainstem flows 284 miles from its source.	Lacy, Stuart, Smith (1986) / 1984	Boulders, rock weirs, and associated holding pools, 146 rock jetties, side channels. - Increase chinook and steelhead production.	- Total number of additional anadromous fish derived from enhancement work is estimated at 7171 smolts and 107.56 adults of spring chinook and 2796 smolts and 111.60 adults of summer steelhead. - Significant increase in number of rearing juveniles in side channels.
4 **Hot Springs Fork of the Collawesh River, Oregon** - Major sub-drainage in the Clackamas River drainage. - Mainstem length 14.6 miles. - Basin area 60 sq. mi.	Cain (1987) / 1986	Logs and boulders positioned to scour pools in riffle dominated areas and to provide cover in existing pools. One perennial side channel created to provide habitat and slow water refuge during high flows in mainstem. - Emphasis species for natural production are spring chinook and coho salmon, and winter steelhead.	- Most structures functioned well and had begun to create expected changes in habitat diversity. - Creation of overwinter quiet-water habitat in side channel was successful. - Three structures had shifted enough to partially diminish their function. - Channel complexity dramatically improved with felled trees and boulder placement.
5 **Suislaw River, Oregon**	Hammer (1977) / 1968-1975	Various gabion designs. - Create spawning habitat and fish cover.	- Many structures washed out or rolled over and no longer hold gravel. - Chinook, coho, and steelhead spawning recorded behind some structures. - Success not as high as expected.

Appenix A (continued)

Table A1: Summary of Habitat Complexing on Some Small Streams in the Pacific Northwest

	STREAM/ LOCATION	REFERENCES/ YEAR OF STUDY	STRUCTURES/ METHODS USED/PURPOSE	EVALUATION/ RESULTS
6	**Beach Creek, Oregon**	Claire (1978) / - - - -	Boulder placement. - Create rearing habitat.	- Boulders reduce water velocity, created pools and gravel bars. - Steelhead.
7	**Fifteen Mile Creek, Oregon** - Tributary to Columbia River.	Newton (1978) / 1974	Rock drop structures. - Create rearing habitat for steelhead.	- Structures intact after 3 years. - Adult steelhead in spring using new pools. - Redds observed near structures. - Juveniles used area for rearing.
8	**Fish Creek, Oregon** - Tributary to upper Clackamas River.	Everest et al. (1985) / 1983	Boulder berms, off channel pond, side channel, large woody debris applied to stream edge. - Increase salmonid habitat.	- Evaluations are continuing.
9	**Camp Creek, Oregon**	Green (1984) / 1982	Single log weirs and fencing. - To increase and improve pool areas for rearing steelhead and chinook.	- Evaluation is being done by ODFW. - Annual steelhead smolt production is estimated to equal 10,240. Other salmonid increases unknown.
10	**Clear Creek and Granite Creek, Oregon**	Andrews (1984) / 1984	Rock structures, boulders, and riprap. - To increase spawning and rearing of chinook.	- Predicted levels of increased chinook production (4,540 smolts or 29 adult spawners annually).
11	**Peavine Creek, Oregon** - Wallowa River Valley.	Miller (1987) / 1983 - 1984	Log weirs, riprap deflectors, deciduous plantings, fencing. - Objective to improve stream stability and create salmonid pool habitat.	- No structural failures and production was increased. - Pool habitat was successfully increased. - Authors predict an increase of 5400 wild steelhead smolts or 102 adult spawners.
12	**Lolo Creek, Idaho** - Tributary to Clearwater River.	Murphy, Espinosa (1986) / 1983-1984	K dams, log weirs, boulders, rootwads, deflectors, bank cover. - Ojective to increase diversity of salmonid habitat.	- Evaluations not complete but so far indicate progressive results for spring chinook and summer steelhead. - A 5-year monitoring program is planned.
13	**Hurdygurdy Creek, California** - Tributary to South Fork Smith River in northwestern California. - Drains 78.0 km². - 22.7 km in length.	Moreau (1984) / 1982 and 1983	Boulder wind deflectors, clusters, and weirs. - Increase rearing and spawning habitat for steelhead trout and chinook salmon.	- Larger steelhead juveniles were found along edges of boulder clusters and near points of boulder wind deflectors in deep water. - In June, 0+ chinook used boulder clusters and moved into deep pools by September. - Parr production increased with boulder clusters and deflectors in wide, shallow riffles. - Boulders smaller than 0.5 m³ or rounded "river rock" tended to move.

Appendix A (continued)
Table A1: Summary of Habitat Complexing on Some Small Streams in the Pacific Northwest

STREAM/ LOCATION	REFERENCES/ YEAR OF STUDY	STRUCTURES/ METHODS USED/PURPOSE	EVALUATION/ RESULTS
14 **Keogh River, British Columbia** - Area, 129 km².	Ward and Slaney (1980) / 1977-1978	Three gabion designs, boulder groupings with cable log cover, deflectors with log cover attached to revetment, other deflectors, and V-notch weirs. - Create rearing habitat for steelhead trout and coho salmon smolts.	- Boulder groupings, boulder V-notch weirs, and boulder deflectors with log cover, in that order, were most effective in increasing density of steelhead trout parr in riffles. - Boulder deflectors alone and gabion structures were unsuccessful. - Total salmonid biomass was higher in boulder than in gabion structures during summer. - Attached log cover to boulder clusters were the most stable and resulted in the highest fish densities. - Boulders placed with helicopters compared favourably with costs of using heavy equipment.
15 **Coldwater River, British Columbia.** - Tributary to the Nicola River. - Approx. 100 km in length.	Beniston, Dunford, Lister (1987) / 1987 - 1988	Cabled pine trees and rock mitigation structures consisting of boulder groups (both nearshore and offshore), single boulders and spurs. - Determine the effect of mitigation structures on chinook, coho and steelhead densities, fish biomass and rearing capability.	- In early summer, the mitigation features were not found to support a significantly different biomass and numerical density of chinook and steelhead than the controls, however, a significantly greater biomass and density of coho was found. - By late summer, fish biomass and densities of all groups were significantly higher at mitigation features. - This was believed to be related to the fact that a decline in stream flows between early and late summer results in mitigation features providing greater depths and rock cover than the controls (unalteted habitat). - With the exception of nearshore boulder groups and cabled tree structures, mitigation features consistently showed higher (although not necessarily statistically significant) fish utilization for all salmonids in early and late summer. - In early summer controls supported higher steelhead parr biomass than the nearshore boulder group and cobbled structures. - Installed mitigation measures appeared to have increased chinook and coho rearing capability by 19-25% and steelhead parr by 30%. Steelhead (0+) were indifferent to the mitigation.

APPENDIX B

Summary of Habitat Complexing Structure Construction, Modification and/or Removal and Rationale, 1988 to 1990

Appendix B

Table B1: Summary of Habitat Complexing Construction, Modification and / or Removal and Rationale, 1988 to 1990

Location (km)	Site Number	Year / Season 88 S	88 F	89 S	89 F	90 S	90 F	Nature of Modification	Modification and/or Removal Rationale
17.9-18.6	RM17.9SC	C							
24.35	RM24.35RS		C		M		M	- thinned (89 and 90)	- to reduce debris density and increase velocities (89 and 90)
25.1	RM25.1RS		C		M		R	- separated into 2 structures (89), removed (90)	- to reduce structure size and increase velocities (89); inadequate velocities (90)
26.2	RM26.2RS		C				R	- removed (90)	- inadequate velocites (90)
30.7	RM30.7RS		C				R	- removed (90)	- anchor system failure, structure collapsed (89), inadequate velocities (90)
31.4	RM31.4BP		C						
24.4	RM24.4FC		C						
27.4	RM27.4FC		C		M			- surfical debris placed within cribbing (89)	- to provide subsurface cover (89)
25.05	RM25.05CJ		C	M			R	- weighted and boomed (89), removed (90)	- to increase stability and debris entrapment (89); inadequate (90)
32.05	RM32.05CJ		C	M				- weighted and boomed in groups (89)	- to increase stability and debris entrapment (89)
33.65	MC33.65CJ		C	M			R	- weighted and boomed (89), removed (90)	- to increase stability and debris entrapment (89); inadequate (90)
75 m d/s	**Test Section 1**							All structures in side channel (TS1 to TS4)	
	SCTS1BP1		C		M	RR		- thinned (89)	- to reduce debris density and increase velocities (89)
	SCTS1BP2		C		M	RR		- removed and replaced (90)	- original structures did not allow adequate velocities (90)
	SCTS1RS1		C		M	RR		- replaced with smaller structures partially	
	SCTS1RS2		C		M	RR		spanning channel	
	SCTS1RS3		C		M	RR			
325 m d/s	**Test Section 2**								
	SCTS2BP1		C		M	RR			
	SCTS2BP2		C		M	RR			
	SCTS2RS1		C		M	RR			
	SCTS2RS2		C		M	RR			
	SCTS2RS3		C		M	RR			
375 m d/s	**Test Section 3**								
	SCTS3BP1		C		M	RR			
	SCTS3BP2		C		M	RR			
	SCTS3RS1		C		M	RR			
	SCTS3RS2		C		M	RR			
	SCTS3RS3		C		M	RR			
475 m d/s	**Test Section 4**								
	SCTS4BP1		C		M	RR			
	SCTS4BP2		C		M	RR			
	SCTS4RS1		C		M	RR			
	SCTS4RS2		C		M	RR			
	SCTS4RS3		C		M	RR			

Appendix B (continued)

Table B1: Summary of Habitat Complexing Construction, Modification and / or Removal and Rationale, 1988 to 1990

Location (km)	Site Number	Year / Season 88 S	88 F	89 S	89 F	90 S	90 F	Nature of Modification	Modification and/or Removal Rationale
18.6	RM18.6SCDB		C			Re		- relocated to u / s end of channel (km 17.9) (90)	- to retain seeded debris and deflect river debris (90)
24.6	RM24.6PBL			C	M			- anchor system modified (89)	- to prevent stranding of structure by high flows (89)
24.7	RM24.7PBL			C	M		R	- anchor system modified (89), removed (90)	- to prevent stranding of structure by high flows (89); inadequate velocities (90)
24.8	RM24.8PBL			C	M		M	- anchor modified (89); debris added (90)	- to prevent stranding of structure by high flows (89); to fully seed trap (90)
24.9	RM24.9PBL			C	M		R	- anchor system modified (89), removed (90)	- to prevent stranding of structure by high flows (89); inadequate velocities (90)
31.0	RM31.0PBL			C	M		M	- anchor modified (89); debris added (90)	- to prevent stranding of structure by high flows (89); to fully seed trap (90)
31.1	RM31.1PBL			C	M		M	- anchor modified (89); debris added (90)	- to prevent stranding of structure by high flows (89); to fully seed trap (90)
31.3	RM31.3PBL			C	M		R	- anchor system modified (89), removed (90)	- to prevent stranding of structure by high flows(89); inadequate velocities (90)
34.7	RM34.7PDC			C					
35.4	MC35.4PDC			C					
17.0	RM17.0PB			C					
17.15	RM17.15PB			C					
17.3	RM17.3PB			C					
25.15	RM25.15RS				C		R	- second half of RM25.1RS (89), removed (90)	- inadequate velocities (90)
10.0	RM10.0DWS					C			
12.3	RM12.3DWS					C	M	- relocated in current (90)	- to improve Chinook usage during early life stage (June and July) (90)
12.4	RM12.4DWS					C	M	- relocated in current (90)	- to improve Chinook usage during early life stage (June and July) (90)
14.85	RM14.85DWS					C	M	- relocated in current (90)	- to improve Chinook usage during early life stage (June and July) (90)
14.95	RM14.95DWS					C	R	- removed (90)	- removed by 1990 cooling flows
10.2	LM10.2DWS					C	M	- relocated in current (90)	- to improve Chinook usage during early life stage (June and July) (90)
13.7	LM13.7DWS					C			
21.3	LM21.3RDC					C	M	- debris supplemented (90)	- to fully seed trap (90)
21.4	LM21.4RDC					C			
22.6	LM22.6RDC					C			
22.7	LM22.7RDC					C			
22.85	LM22.85RDC					C			
24.2	LM24.2RDC					C			
24.3	LM24.3RDC					C	M	- debris supplemented (90)	- to fully seed trap (90)
Where,	RM = right margin							RS = rootwad sweeper	C = constructed
	MC = mid-channel							BP = brush pile	M = modified
	LM = left margin							FC = floating crib	R = removed
	SC= side channel							PBL = pseudo beaver lodge	RR = removed and replaced
	TS = test section							DWS = deep water sweeper	Re = relocated
								CJ = channel jack	
								PDC = pipe-pile debris catcher	
								RDC = rail debris catcher	
								DB = debris boom	
								PB = point bar	

APPENDIX C

Physical Assessment of Habitat Complexes, 1989 to 1990

Appendix C

Table C1: Spring 1989 Physical Assessment of Habitat Complexes, 1989 to 1990

Location (km)	Site Number	Spring 1989 Physical Assessment; Q = 56.6 m³/s (2000 cfs) Observations on Physical Condition	Spring 1989 Physical Assessment; Q= 56.6 m³/s (2000 cfs) Recommendations
17.9-18.6	RM17.9SC	- channel sound	
24.35	RM24.35RS	- structure sound, miminal disruption by winter conditions	- leave in present form
24.4	RM24.4FC	- structure sound, miminal disruption by winter conditions	- leave in present form
25.05	RM25.05CJ	- several channel jacks toppled, minimal debris entrapment	- structure design modifications required
25.1	RM25.1RS	- structure sound, miminal disruption by winter conditions	- leave in present form
26.2	RM26.2RS	- structure sound, miminal disruption by winter conditions	- leave in present form
27.4	RM27.4FC	- structure sound, miminal disruption by winter conditions	- leave in present form
30.7	RM30.7RS	- structure sound, miminal disruption by winter conditions	- leave in present form
31.4	RM31.4BP	- structure sound, miminal disruption by winter conditions	- leave in present form
32.05	RM32.05CJ	- several channel jacks toppled, minimal debris entrapment	- structure design modifications required
33.65	MC33.65CJ	- several channel jacks toppled, minimal debris entrapment	- structure design modifications required

		Spring 1989 Physical Assessment; Q = 56.6 m³/s (2000 cfs)							
		U/S End of Complex		Outside Shear Zone		D/S End of Complex		Cover	Substrate
Location (km)	Site Number	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Area (m²)	c=cobble, b=boulder, g=gravel s=sand, f=fines
17.9-18.6	RM17.9SC	-	-	-	-	-	-	-	-
24.35	RM24.35RS	0.64	0.15	0.90	0.52	0.70	0.00	587.3	30%lg; 40%sg; 30%f
24.4	RM24.4FC	0.80	0.00	0.80	0.25	0.86	0.00	65.0	10%sc; 35%lg; 35%sg; 20%f
25.05	RM25.05CJ	1.10	0.37	1.80	0.48	1.82	0.22	480.0	15%sc; 40%lg; 30% sg; 15%f
25.1	RM25.1RS	0.84	0.04	1.96	0.15	0.90	0.00	529.0	40%sc; 30%lg; 10%sg; 20%f
26.2	RM26.2RS	0.90	0.15	1.62	0.52	0.72	0.00	410.0	20%sc; 50%lg; 10%sg; 20%f
27.4	RM27.4FC	1.54	0.21	2.18	0.58	0.68	0.25	112.5	20%sc; 40%lg; 10%sg; 30%f
30.7	RM30.7RS	0.98	0.23	1.58	0.98	1.08	0.00	300.0	30%lg; 20%sg; 50%f
31.4	RM31.4BP	0.78	0.23	1.06	0.69	0.74	0.00	84.0	10%sc; 60%lg; 10%sg; 20%f
32.05	RM32.05CJ	1.86	0.60	-	-	1.32	0.74	-	50%lc; 20%b; 20%sc; 10%lg
33.65	MC33.65CJ	1.74	0.59	-	-	0.90	0.91	-	20%sc; 60%lg; 10%sg; 10%f

Where,

RM = right margin	RS = rootwad sweeper	CJ = channel jack	u/s = upstream
MC = mid-channel	BP = brush pile	PDC = pipe-pile debris catcher	d/s = downstream
LM = left margin	FC = floating crib	RDC = rail debris catcher	
SC= side channel	PBL = pseudo beaver lodge	DB = debris boom	
TS = test section	DWS = deep water sweeper	PB = point bar	

Appendix C (continued)
Table C2: Fall 1989 Physical Assessment of Habitat Complexes

Location (km)	Site Number	Fall 1989 Physical Assessment; Q = 28.3 m³/s (1000 cfs) Observations on Physical Conditions	Fall 1989 Physical Assessment; Q = 28.3 m³/s (1000 cfs) Recommendations
17.0	RM17.0PB	- active erosion, flattened, excavated pool filled with sediment, submerged at Q = 2000 cfs	- leave in present form, structure should be stable at high flows
17.15	RM17.15PB	- no active erosion, surface washed of fines	- leave in present form
17.3	RM17.3PB	- no active erosion, surface washed of fines	- leave in present form
17.9-18.6	RM17.9SC	- side channel sound, damming effect due to density of habitat complexes	- remove key components of habitat complexing throughout the channel
75 m d/s		- complexes compacted and/or shifted	
	SCTS1BP1	- low velocities	
	SCTS1BP2	- deposition of fine materials on channel bottom	
	SCTS1RS1		
	SCTS1RS2		
	SCTS1RS3		
325 m d/s		- complexes compacted and/or shifted	- remove significant amount of habitat complexing
	SCTS2BP1	- habitat complexing particularly dense	- reduce material in each complex to attempt to increase flow through velocities throughout side channel
	SCTS2BP2	- low velocities	
	SCTS2RS1	- deposition of fine materials on channel bottom	
	SCTS2RS2		
	SCTS2RS3		
375 m d/s		- complexes compacted and/or shifted	
	SCTS3BP1	- low velocities	
	SCTS3BP2	- deposition of fine materials on channel bottom	
	SCTS3RS1		
	SCTS3RS2		
	SCTS3RS3		
475 m d/s		- complexes compacted and/or shifted	
	SCTS4BP1	- low velocities	
	SCTS4BP2	- deposition of fine materials on channel bottom	
	SCTS4RS1		
	SCTS4RS2		
	SCTS4RS3		
18.6	RM18.6SCDB	- structure sound, successful retainment of side channel debris	- leave in present form
24.35	RM24.35RS	- structure sound, shifted slightly d/s and inshore, velocites impeded by complex density and location	- remove every second bundle to improve velocity distribution
24.4	RM24.4FC	- structure sound, beaver lodge covered 75% of surface area	- leave in present form to avoid disturbing beavers
24.6	RM24.6PBL	- seeded debris reduced , shifted d/s, offshore corner partially submerged	- reseed with debris, anchoring system requires design modifications

