# *Fish Weirs For The Commercial Harvest Of Searun Arctic Char In The Northwest Territories*

***Date of Report: 1986***

***Author: Ward, W***

***Catalogue Number: 3-25-10***

**Canadian Industry Report of**

**Fisheries and Aquatic Sciences 174**

November 1986

# FISH WEIRS FOR THE COMMERCIAL HARVEST OF SEARUN ARCTIC CHARR IN THE NORTHWEST TERRITORIES

by

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This is the 1st Industry Report

from the Central and Arctic Region, Winnipeg

Cat. no. Fs 97-14 /174E ISSN 0704-3694

Correct citation for this publication is:

Kristofferson, A.H., D.K. McGowan, and W.J. Ward. 1986. Fish weirs for the commercial harvest of searun Arctic charr in the Northwest Territories. Can. Ind. Rep. Fish. Aquat. Sci. 174: iv + 31 p.

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A fish weir was operated on the Jayco River, 100 km NE of Cambridge Bay, Northwest Territories during late summer 1980-83 to test the suitability of using this gear to commercially fish for searun Arctic charr. Harvests (dressed weight) were: 1980 - 9417 kg, 1981 - 8402 kg, 1982 - 4570 kg and 1983 - 5911 kg. The weir was also used to count the number of charr migrating upstream in 1980 (33 389 - partial count) and 1981 (138 795).

A weir constructed principally of plastic netting was used in 1980 but proved to be unsuitable as it became clogged with debris and collapsed during high water periods. In 1981-83 the weir was made primarily of conduit pipe which proved to be very satisfactory.

The fish weir offers many advantages for commercial fishing in comparison to gillnets. Operational flexibility is enhanced, aircraft utilization is optimized, and as well spoilage is virtually eliminated and a top quality product results. Therefore, it is reconunended that the fish weir be considered as an acceptable method of commercial fishing for searun Arctic charr along the coastal Northwest Territories.

Key words: anadromous migrations; Arctic charr; commercial fishing; experimental fishing; river fisheries; Salvelinus alpinus; weirs.

RÉSUMÉ

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Os 1980 à 1983, une pêche avec pare en filets a été menée chaque année vers la fin de l'été sur la rivière Jayco, à 100 km au nerd-est de Cambridge Bay, clans les Territoires du Nord-Ouest, afin da vérifier si cette méthode convenait pour la pêche consnerciale de l'omble chevalier anadrome. Les captures (exprimées en poids habillé) furent en 1980 de 9 417 kg, en 1981 de 8 402 kg, en 1982 de 4 570 kg, et en 1983 de 5 911 kg. La pêche a également servi à compter le nombre d'ombles qui ont remonté la rivière en 1980 (33 389, compte partiel) et en 1981 (138 795).

En 1980, un pare construit principalement en filet plastifié a été employé, mais il a été jugé peu approprié, car il s'obstruait de débris et s'est effondré lors des crues. En 1981, 1982 et 1983, le pare a été construit au moyen de tuyaux principalement, ce qui s'est révélé tout à fait satisfaisant.

Le pare en filets présente beaucoup d'avantages pour la pêche commercial comparativement au filet maillant; P. ex.: plus grande souplesse d'utilisation; optimisation de l'emploi d'avion; Elimination à peu près totale des pertes et production d'un poisson d'excellente qualité. Par conséquent, il est recommandé que le pare en filets soit considéré comme une méthode acceptable de pêche consnerciale de l'omble chevalier anadrome le long des côtes des Territoires du Nerd-Ouest.

Mets-clEs: migrations anadromes; omble chevalier; pêche commercial; pêche expérimental; p@che clans les cours d'eau; Salvelinus alpinus; pare en filets.

## INTRODUCTION

Consnercial fishing for Arctic charr, Salvelinus alpinus (L.), in the Northwest Territories (NWT) provides an opportunity for economic development of a renewable resource in a land where such opportunities are scarce. However, commercially harvestable stocks are often located in remote areas since those in close proximity to communities are heavily fished to satisfy subsistence needs. Utilizing such remote stocks is expensive and often requires the use of aircraft to transport the catch to processing facilities and eventually to market. As well, Arctic charr stocks nust be carefully managed to prevent overexploitation since productivity is low. Demand in excess of the suPply can enhance the market value of this sought after species. Overhead must be held to a minimum and the available harvest must be fully utilized. Above all, premium quality must be maintained.

Presently the largest commercial fishery for Arctic charr in the NWT is located at Cambridge Bay where approximately 55 tonnes of the anadromous (searun) form are harvested annually (Kristofferson et al. 1982). The Department of Fisheries and Oceans (DFO) has monitored this catch since 1971 (Kristofferson and Carder 1980) and initiated detailed population studies in 1978 (Kristofferson et al. 1984) in a continuing effort to develop an effective management strategy. Gillnets are the only gear presently allowed for consnercial fishing in the NWT (NWT Fishery Regulations 1985) although use of this gear is not without problems. Gillnets kill fish and in order to maintain quality and minimize cullage the catch must be iced insnediately. This is often difficult and expensive at remote fishing sites such as those utilized by the Cambridge Bay fishery. Inclement weather and/or mechanical problems with the aircraft can delay transport of the catch to the processing facility with a resultant decline in quality of the product and some loss to cullage. If catches are poor, aircraft sometimes return with less than a full load on board. This is expensive and inefficient. Such difficulties have provided the stimulus for an evaluation of more efficient methods of harvest.