Appendix C (continued)

Table C2: Fall 1989 Physical Assessment of Habitat Complexes

Location (km)	Site Number	Fall 1989 Physical Assessment; Q = 28.3 m³/s (1000 cfs) Observations on Physical Conditions	Fall 1989 Physical Assessment; Q = 28.3 m³/s (1000 cfs) Recommendations
24.7	RM24.7PBL	- seeded debris reduced , shifted d/s, offshore corner partially submerged	- reseed with debris, anchoring system requires design modifications
24.8	RM24.8PBL	- seeded debris reduced , shifted d/s, offshore corner partially submerged	- reseed with debris, anchoring system requires design modifications
24.9	RM24.9PBL	- seeded debris reduced , shifted d/s, offshore corner partially submerged	- reseed with debris, anchoring system requires design modifications
25.05	RM25.05CJ	- offshore channel jack overturned, boom debris entrapment not significant	- remove outermost channel jack and boom nearshore jack to shore
25.1	RM25.1RS	- structure too large, debris shifted d/s, velocities impeded by complex density and location	- separate into 2 structures
26.2	RM26.2RS	- structure too large, debris significantly shifted d/s, velocities impeded by complex density and location	- thin debris to increase flow through velocities
27.4	RM27.4FC	- structure sound, shifted slightly d/s, debris providing surficial cover only	- cut and place excess debris on top of structure within cribbing
30.7	RM30.7RS	- shifted 70 m d/s, orientated parallel to shore, velocities impeded by complex density and location	- leave in present form
31.0	RM31.0PBL	- seeded debris reduced , shifted d/s, offshore corner partially submerged	- reseed with debris, anchoring system requires design modifications
31.1	RM31.1PBL	- seeded debris reduced , shifted d/s, offshore corner partially submerged	- reseed with debris, anchoring system requires design modifications
31.3	RM31.3PBL	- seeded debris reduced , shifted d/s, offshore corner partially submerged	- reseed with debris, anchoring system requires design modifications
31.4	RM31.4BP	- structure sound, position unchanged, debris density adequate	- leave in present form
32.05	RM32.05CJ	- offshore channel jack overturned, some debris entrapment by nearshore channel jacks	- remove outermost channel jack and boom nearshore jack to shore
33.65	MC33.65CJ	- portion of structure overturned, but significant debris entrapment	- remove, design inadequate for selected site
34.7	RM34.7PDC	- outermost piling leaning at 15-20 degrees, significant debris entrapment	- do not repair, strengthen outermost pile in future installations
35.4	MC35.4PDC	- outermost piling leaning at 15-20 degrees, significant debris entrapment	- do not repair, strengthen outermost pile in future installations

Where,

RM = right margin
MC = mid-channel
LM = left margin
SC= side channel
TS = test section

RS = rootwad sweeper
BP = brush pile
FC = floating crib
PBL = pseudo beaver lodge
DWS = deep water sweeper
CJ = channel jack
PDC = pipe-pile debris catcher
RDC = rail debris catcher
DB = debris boom
PB = point bar

u/s = upstream
d/s = downstream

Appendix C (continued)

Table C3: Post Forced Spill Spring 1990 Physical Assessment of Habitat Complexes

Location (km)	**Site Number**	**Spring 1990 Physical Assessment; Q = 72.5 m³/s (2560 cfs) (post forced spill) Observations on Physical Conditions**	**Spring 1990 Physical Assessment; Q = 72.5 m³/s (2560 cfs) Recommendations**
17.0	RM17.0PB	- active erosion, structure sound	- leave in present form
17.15	RM17.15PB	- structure sound	- leave in present form
17.3	RM17.3PB	- structure sound	- leave in present form
17.9-18.6	RM17.9SC	- excess debris washed into side channel by high flows	- remove all existing habitat complexes
75 m d/s		- complexes compacted and/or shifted	- recomplex with smaller structures
	SCTS1BP1	- low velocities	- relocate side channel debris boom at u/s end
	SCTS1BP2	- deposition of fine materials on channel bottom	of channel to prevent entry of excess debris
	SCTS1RS1		during high flows
	SCTS1RS2		
	SCTS1RS3		
325 m d/s		- complexes compacted and/or shifted	
	SCTS2BP1	- habitat complexing particularly dense	
	SCTS2BP2	- low velocities	
	SCTS2RS1	- deposition of fine materials on channel bottom	
	SCTS2RS2		
	SCTS2RS3		
375 m d/s		- complexes compacted and/or shifted	
	SCTS3BP1	- low velocities	
	SCTS3BP2	- deposition of fine materials on channel bottom	
	SCTS3RS1		
	SCTS3RS2		
	SCTS3RS3		
475 m d/s		- complexes compacted and/or shifted	
	SCTS4BP1	- low velocities	
	SCTS4BP2	- deposition of fine materials on channel bottom	
	SCTS4RS1		
	SCTS4RS2		
	SCTS4RS3		
18.6	RM18.6SCDB	- structure sound, successful retainment of side channel debris	- relocate to u/s end of channel
24.35	RM24.35RS	- structure sound, hydraulic performance impeded by complex density	- thin complex to increase flow through velocities
24.4	RM24.4FC	- structure sound, beaver lodge covered 100% of surface area	- leave in present form to avoid disturbing beavers
24.6	RM24.6PBL	- structure sound, seeded debris fully maintained	- leave in present form
24.7	RM24.7PBL	- structure sound, seeded debris reduced , very little debris remaining	- leave in present form
24.8	RM24.8PBL	- seeded debris significantly reduced , structure partially submerged	- supplement debris
24.9	RM24.9PBL	- structure sound, washed of all seeded debris, location of low velocities	- leave in present form

Appendix C (continued)

Table C3: Post Forced Spill Spring 1990 Physical Assessment of Habitat Complexes

Location (km)	Site Number	Spring 1990 Physical Assessment; Q = 72.5 m^3/s (2560 cfs) (post forced spill) Observations on Physical Conditions	Spring 1990 Physical Assessment; Q = 72.5 m^3/s (2560 cfs) Recommendations
25.05	RM25.05CJ	- channel jacks stable, limited debris entrapment	- leave in present form
25.1	RM25.1RS	- structure sound, location of low velocities	- leave in present form
25.15	RM25.15RS	- structure sound, location of low velocities	- leave in present form
26.2	RM26.2RS	- structure collapsed	- leave in present form
27.4	RM27.4FC	- structure sound, seeded debris intact	- leave in present form
30.7	RM30.7RS	- structure sound, shifted out of main current	- leave in present form
31.0	RM31.0PBL	- seeded debris significantly reduced, cover thin	- supplement debris
31.1	RM31.1PBL	- seeded debris significantly reduced	- supplement debris
31.3	RM31.3PBL	- seeded debris significantly reduced, almost no debris remaining	- leave in present form
31.4	RM31.4BP	- structure sound	- leave in present form
32.05	RM32.05CJ	- channel jacks stable, debris entrapment, small log jam	- leave in present form
33.65	MC33.65CJ	- outermost channel jack overturned, almost all seeded debris removed	- leave in present form
34.7	RM34.7PDC	- significant debris entrapment, very large log jam	- leave in present form
35.4	MC35.4PDC	- significant debris entrapment, very large log jam	- leave in present form

Appendix C (continued)
Table C4: Summer 1990 Physical Assessment of Habitat Complexes

		Summer 1990 Physical Assessment; Q = 56.6 m³/s (2000 cfs) (pre-summer program)							
		U/S End of Complex		Outside Shear Zone		D/S End of Complex		Cover	Substrate
Location (km)	Site Number	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Area (m^2)	c=cobble, b=boulder, g=gravel s=sand, f=fines
10.0	RM10.0DWS	-	-	-	0.39	-	-	10.5	-
10.2	LM10.2DWS	-	-	-	0.16	-	0.02	12.5	-
12.3	RM12.3DWS	-	0.42	-	0.63	-	0.38	31.3	-
12.4	RM12.4DWS	-	0.12	-	0.70	-	0.01	35.0	-
13.7	LM13.7DWS	-	0.01	-	0.01	-	0.00	45.0	-
14.85	RM14.85DWS	-	0.13	-	0.71	-	0.09	25.0	-
14.95	RM14.95DWS	-	0.07	-	0.85	-	0.22	28.8	-
17.0	RM17.0PB	-	-	-	-	-	-	-	-
17.15	RM17.15PB	-	-	-	-	-	-	-	-
17.3	RM17.3PB	-	-	-	-	-	-	-	-
17.9-18.6	RM17.9SC	-	-	-	-	-	-	-	-
21.3	LM21.3RDC	0.80	0.26	1.15	0.63	0.80	0.26	12.0	-
21.4	LM21.4RDC	0.70	0.26	1.20	0.79	0.70	0.15	14.0	-
22.6	LM22.6 RDC	0.70	0.25	1.10	0.82	0.65	0.10	28.0	-
22.7	LM22.7RDC	0.60	0.15	1.10	0.73	0.65	0.22	36.0	-
22.85	LM22.85RDC	0.80	0.59	1.20	0.95	0.75	0.10	31.0	-
24.2	LM24.2RDC	0.75	0.40	1.15	1.00	0.80	0.20	14.0	-
24.3	LM24.3RDC	0.75	0.24	1.00	0.62	0.70	0.20	15.0	-
24.35	RM24.35RS	-	-	-	-	-	-	-	-
24.4	RM24.4FC	-	-	-	-	-	-	-	-
24.6	RM24.6PBL	-	-	-	-	-	-	-	-
24.7	RM24.7PBL	-	-	-	-	-	-	-	-
24.8	RM24.8PBL	-	-	-	-	-	-	-	-
24.9	RM24.9PBL	-	-	-	-	-	-	-	-
25.05	RM25.05CJ	-	-	-	-	-	-	-	-
25.1	RM25.1RS	-	-	-	-	-	-	-	-
25.15	RM25.15RS	-	-	-	-	-	-	-	-
26.2	RM26.2RS	-	-	-	-	-	-	-	-
27.4	RM27.4FC	-	-	-	-	-	-	-	-
30.7	RM30.7RS	-	-	-	-	-	-	-	-
31.0	RM31.0PBL	-	-	-	-	-	-	-	-

Appendix C (continued)
Table C4: Summer 1990 Physical Assessment of Habitat Complexes

		Summer 1990 Physical Assessment; Q = 56.6 m^3/s (2000 cfs) (pre-summer program)							
		U/S End of Complex		Outside Shear Zone		D/S End of Complex		Cover	Substrate
Location (km)	Site Number	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Area (m^2)	c=cobble, b=boulder, g=gravel s=sand, f=fines
31.1	RM31.1PBL	-	-	-	-	-	-	-	-
31.3	RM31.3PBL	-	-	-	-	-	-	-	-
31.4	RM31.4BP	-	-	-	-	-	-	-	-
32.05	RM32.05CJ	-	-	-	-	-	-	-	-
33.65	MC33.65CJ	-	-	-	-	-	-	-	-
34.7	RM34.7PDC	-	-	-	-	-	-	-	-
35.4	MC35.4PDC	-	-	-	-	-	-	-	-

Where,
RM = right margin
MC = mid-channel
LM = left margin
SC= side channel
TS = test section

RS = rootwad sweeper
BP = brush pile
FC = floating crib
PBL = pseudo beaver lodge
DWS = deep water sweeper
CJ = channel jack
PDC = pipe-pile debris catcher
RDC = rail debris catcher
DB = debris boom
PB = point bar

u/s = upstream
d/s = downstream

Appendix C (continued)
Table C5: Fall 1990 Physical Assessment of Habitat Complexes

Location (km)	Site Number	Fall 1990 Physical Assesment; Q = 28.3 m³/s (1000 cfs) Observations on Physical Conditions	Fall 1990 Physical Assessment: Q = 28.3 m³/s (1000 cfs) Recommendations
10.0	RM10.0DWS	- structure reduced in size, shifted downstream	- relocate in current
10.2	LM10.2DWS	- structure sound, offshore end shifted inshore, partially de-watered	- relocate in current
12.3	RM12.3DWS	- structure sound, offshore end shifted inshore, totally de-watered	- relocate in current
12.4	RM12.4DWS	- structure sound, offshore end shifted inshore, partially de-watered	- relocate in current
13.7	LM13.7DWS	- structure sound, offshore end shifted inshore, partially de-watered	- relocated in current
14.85	RM14.85DWS	- structure sound, offshore end shifted inshore, totally de-watered	- relocate in current
14.95	RM14.95DWS	- RM14.95DWS Removed By 1990 Cooling Flows	- N / A
17.0	RM17.0PB	- structure sound, submerged at Q = 2000 cfs	- leave in present form
17.15	RM17.15PB	- structure sound, submerged at Q = 8000 cfs	- leave in present form
17.3	RM17.3PB	- structure sound, submerged at Q = 3000 cfs	- leave in present form
17.9-18.6	RM17.9SC	- RM17.9SC Recomplexed in the Spring of 1990	
		- recomplexing consisted of sweepers laid into the RB of the channel or salvaged log debris partially buried in the LB of the channel	
		- these features extended up to a maximum of 2 / 3 of the channel width, were angled d / s to deflect future debris and spaced 30 m apart	
		- new complex structures sound, flows and velocities in lower part of design criteria range, insufficient cover area	- supplement recomplexed regions with debris
17.9	RM17.9*SCDB	- debris boom sound, retained seeded debris and deflected river debris	- leave in present form (*relocated from km 18.6)
21.3	LM21.3RDC	- minimal debris entrapment, seeded debris significantly reduced	- supplement with additional debris
21.4	LM21.4RDC	- structure sound, significant debris entrapment, large log jam	- leave in present form
22.6	LM22.6RDC	- structure sound, significant debris entrapment, large log jam	- leave in present form
22.7	LM22.7RDC	- structure sound, significant debris entrapment, large log jam	- leave in present form
22.85	LM22.85RDC	- structure sound, some debris entrapment	- leave in present form
24.2	LM24.2RDC	- structure sound, significant debris entrapment, colonized by beavers	- leave in present form to avoid disturbing beavers
24.3	LM24.3RDC	- structure sound, no debris entrapment, seeded debris reduced	- supplement with additional debris
24.35	RM24.35RS	- structure sound and stable, low velocities	- thin to reduce complex density
24.4	RM24.4FC	- structure sound, 100% of surface area covered by a beaver lodge	- leave in present form to avoid disturbing beavers
24.6	RM24.6PBL	- structure sound, significant debris entrapment, large log jam	- leave in present form
24.7	RM24.7PBL	- structure sound, seeded debris significantly reduced, low velocities	- remove, inadequate velocities, u / s of constriction*
24.8	RM24.8PBL	- structure sound, seeded debris significantly reduced	- supplement with additional debris
24.9	RM24.9PBL	- structure sound, seeded debris significantly reduced, low velocities	- remove, inadequate velocities, u / s of constriction*
25.05	RM25.05CJ	- structure sound, virtually no debris entrapment	- remove, no debris entrapment, design inadequate
25.1	RM25.1RS	- structure sound and stable, low velocities	- remove, inadequate velocities, u / s of constriction*
25.15	RM25.15RS	- structure sound and stable, low velocities	- remove, inadequate velocities, u / s of constriction*
26.2	RM26.2RS	- structure sound and stable, low velocities	- remove, inadequate velocities

Appendix C (continued)

Table C5: Fall 1990 Physical Assessment of Habitat Complexes

Location (km)	Site Number	Fall 1990 Physical Assesment; Q = 28.3 m^3/s (1000 cfs) Observations on Physical Conditions	Fall 1990 Physical Assessment: Q = 28.3 m^3/s (1000 cfs) Recommendations
27.4	RM27.4FC	- structure sound and stable, low velocities	- reorient 90 degrees to improve velocities
30.7	RM30.7RS	- structure remains shifted d/s and collapsed, low velocities	- remove, inadequate velocities
31.0	RM31.0PBL	- structure sound, seeded debris signficantly reduced	- supplement with additional debris
31.1	RM31.1PBL	- structure sound, seeded debris signficantly reduced	- supplement with additional debris
31.3	RM31.3PBL	- structure sound, seeded debris significantly reduced , low velocities	- remove, inadequate velocities
31.4	RM31.4BP	- structure sound and stable	- leave in present form
32.05	RM32.05CJ	- structure sound, debris entrapment, log jam	- leave in present form
33.65	MC33.65CJ	- channel jacks overturned,no debris entrapment	- remove, no debris entrapment, design inadequate
34.7	RM34.7PDC	- significant debris entrapment, large log jam	- leave in present form
35.4	MC35.4PDC	- significant debris entrapment, large log jam	- leave in present form

* km 25.4 - location of hydraulic constriction

Appendix C (continued)
Table C5: Fall 1990 Physical Assessment of Habitat Complexes

		Fall 1990 Assessment; Q = 28.3 m3/s (1000 cfs)							
		U/S End of Complex		Outside Shear Zone		D/S End of Complex		Cover	Substrate
Location (km)	Site Number	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Area (m2)	c=cobble, b=boulder, g=gravel s=sand, f=fines
10.0	RM10.0DWS	-	-	-	-	-	-	10.5	-
10.2	LM10.2DWS	-	-	-	-	-	-	5.0	-
12.3	RM12.3DWS	-	-	-	-	-	-	2.0	-
12.4	RM12.4DWS	-	-	-	-	-	-	1.0	-
13.7	LM13.7DWS	-	-	-	-	-	-	45.0	-
14.85	RM14.85DWS	-	-	-	-	-	-	1.0	-
14.95	RM14.95DWS	-	-	RM14.95DWS Removed By 1990 Cooling Flows				-	-
17.0	RM17.0PB	-	-	-	-	-	-	-	-
17.15	RM17.15PB	-	-	-	-	-	-	-	-
17.3	RM17.3PB	-	-	-	-	-	-	-	-
17.9-18.6	RM17.9SC	-	-	-	-	-	-	-	-
21.3	LM21.3RDC	0.60	0.29	0.90	0.58	0.52	0.13	5.0	-
21.4	LM21.4RDC	0.93	0.30	1.60	0.53	0.50	0.09	43.3	-
22.6	LM22.6 RDC	0.98	0.15	1.14	0.41	0.82	0.10	49.6	-
22.7	LM22.7RDC	0.50	0.13	0.80	0.52	0.26	0.05	24.0	-
22.85	LM22.85RDC	0.38	0.19	0.90	0.38	0.48	0.04	27.7	-
24.2	LM24.2RDC	0.92	0.47	1.10	0.73	0.66	0.01	36.7	-
24.3	LM24.3RDC	0.62	0.33	0.75	0.54	0.38	0.16	10.8	-
24.35	RM24.35RS	0.26	0.16	0.36	0.29	0.44	0.04	-	-
24.4	RM24.4FC	0.46	0.12	0.68	0.28	0.22	0.00	-	-
24.6	RM24.6PBL	0.70	0.22	1.05	0.40	0.90	0.16	120.0	-
24.7	RM24.7PBL	0.54	0.06	0.93	0.13	0.52	0.09	-	-
24.8	RM24.8PBL	0.68	0.14	0.95	0.27	0.47	0.03	-	-
24.9	RM24.9PBL	0.52	0.15	0.96	0.26	0.94	0.05	-	-
25.05	RM25.05CJ	0.24	0.04	0.80	0.25	1.14	0.01	-	-
25.1	RM25.1RS	0.74	0.21	1.00	0.23	0.20	0.04	-	-
25.15	RM25.15RS	0.50	0.04	0.90	0.10	0.51	0.00	-	-

Appendix C (continued)
Table C5: Fall 1990 Physical Assessment of Habitat Complexes

		Fall 1990 Assessment; Q = 28.3 m3/s (1000 cfs)							
		U/S End of Complex		Outside Shear Zone		D/S End of Complex		Cover	Substrate
Location	Site	Depth	Velocity	Depth	Velocity	Depth	Velocity	Area	c=cobble, b=boulder, g=gravel
(km)	Number	(m)	(m/s)	(m)	(m/s)	(m)	(m/s)	(m2)	s=sand, f=fines
26.2	RM26.2RS	0.96	0.16	0.88	0.25	0.40	0.04	-	-
27.4	RM27.4FC	0.75	0.14	1.30	0.28	0.40	0.00	48.0	-
30.7	RM30.7RS	0.95	0.05	1.80	0.08	0.55	0.00	75.0	-
31.0	RM31.0PBL	0.90	0.24	1.45	0.35	0.45	0.10	21.0	-
31.1	RM31.1PBL	0.58	0.13	1.70	0.32	0.40	0.13	28.0	-
31.3	RM31.3PBL	0.25	0.12	1.18	0.25	0.38	0.12	0.0	-
31.4	RM31.4BP	0.47	0.18	0.70	0.22	0.52	0.07	25.0	-
32.05	RM32.05CJ	0.70	0.20	1.00	0.65	0.25	0.16	210.0	-
33.65	MC33.65CJ	1.30	0.26	1.00	0.31	0.80	0.34	5.0	-
34.7	RM34.7PDC	1.18	0.27	1.30	0.70	0.80	0.00	400.0	-
35.4	MC35.4PDC	1.06	0.13	1.05	0.36	0.85	0.10	510.0	-

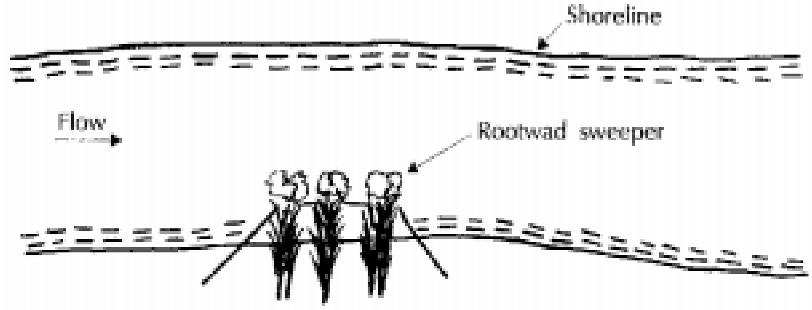
Where,
RM = right margin
MC = mid-channel
LM = left margin
SC= side channel
TS = test section

RS = rootwad sweeper
BP = brush pile
FC = floating crib
PBL = pseudo beaver lodge
DWS = deep water sweeper
CJ = channel jack
PDC = pipe-pile debris catcher
RDC = rail debris catcher
DB = debris boom
PB = point bar

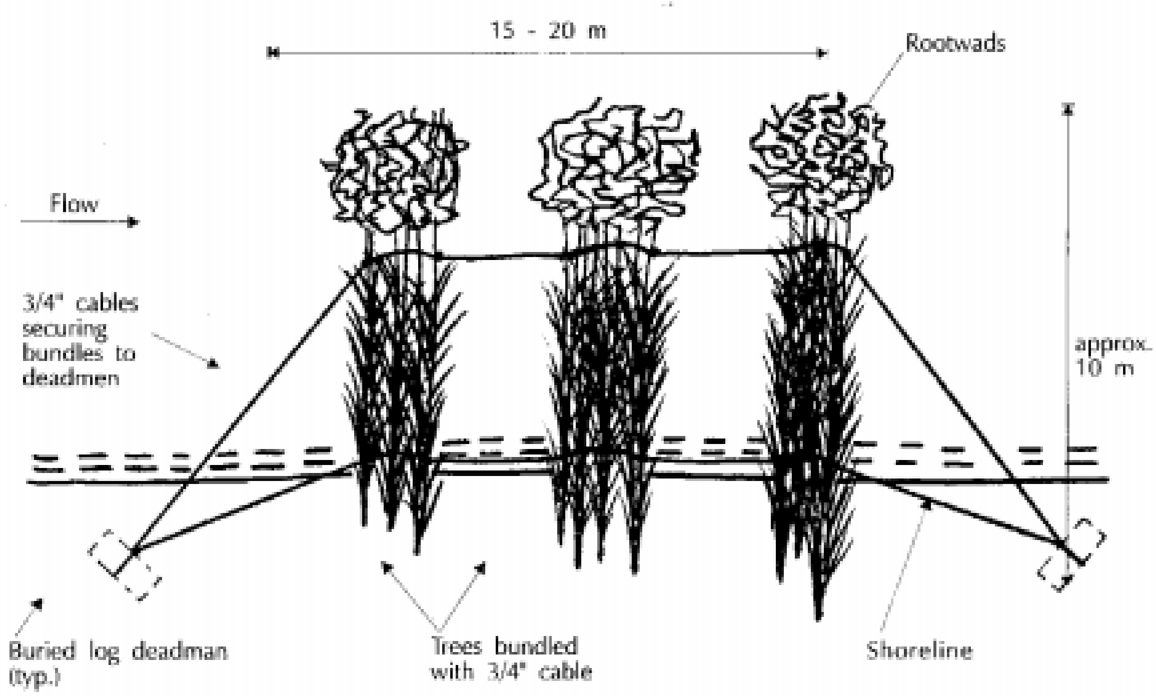
u/s = upstream
d/s = downstream

APPENDIX D

Sketches of Habitat Complexes (As Built), 1988 to 1990

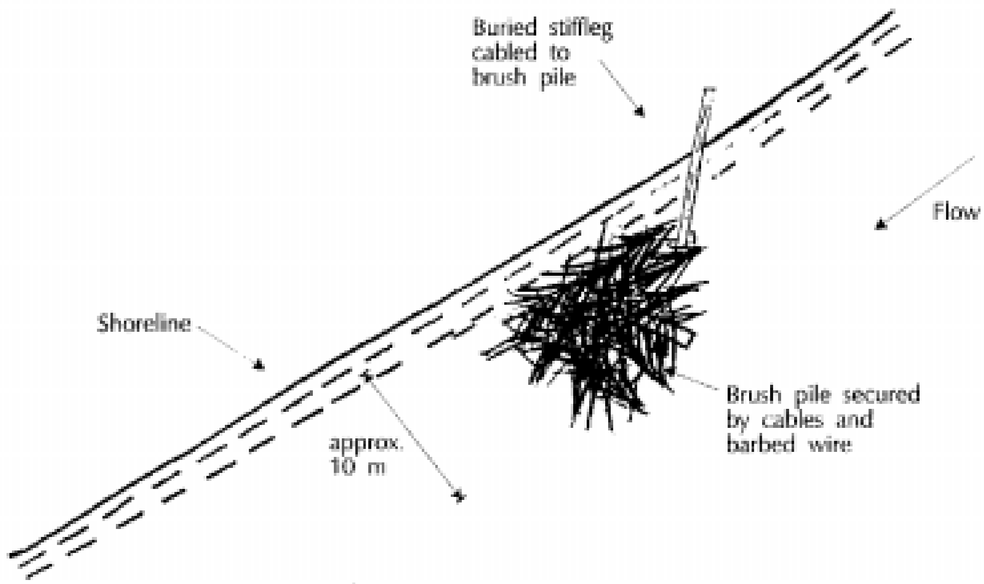


PLAN



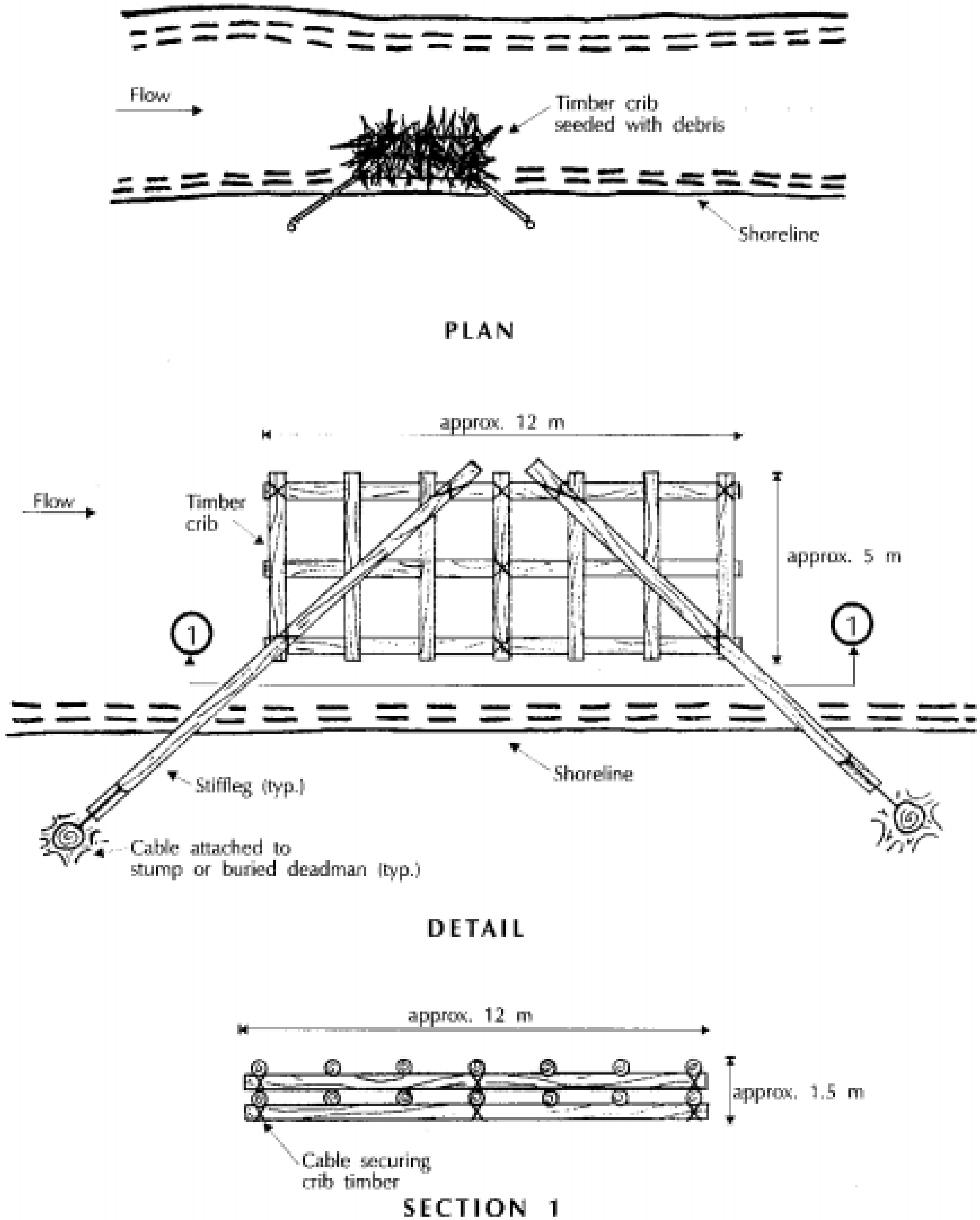
DETAIL

Nechako Fisheries Conservation Program	Map # RM903-1a	Not To Scale
FIGURE 1. ROOT WAD SWEEPER (1988)		

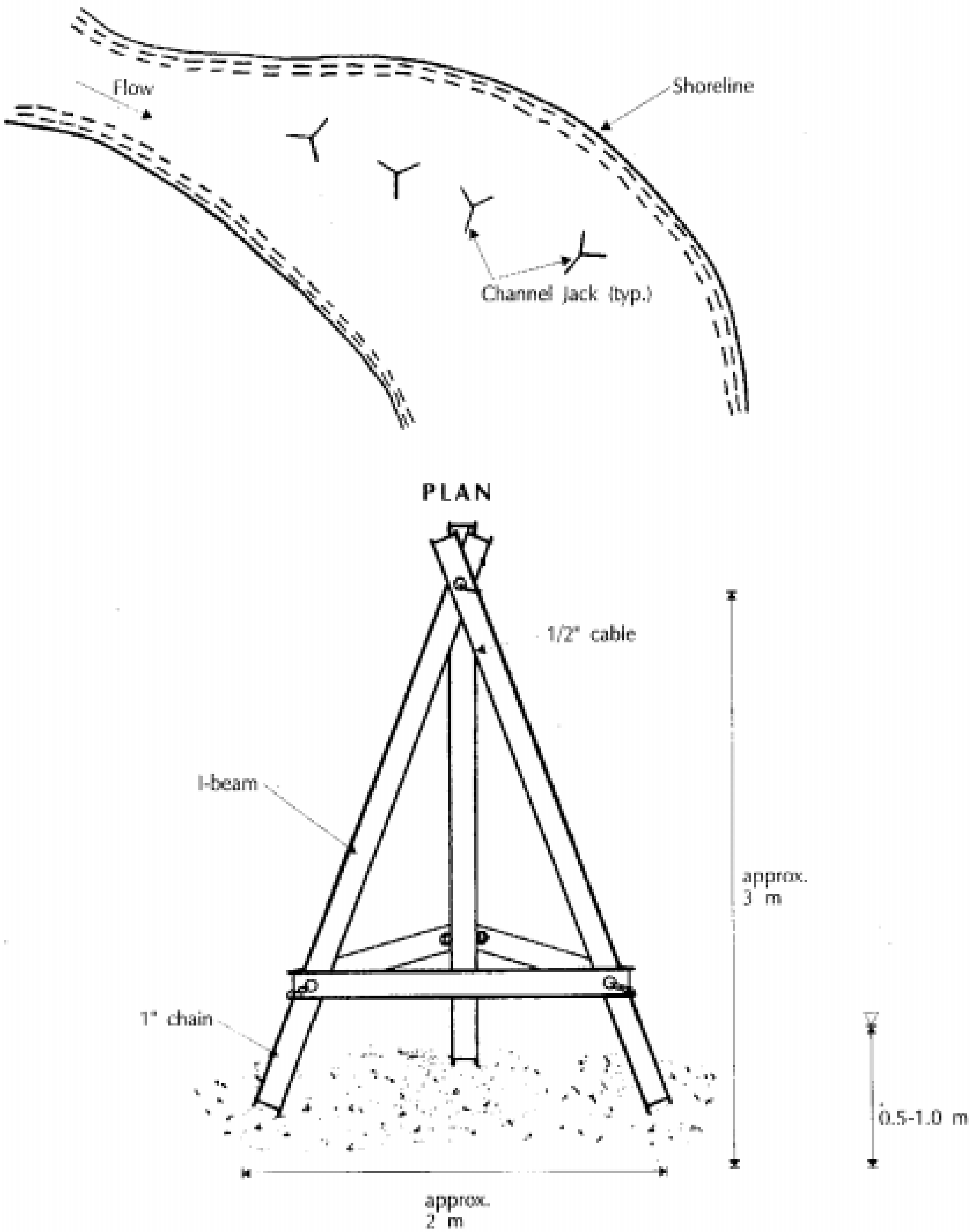


PLAN

Nechako Fisheries Conservation Program	Map # RM903-2a	Not To Scale
FIGURE 2. MAINSTEM BRUSH PILE (1988)		

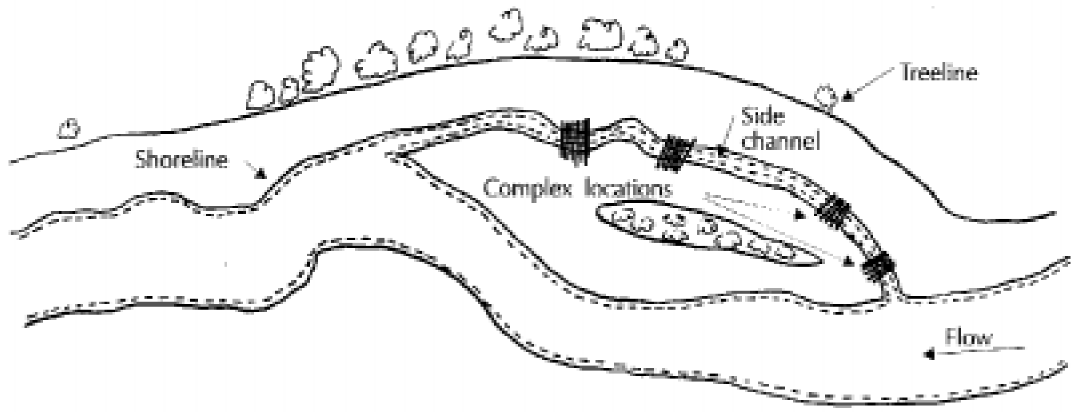


Nechako Fisheries Conservation Program	Map # RM903-3a	Not To Scale
FIGURE 3. FLOATING CRIB (1988)		

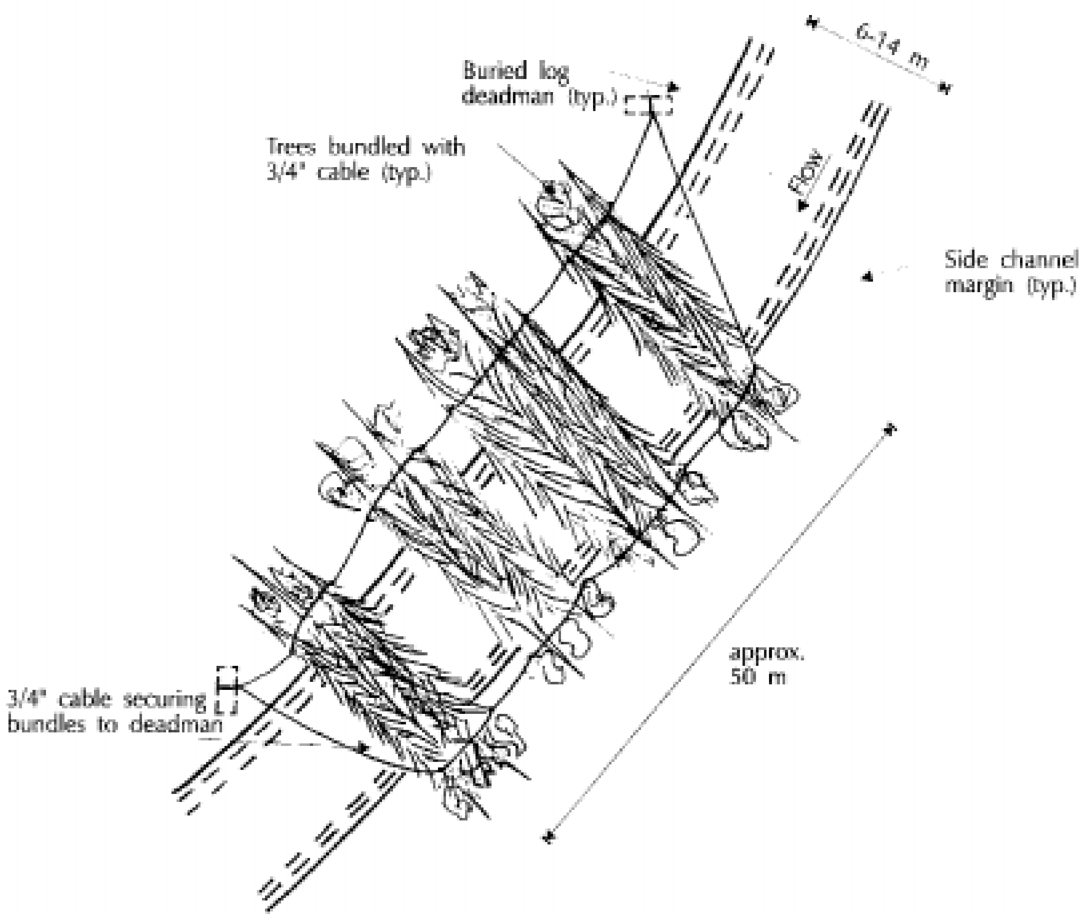


DETAIL (ELEVATION)

Nechako Fisheries Conservation Program	Map # RM903-4a	Not To Scale
FIGURE 4. CHANNEL JACKS (1988)		

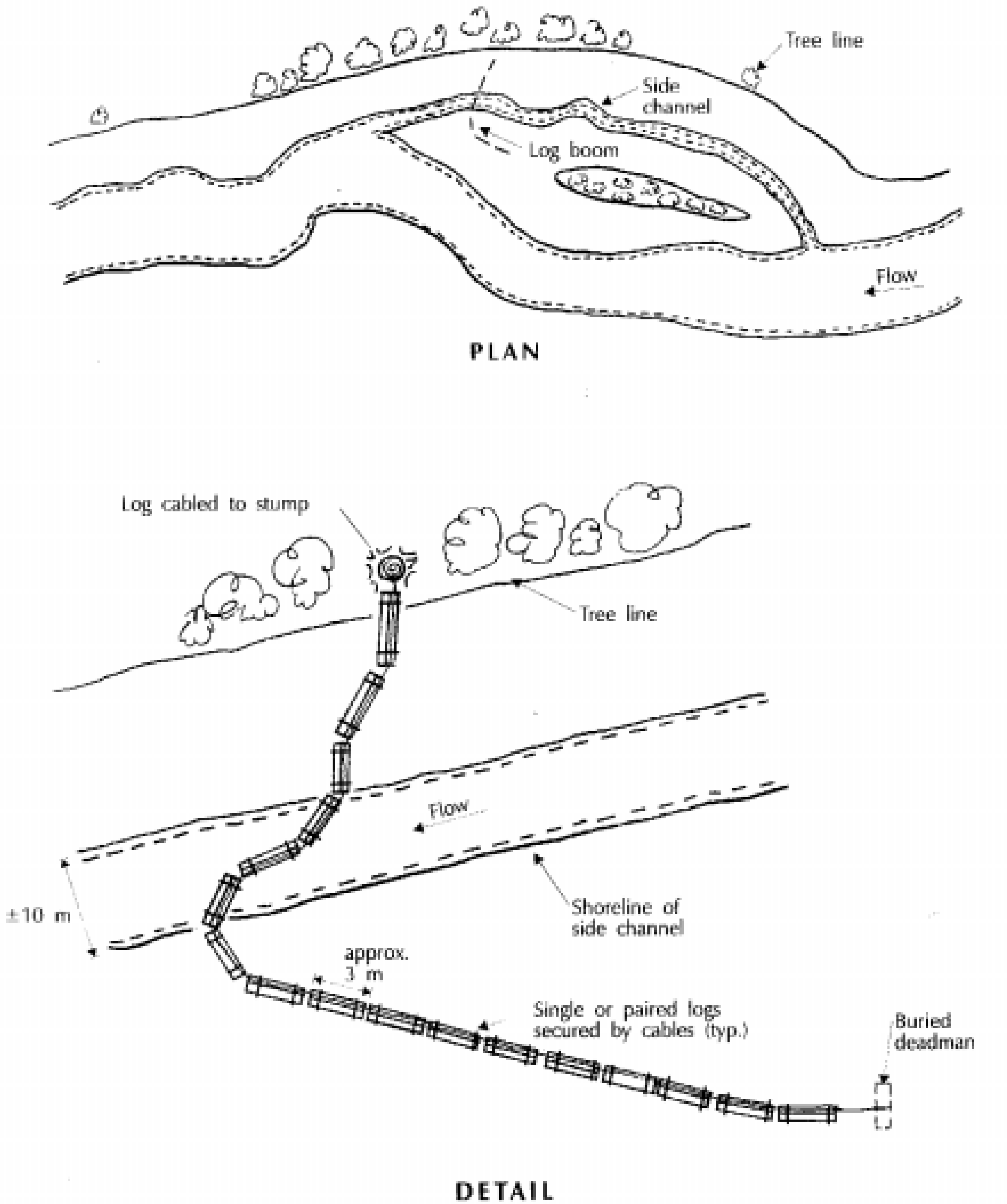


PLAN

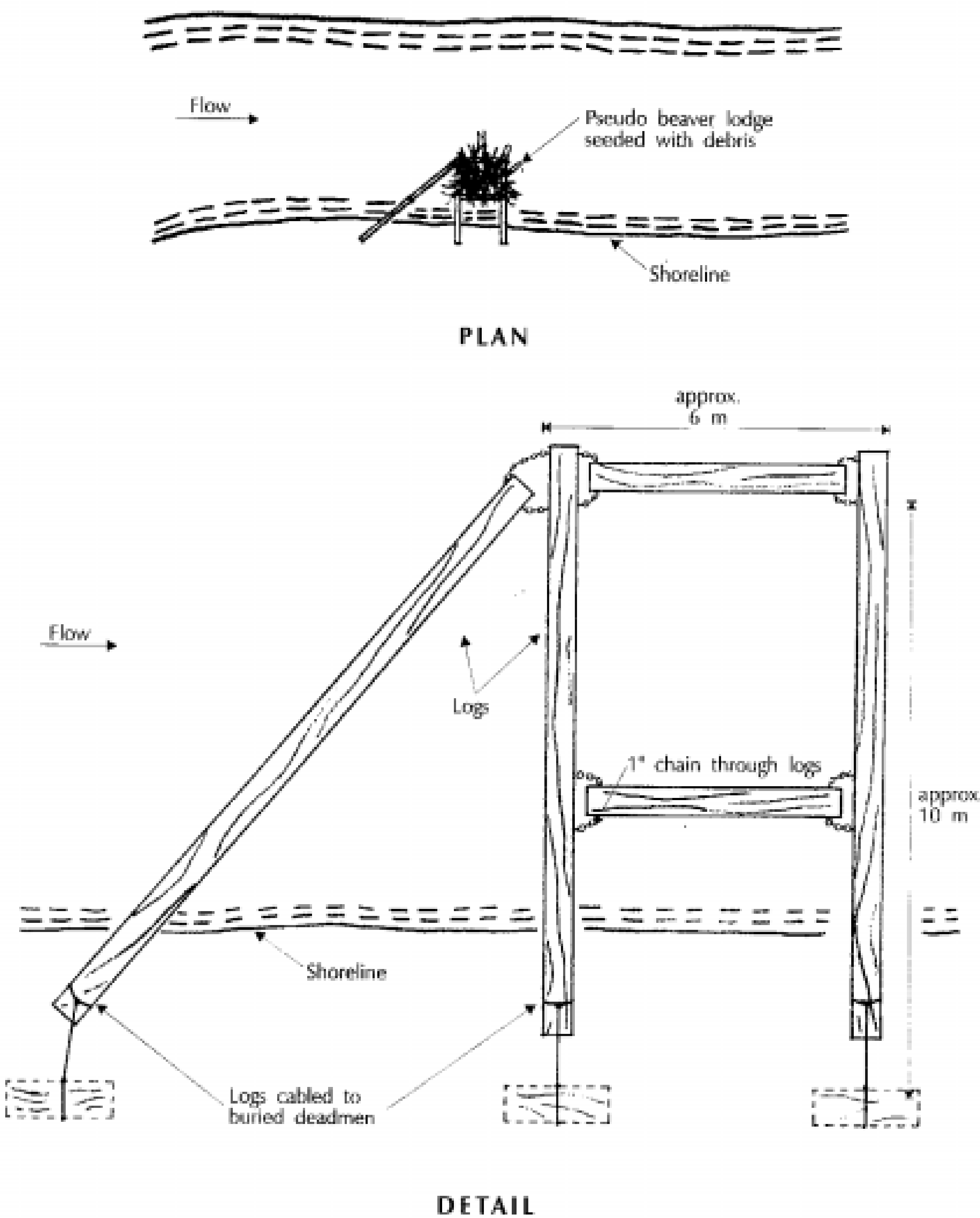


DETAIL

Nechako Fisheries Conservation Program	Map # RM903-5a	Not To Scale
FIGURE 5. SIDE CHANNEL BRUSH PILE (1988)		



Nechako Fisheries Conservation Program	Map # RM903-6a	Not To Scale
FIGURE 6. SIDE CHANNEL DEBRIS BOOM (1988)		

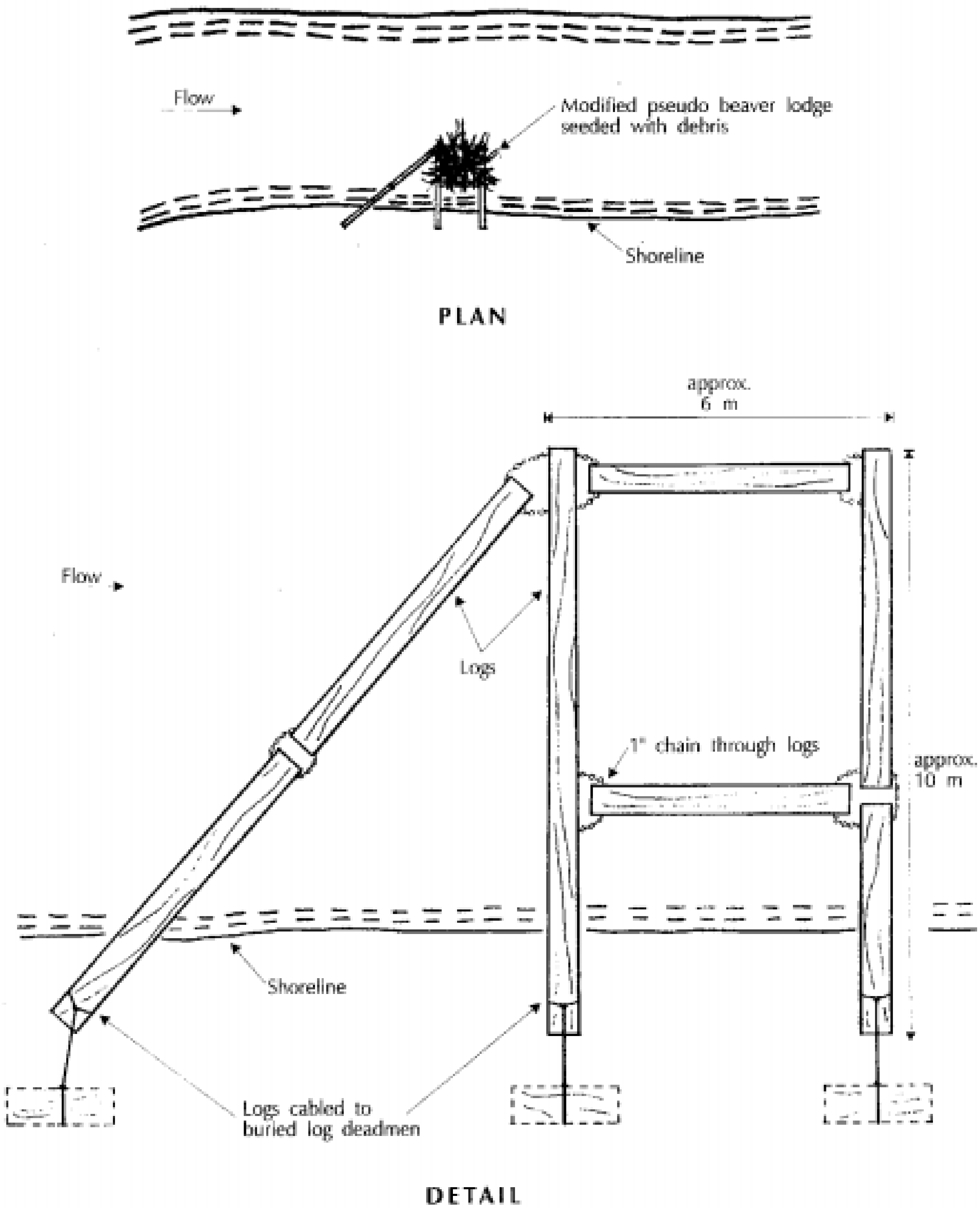


Nechako Fisheries Conservation Program

Map # RM903-7a

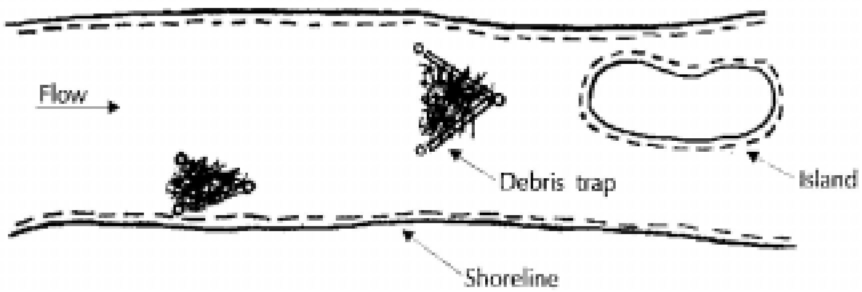
Not To Scale

FIGURE 7. PSEUDO BEAVER LODGE (SPRING 1989)

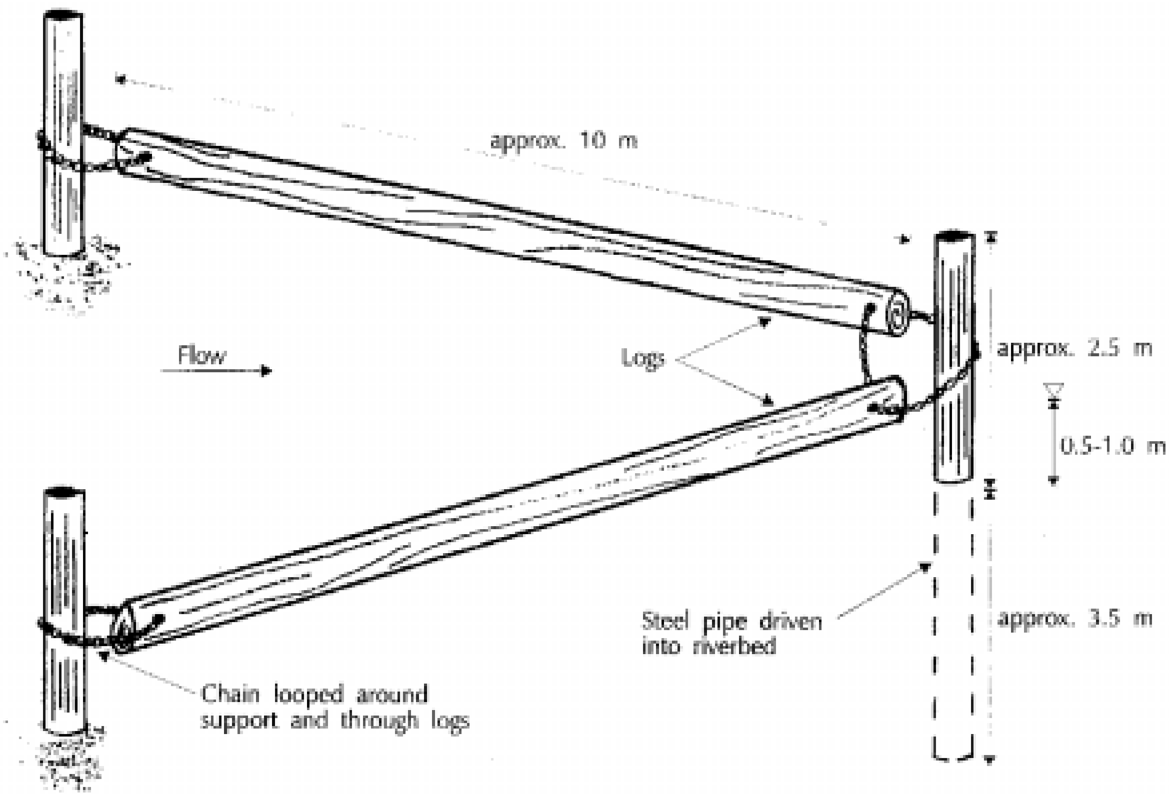


Nechako Fisheries Conservation Program | Map # RM903-8a | Not To Scale

FIGURE 8. PSEUDO BEAVER LODGE (FALL 1989)

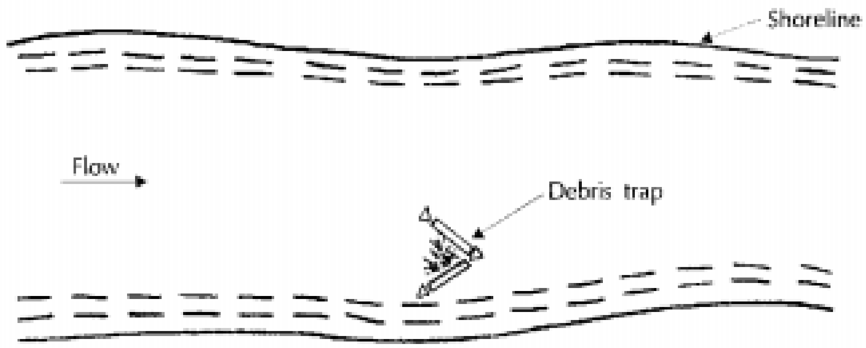


PLAN

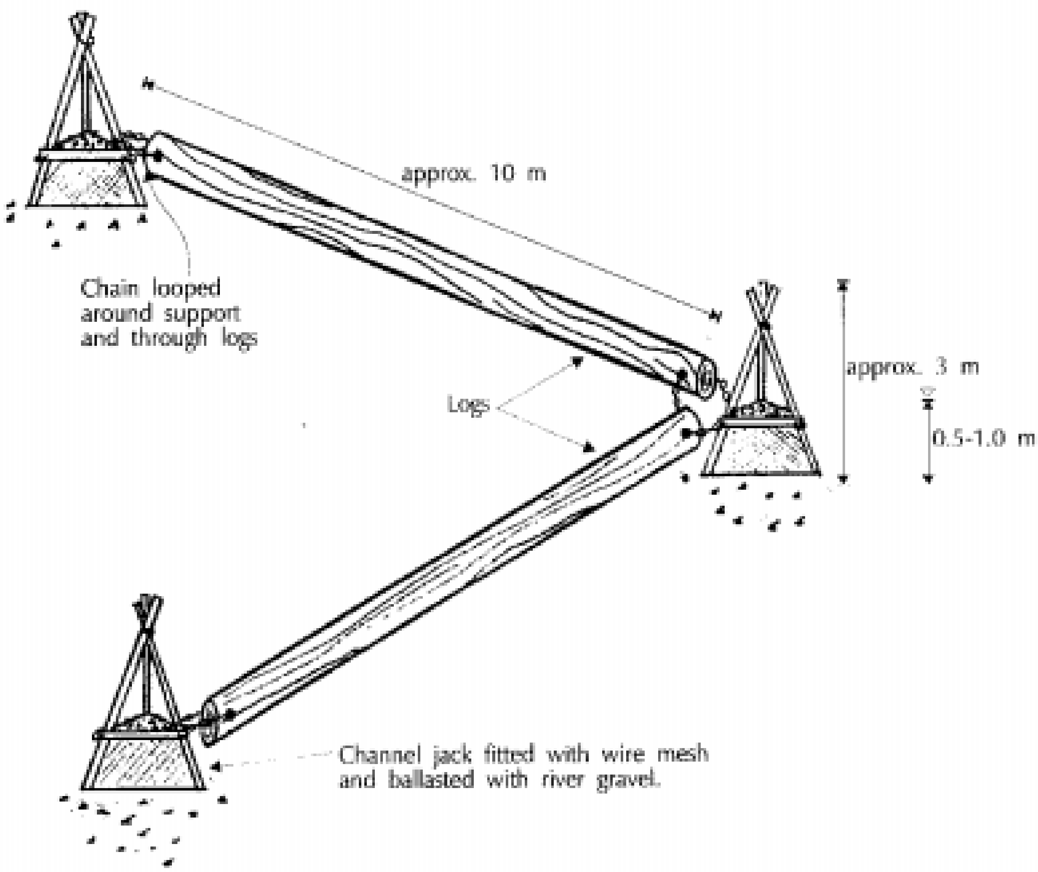


DETAIL

Nechako Fisheries Conservation Program	Map # RM903-9a	Not To Scale
FIGURE 9. PIPE PILE DEBRIS CATCHER (1989)		

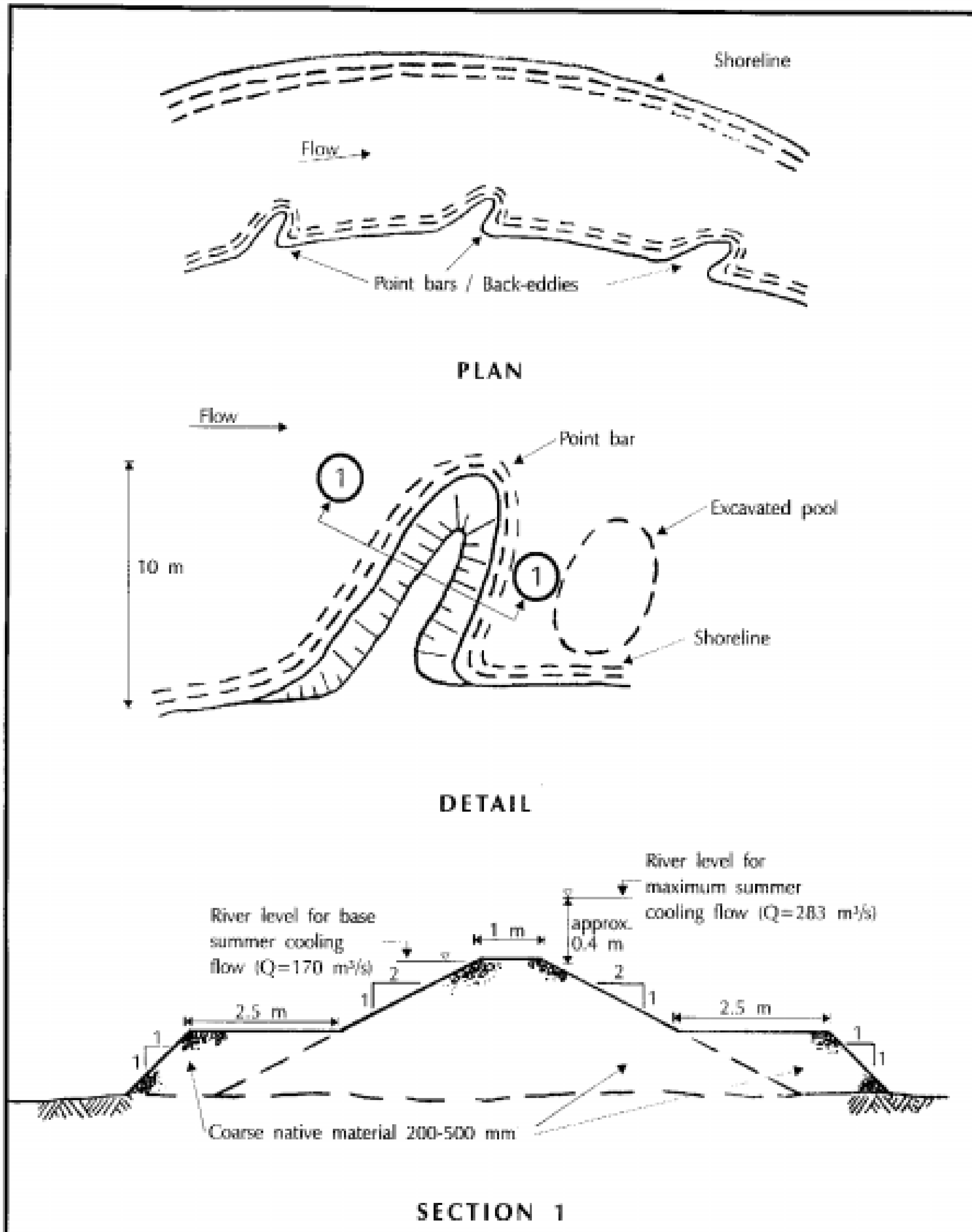


PLAN

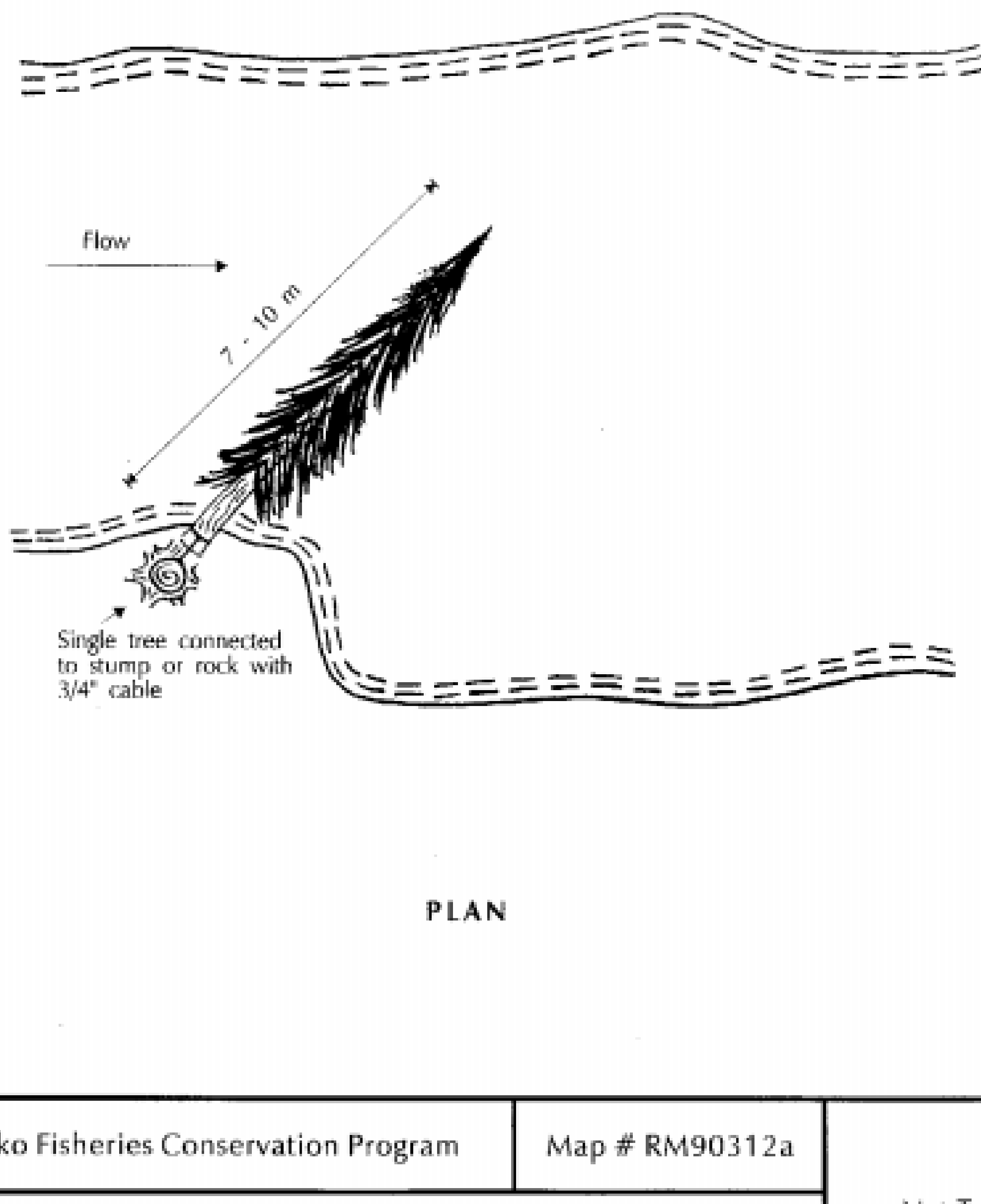


DETAIL

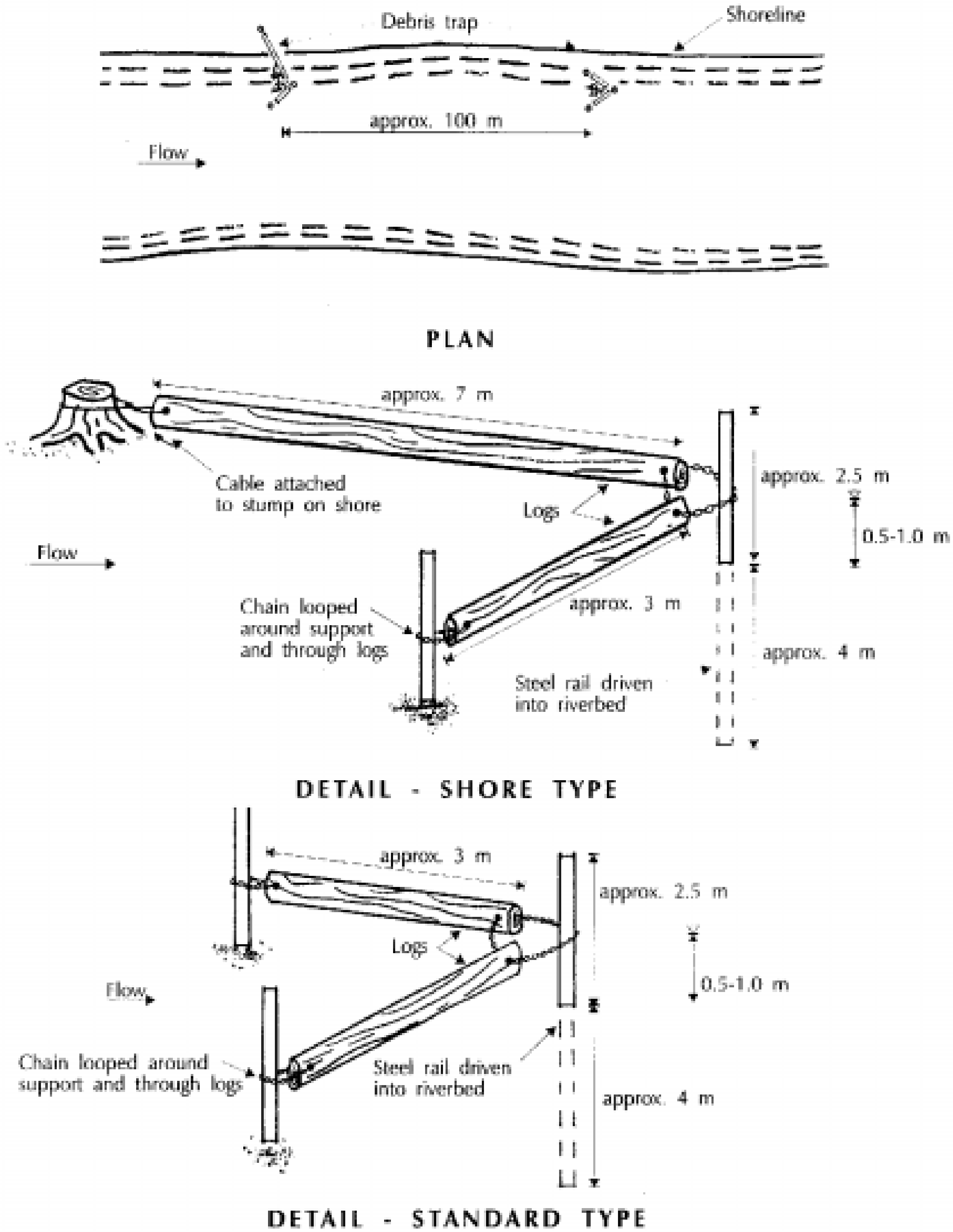
Nechako Fisheries Conservation Program	Map # RM90310a	Not To Scale
FIGURE 10. CHANNEL JACK DEBRIS CATCHER (1989)		



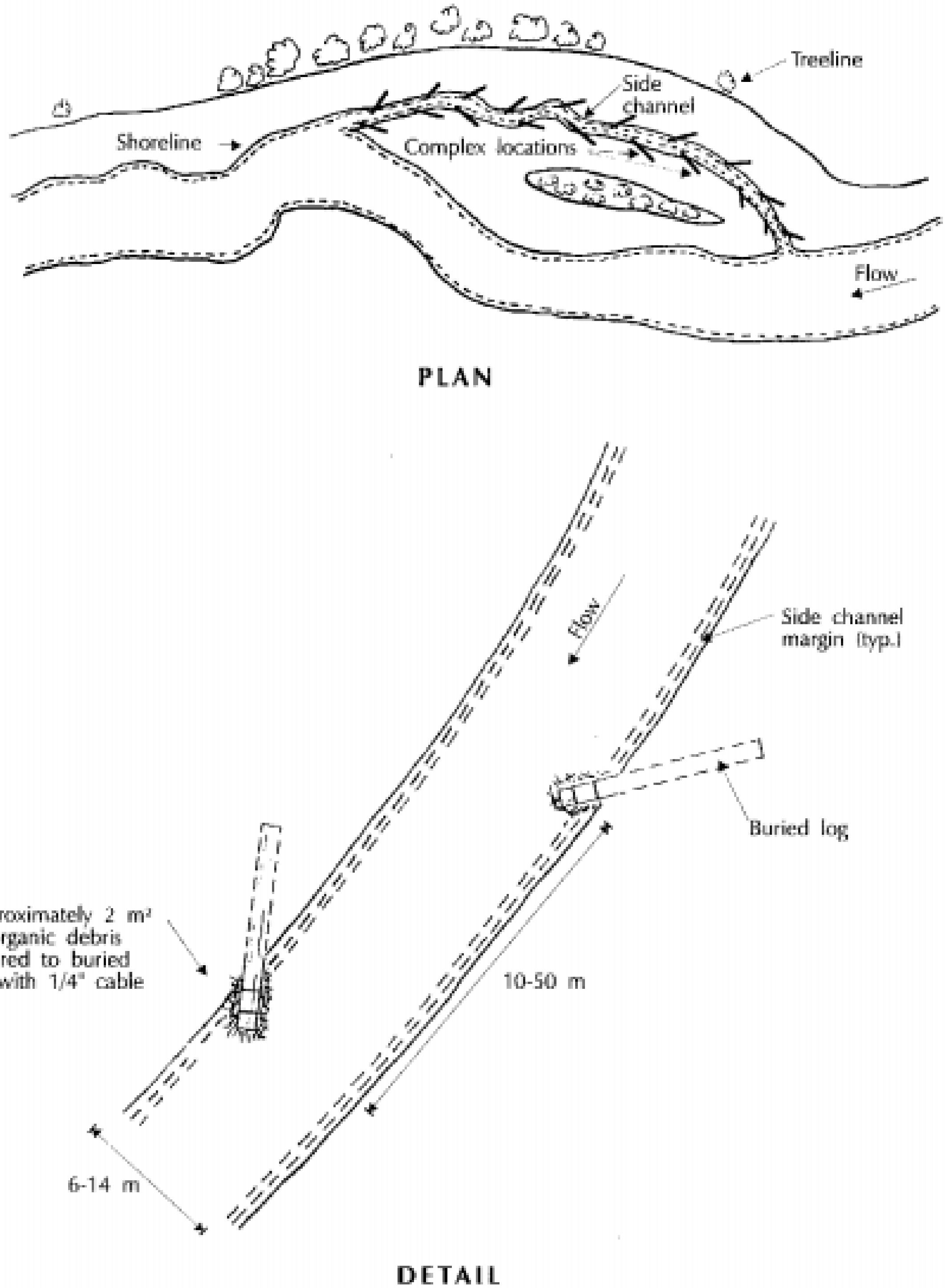
Nechako Fisheries Conservation Program	Map # RM90311a	Not To Scale
FIGURE 11. POINT BAR (1989)		



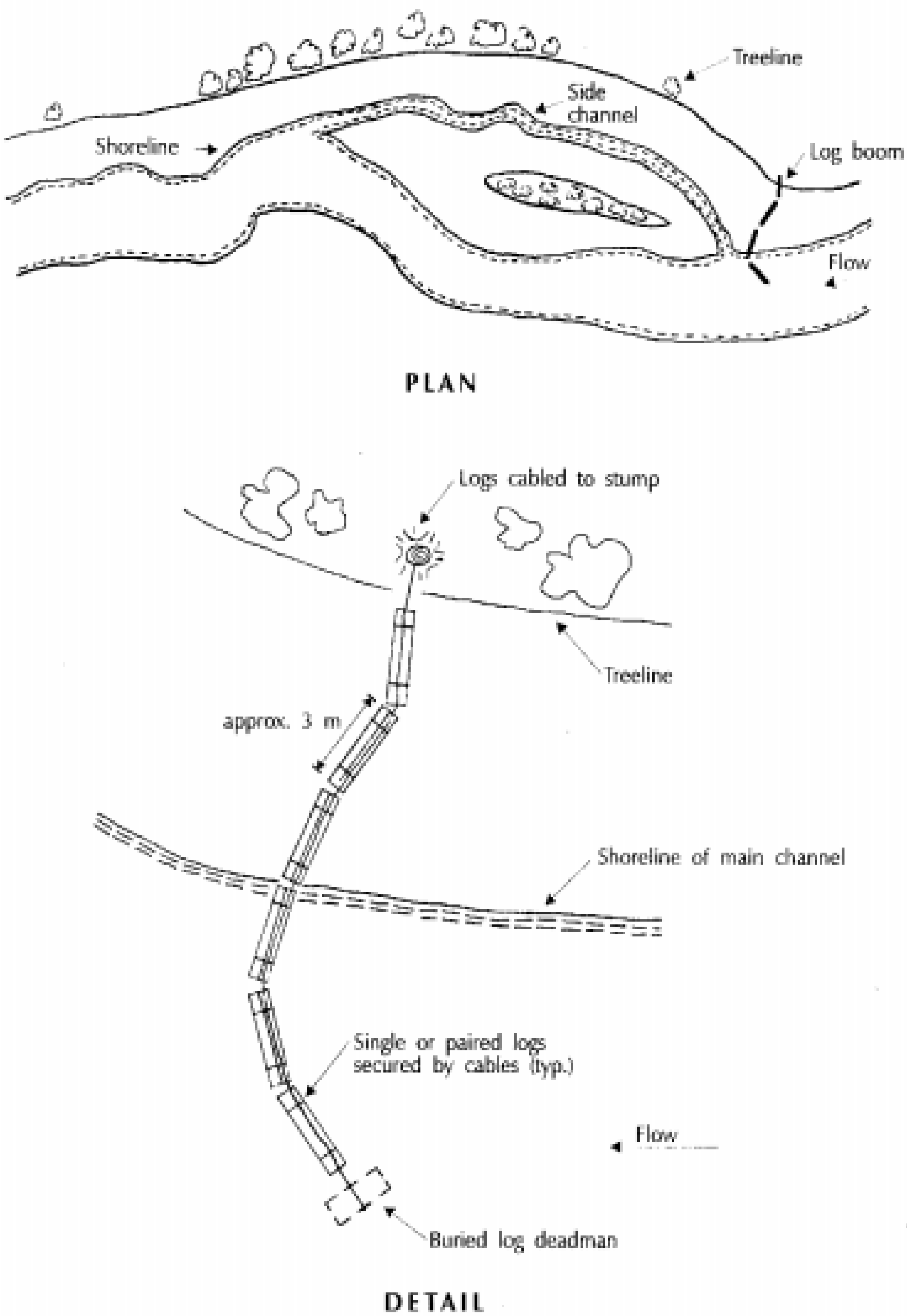
Nechako Fisheries Conservation Program	Map # RM90312a	Not To Scale
FIGURE 12. DEEP WATER SWEEPER (1990)		



Nechako Fisheries Conservation Program	Map # RM90313a	Not To Scale
FIGURE 13. RAIL DEBRIS CATCHER (1990)		



Nechako Fisheries Conservation Program	Map # RM90314a	Not To Scale
FIGURE 14. SIDE CHANNEL COMPLEX (1990)		



Nechako Fisheries Conservation Program	Map # RM90315a	Not To Scale
FIGURE 15. SIDE CHANNEL DEBRIS BOOM (1990)		

APPENDIX E

Habitat Complex Physical Assessment Photos, 1988 to 1990

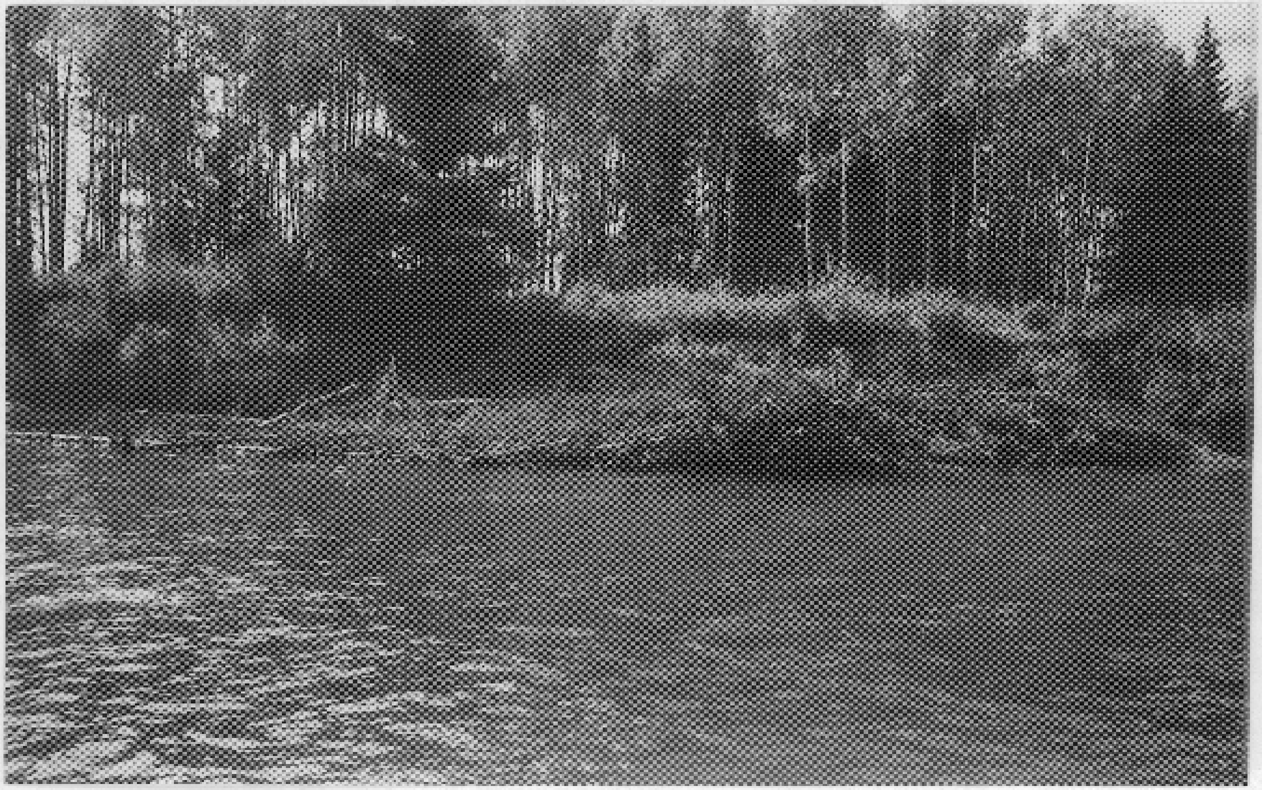


Photo 1: Rootwad Sweeper (RM30.7RS) Shifted Downstream by Magnitude of Summer Cooling Flows

Photo 2: Brush Pile (RM31.4BP) Structure Sound

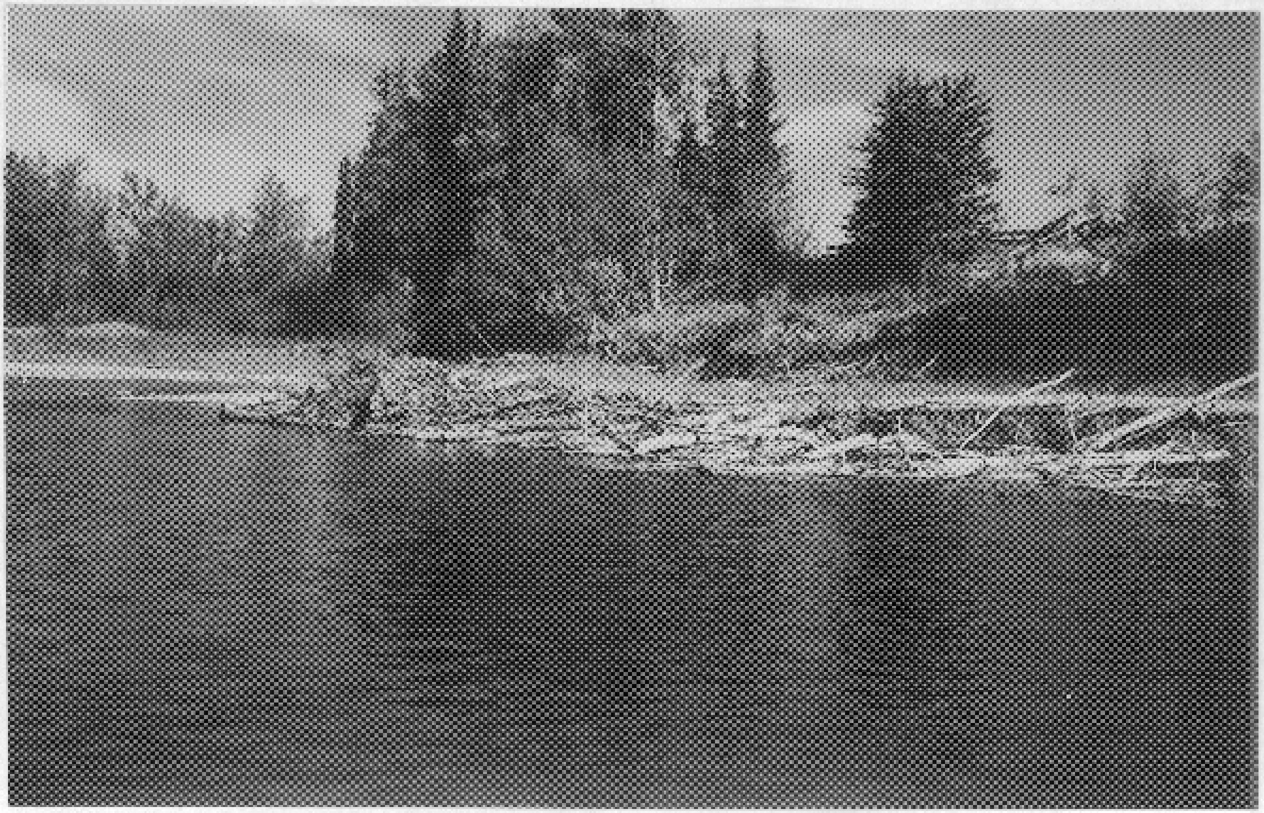


Photo 3: Floating Crib (RM27.4FC) Structure Sound

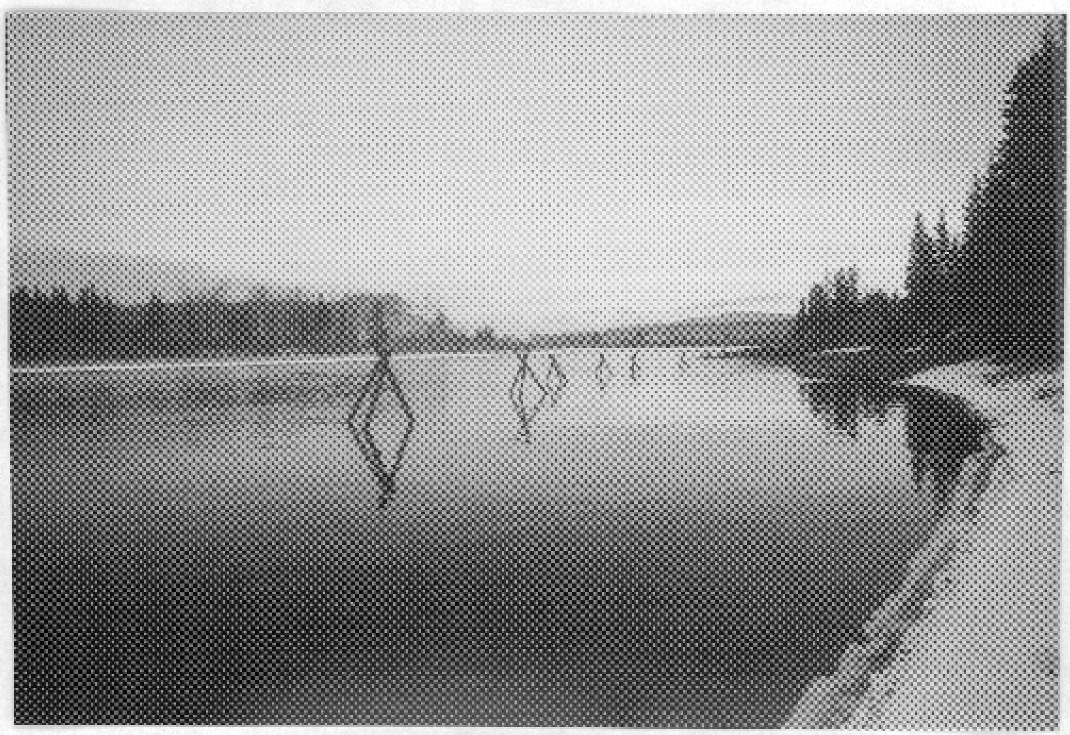


Photo 4: A Set of 5 Channel Jacks (RM32.05CJ - 1988) Placed Along the River Margin

Photo 5: Aerial View of Side Channel Habitat Complex Test Section (1988)

Photo 6: Side Channel Habitat Complex Test Section (1988)
(Note density of full spanning structure and subsequent flow reduction in channel.)

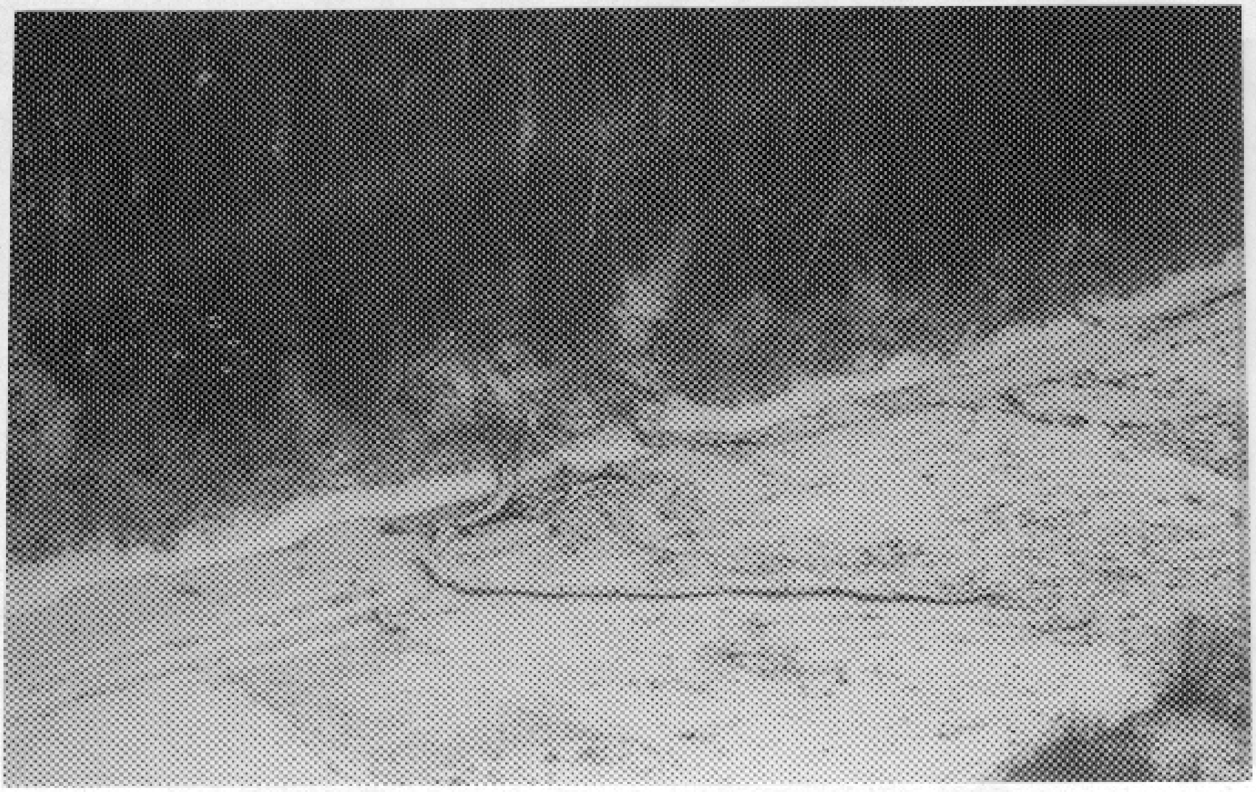


Photo 7: Aerial View of Side Channel Debris Boom (1988)
(Note full spanning structure and upstream debris retention in channel.)

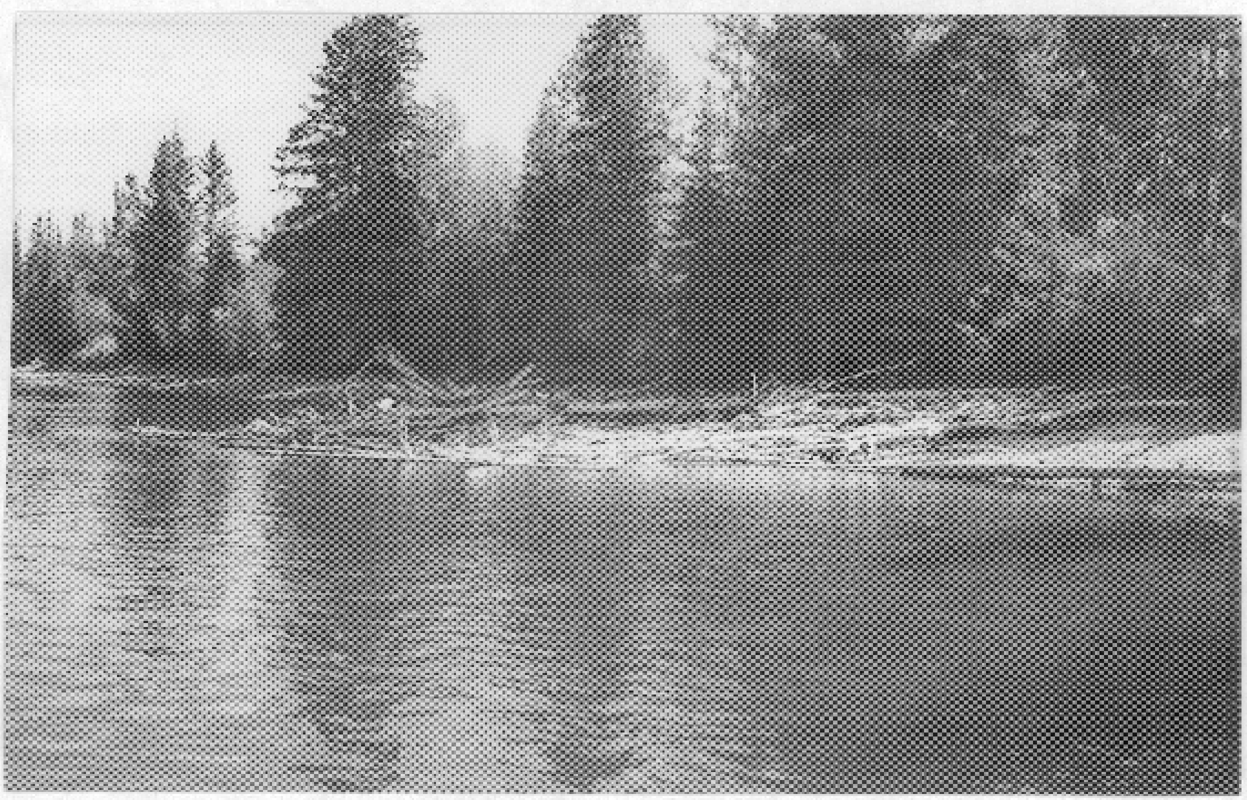


Photo 8: Pseudo Beaver Lodge (RM24.6PBL) Showing Significant Amount of Debris Collected During Cooling Flows

Photo 9: Pseudo Beaver Lodge (RM31.1PBL) Shown Stranded on Shore With Debris Lost Following Lowered Water Level

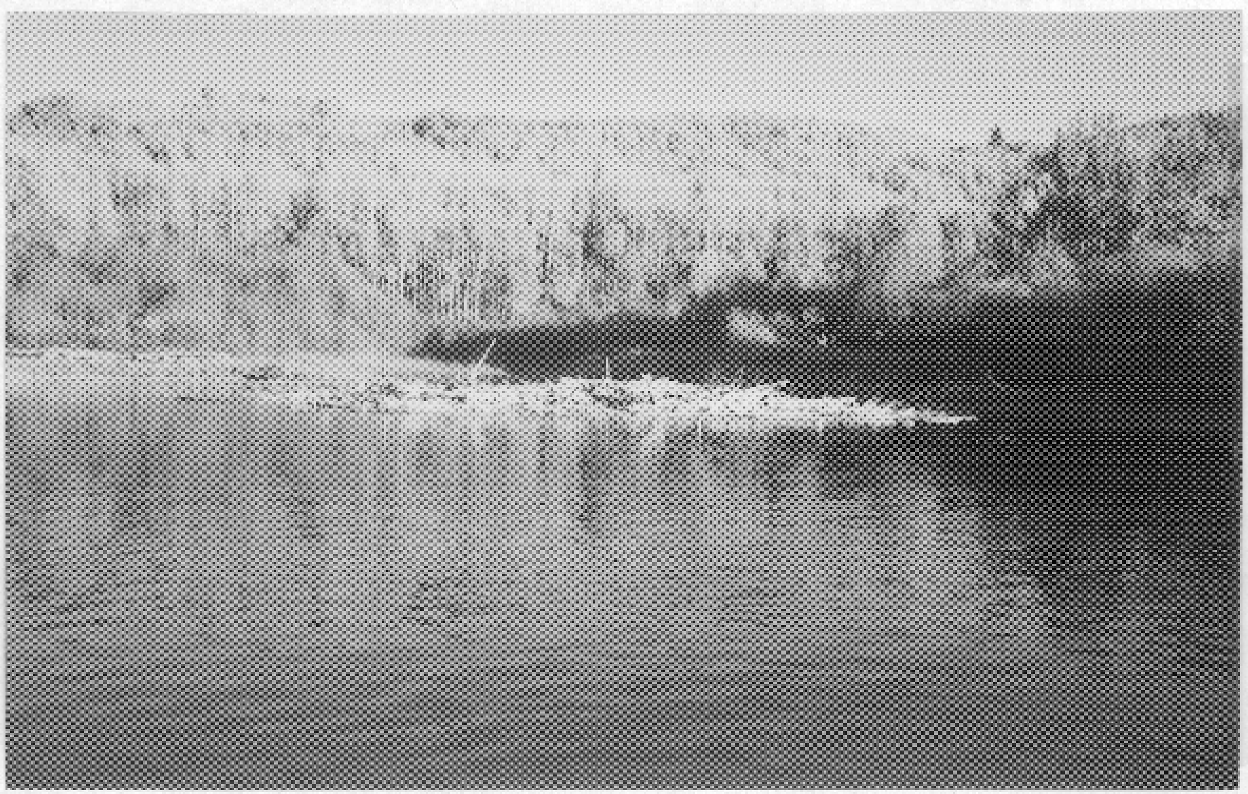


Photo 10: Pipe Pile Debris Catcher (RM35.4PDC) Demonstrating Significant Debris Entrapment

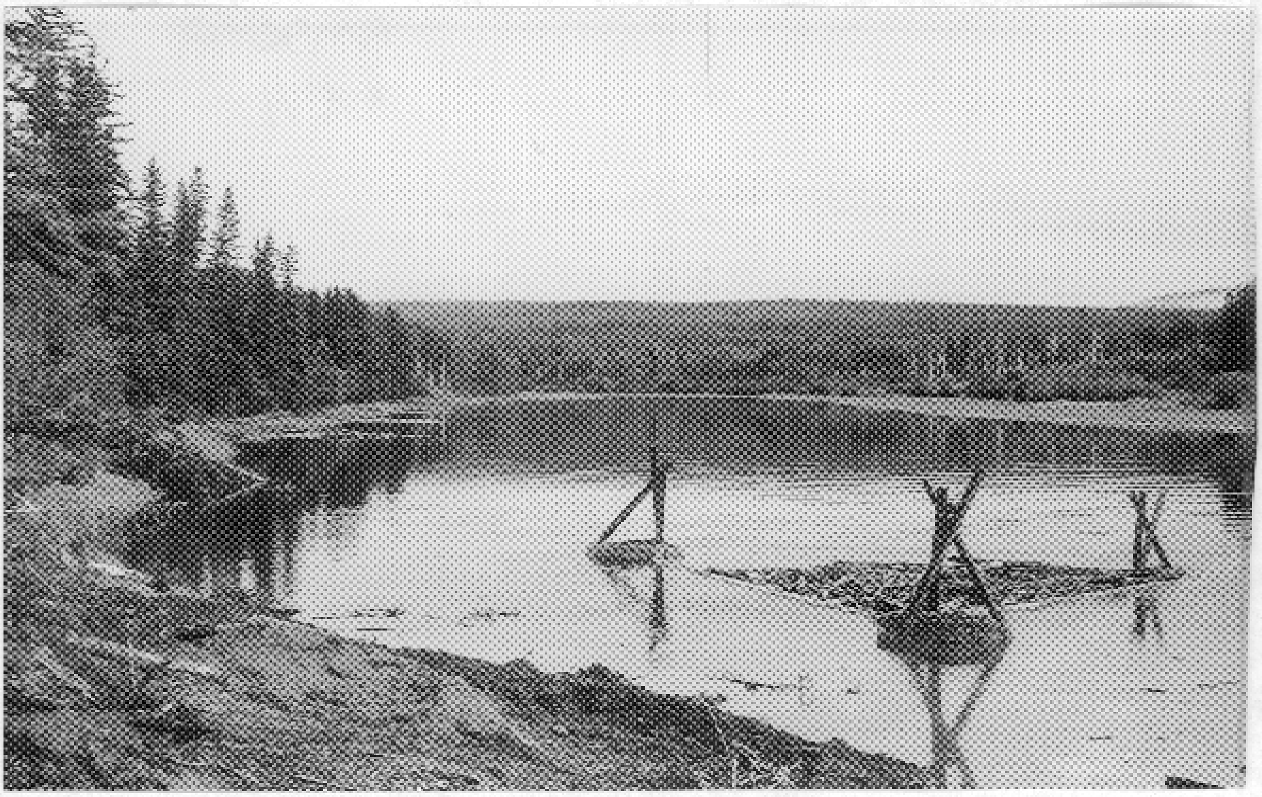


Photo 11: Boomed and Ballasted Channel Jacks (RM25.0CJ), 1989 Seeded With Debris

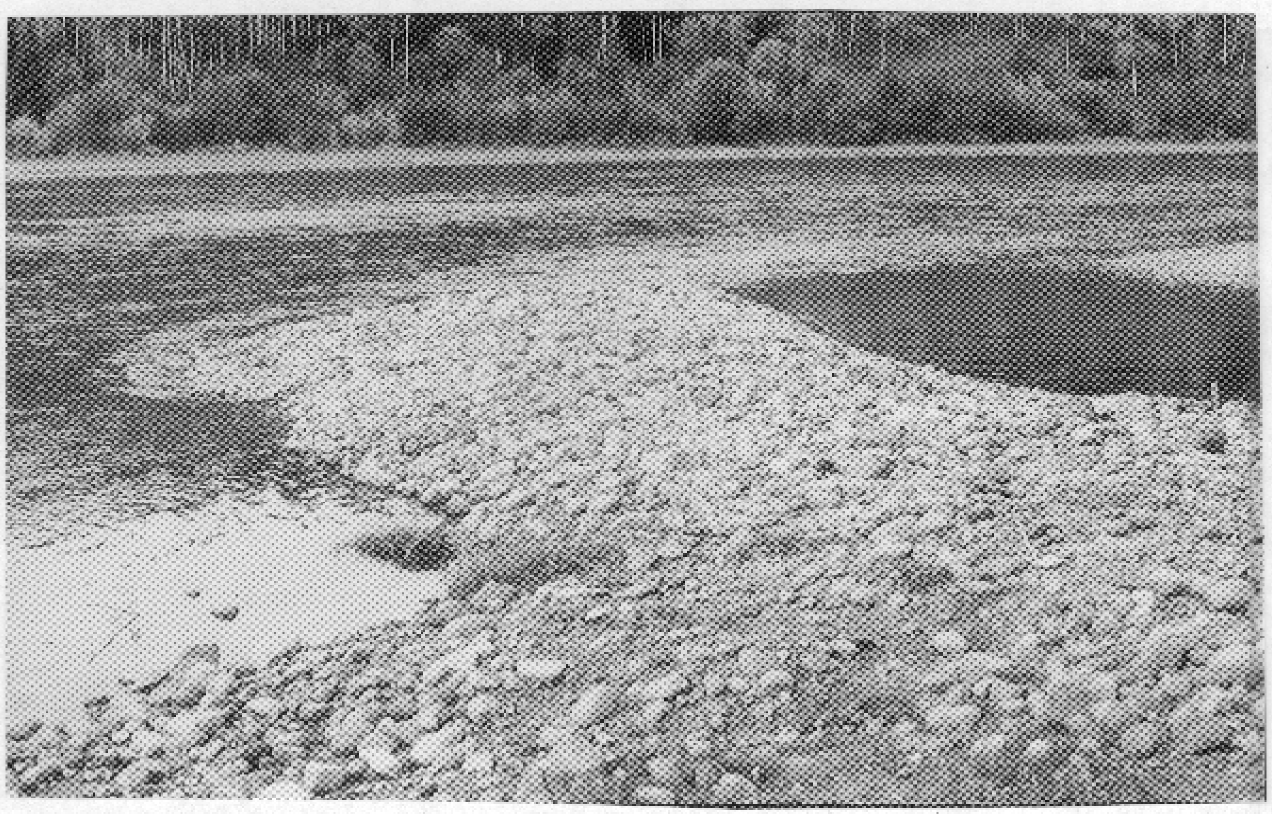


Photo 12: Point Bar (RM17.0PB) Looking Downstream

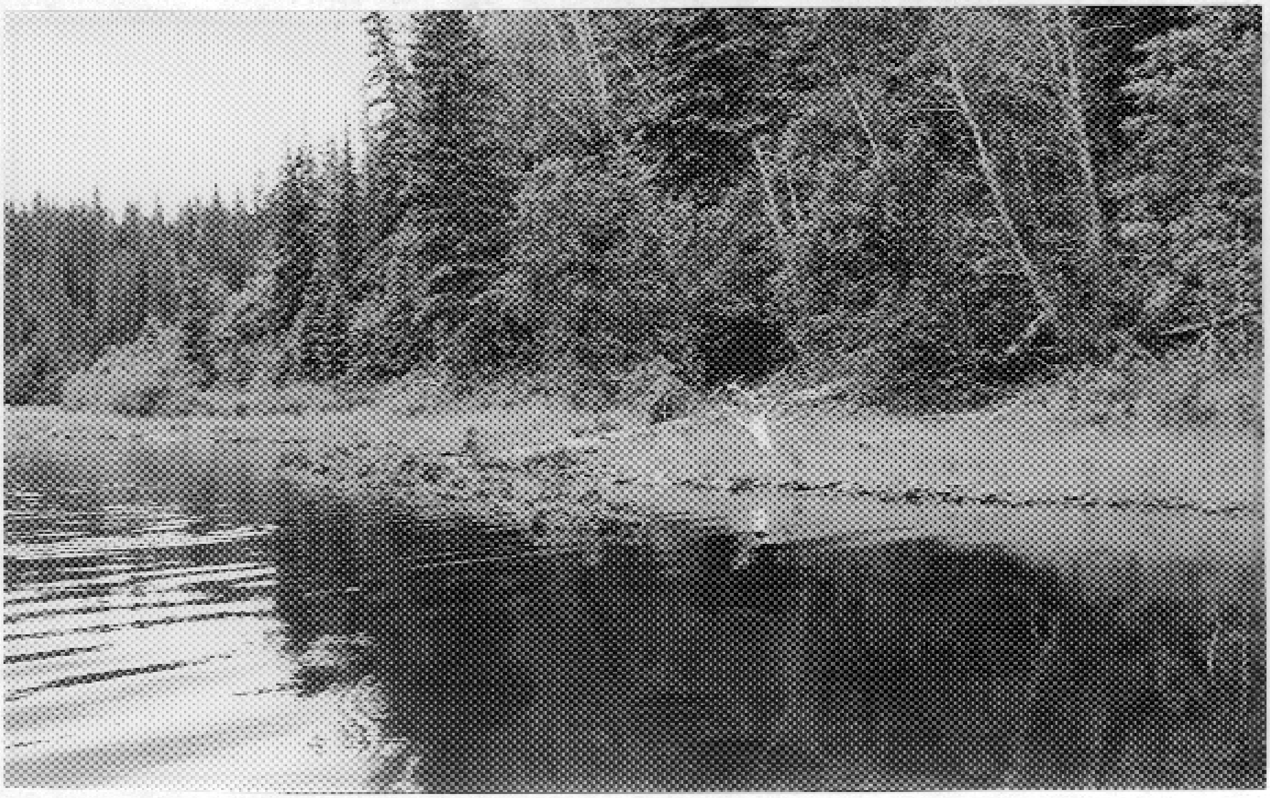


Photo 13: Deep Water Sweeper (LM13.7DWS) Looking Upstream

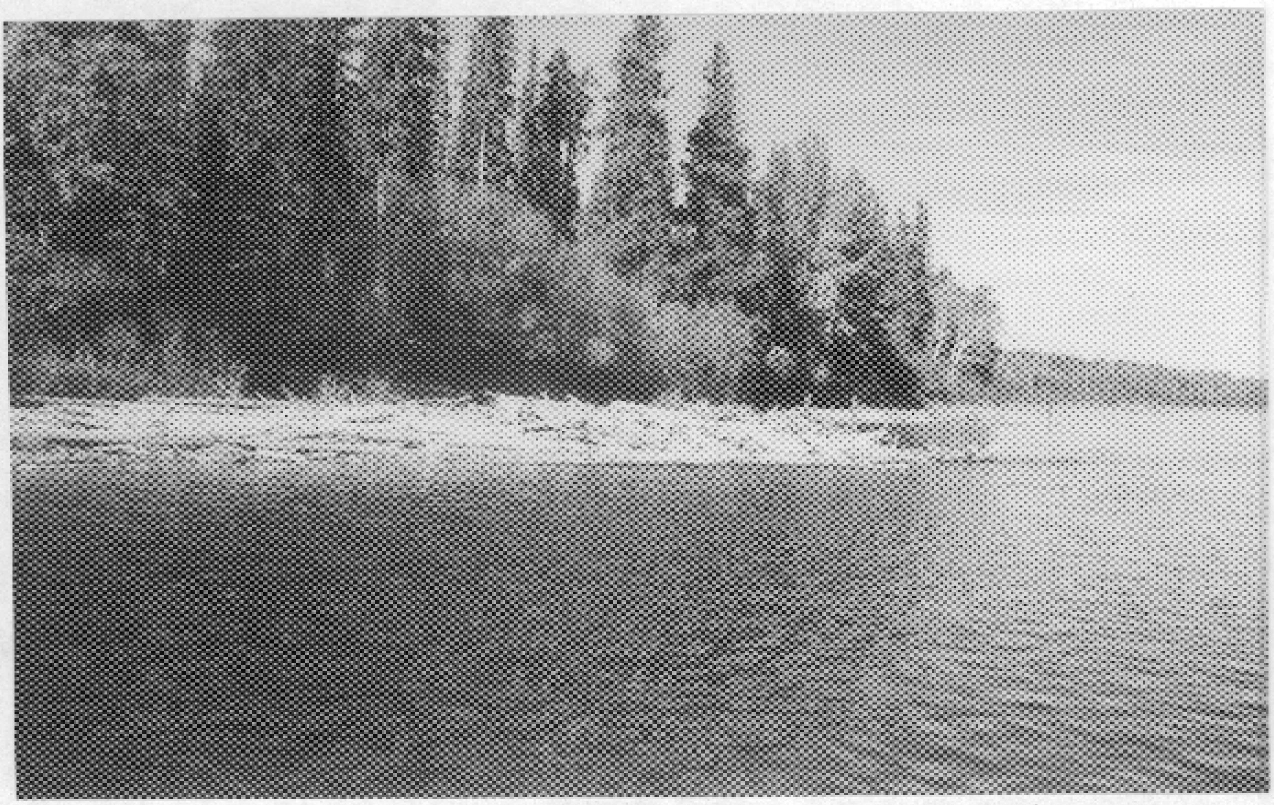


Photo 14: Rail Debris Catcher (LM22.6RDC) Demonstrating Significant Debris Entrapment Following Cooling Flows

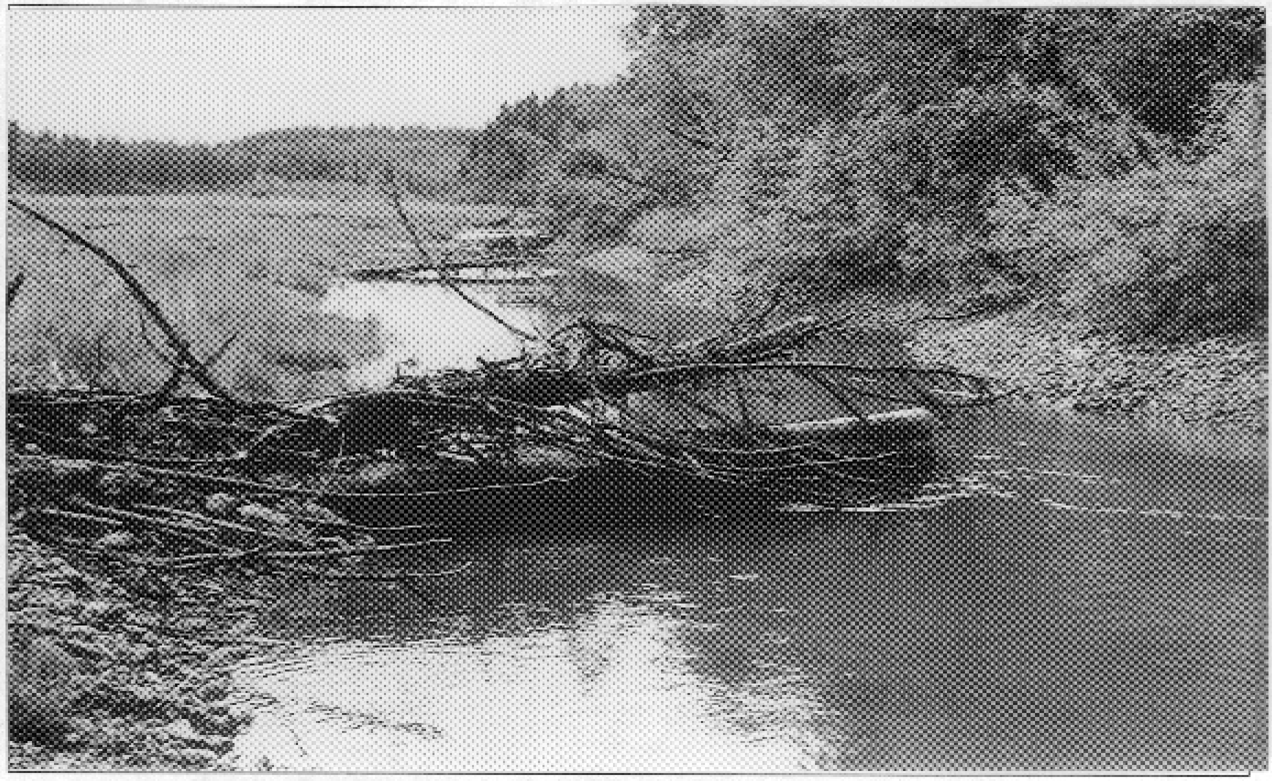


Photo 15: Modified Side Channel Habitat Complexes (1990)
(Note partially spanning single tree angled downstream and cover debris cabled at margin reducing amount of debris entrapment and resulting in increased velocities.)

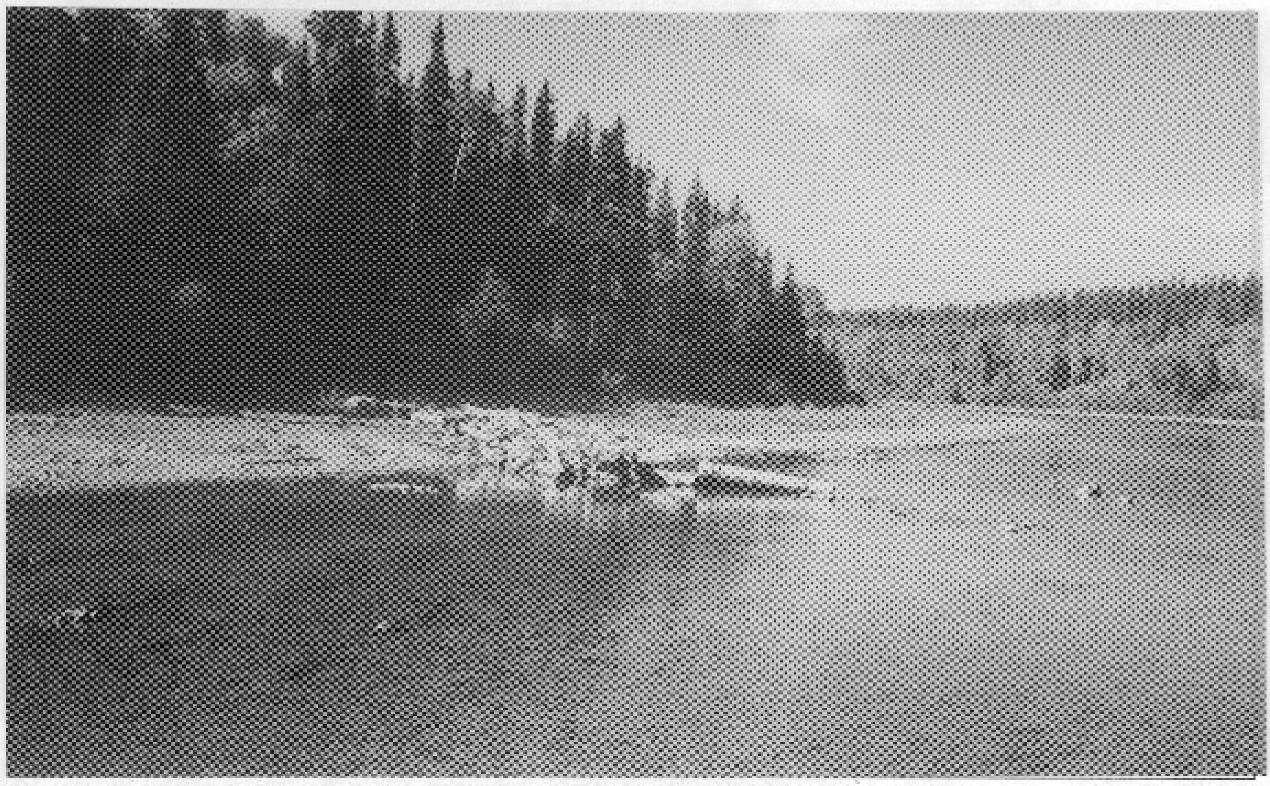


Photo 16: Relocated Side Channel Debris Boom (1990) Following 1990 Summer Cooling Flows (Structure was relocated upstream of side channel entrance to divert floating debris from entering side channel.)

APPENDIX F

Habitat Complex Construction Photos, 1988 to 1990

Photo 1: Seeding Floating Crib (RM24.4FC) With Debris From Shore
Using a Backhoe

Photo 2: Assembly of Channel Jacks Using Backhoe

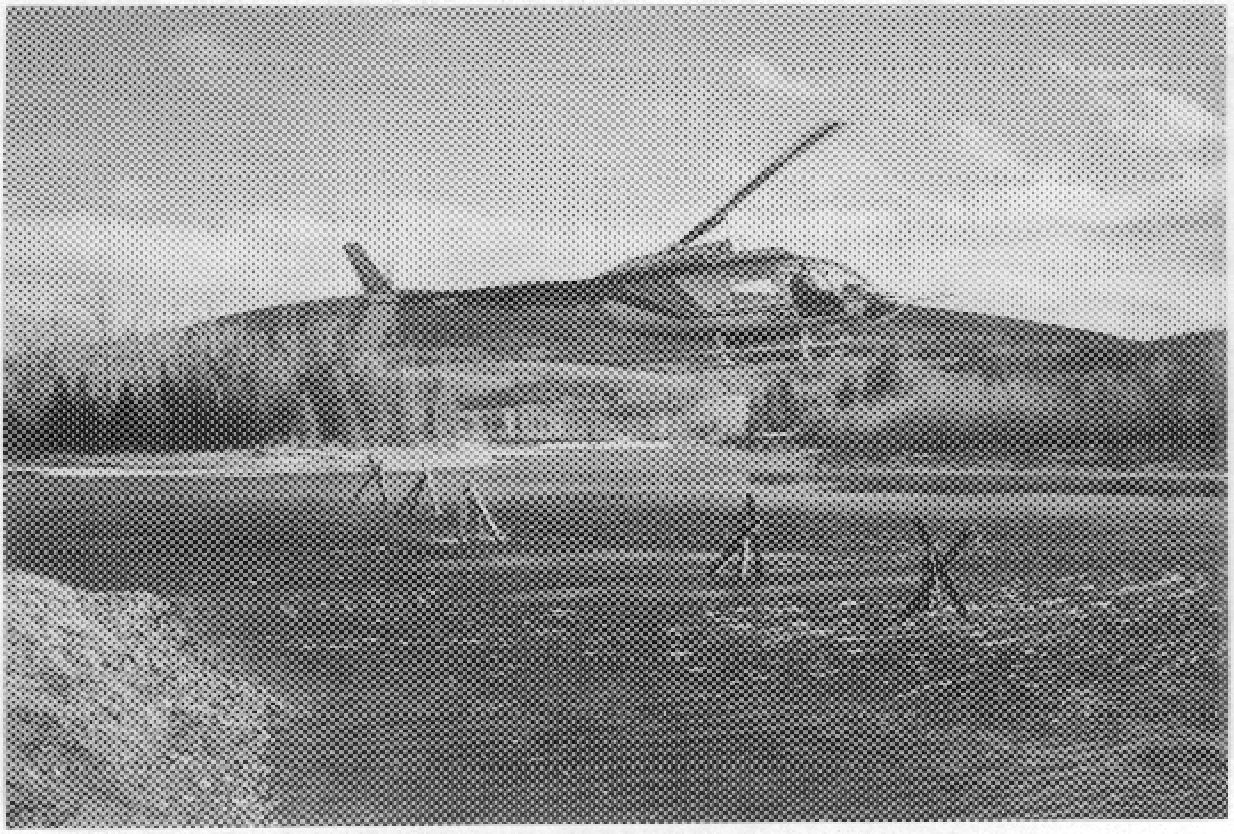


Photo 3: Installing Channel Jacks (MC33.65CJ) By Helicopter in Deep Water

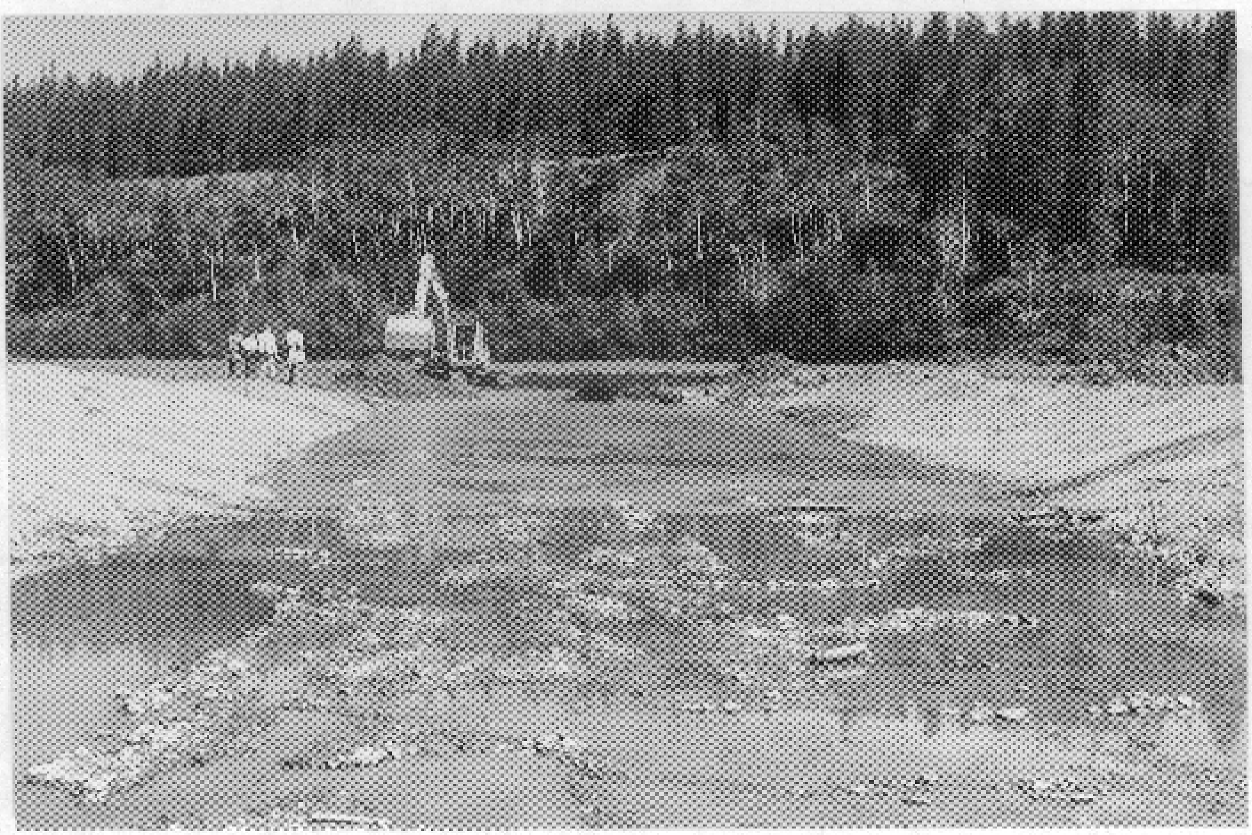


Photo 4: Excavation of Side Channel Using Backhoe

Photo 5: Typical Installation of Side Channel Habitat Complexes (1988) Using Backhoe for Placement of Trees Across Channel

Photo 6: Assembly of Side Channel Debris Boom (1988) Showing Cable Attachment

Photo 7: Typical Stump Anchor Cable Attachment Using the Threading and Looping Method (1989 and later)

Photo 8: Installation of Rails for Rail Debris Catchers Using a Backhoe Equipped With a Compactor Attachment For Increased Productivity

Photo 9: Typical Deadman Anchor Excavation
(Cables from habitat complexes were anchored to a 3 m log section which was buried in excavated pit.)