DFO has used fish weirs to enumerate the upstream migration of commercially exploited charr stocks in the Cambridge Bay area (Kristofferson et al. 19B4). Since the weir is a very effective capture mechanism, it was proposed to examine its potential for commercial fishing. The objective of this study was to investigate the suitability of a fish weir for the coinnercial harvest of Arctic charr while simultaneously using it to conduct a biological investigation of a charr run. Funding for this project was provided under the Fisheries Development Program, DFO, Uestern Region. Field work was conducted by DFO staff. The project began in 1980 and continued through 1983. Biological data collected during this study will be published in another report.

## LIFE HISTORY OF ARCTIC CHARR

Detailed life histories of Arctic charr are provided by McPhail and Lindsey (1970), Scott and Crossman (1973) and Johnson (1980). As described by the above, one form of charr spends its entire life in freshwater. It is either confined to this environment in a landlocked lake or, chooses not to descend to sea to feed. The landlocked form is usually small (30-50 cm), slow growing, and some populations are heavily parasitized. Hence, it is presently of little consnercial value.

The searun form spawns in freshwater in fall, the eggs incubate over winter and hatch in spring, and the young spend their first 4-7 years entirely in freshwater. At this age, when about 15-20 cm in length, they can descend the rivers with the older charr in the spring and enter salt water to feed. Feeding takes place along the coastlines during the summer. By taking advantage of the relatively abundant food resources in the sea these charr grow more rapidly than their freshwater relatives and attain a larger size (60-80 cm). The searun charr, because of its large size, is the form most valuable to the commercial fishery. Sexual maturity is reached when the charr are about 45-60 cm in length. Spawners often do not undertake the seaward feeding migration the summer prior to spawning. In the Northwest Territories, it appears that most individuals do not spawn in successive years after they reach maturity. Hence, the searun component is largely comprised of immature and mature, non-spawning charr. In mid-August to early September all the charr at sea return to fresh water to spend the winter. The optimum time to harvest charr is during this fall upstream migration, when they are in prime condition.

## MATERIALS ANO METHODS

### SITE SELECTION

Jayco Lake (69″48′N, 103″12′W), located about 100 km northeast of Cambridge Bay on Victoria Island (Fig. 1) was chosen as the site to conduct the study. Commercial fishing using gillnets has taken place here since 1975. Jayco Lake drains into Albert Edward 8ay via a short river, about 5 km in length, referred to here as the Jayco River.

The weir itself was located in the main channel of the river between the north shore and an island, approximately 400 m downstream from the camp site (Fig. 2). At this location the river was about 50 m wide and 1 m at its deepest point. The bottom was rock and gravel.

### WEIR DESIGN ANO OPERATION

Since the study involved a biological evaluation of the charr stock as well as an evaluation of the weir as a possible method for commercial harvest, three components were needed: (1) a weir, to concentrate the charr in a small area; (2) a trap, through which all the charr must pass for counting and biological sampling; and (3) a holding pen, in which to keep the charr alive until transport to freezer facilities could be assured.

A workforce of five DFO personnel and six Inuit fishermen from the Ikaluktutiak Co-operative, Cambridge Bay, constructed the weir on August 20 and 21, 1980. A prefabricated trap was assembled at the site. See Appendices for all construction details. The trap was positioned in the river, about mid-stream, in water about 1 m deep (Fig. 3). Ballast was applied to keep it in position on the bottom. The wings of the weir extended downstream from the entrance of the trap to each shore, forming an angle of 90° at the apex (Fig. 3). In order to prevent fish from swimming around the weir through a side channel, a 200 m long barrier was erected across this channel (Fig. 2).

The same construction technique used to build the wings of the weir was used to build a chute or passageway, 0.8 m wide by 36 m long, on the upstream side of the trap (Fig. 3). It led from one of the upstream drop gates at an angle towards the shore. Here it opened into a holding pen, 8 m x 12 m, one side of which was formed by the river bank. A sorting panel was installed in the upstream side to allow small, conanercially undesirable charr to escape from the holding pen.

All charr that entered the trap were counted. For the duration of the study a daily sample of these charr was weighed, measured (fork length) and tagged. Tagged chain were immediately released while untagged charr were directed into the chute that led to the holding pen. An aircraft was sunanoned from Cambridge Bay by two-way radio once the holding pen contained enough charr for a full load. Since the fishermen required about 2 h to catch and dress a load (about 550 kg) of charr the arrival time of the aircraft was scheduled to coincide with the completion of dressing. The fishermen drew a 15 m x 2.4 m beach seine (5 cm mesh) through the holding pen into shallow water at the river bank. Large charr were selected from the seine, dispatched by a blw to the head with a wooden baton, and dressed. The catch was weighed on shore and then flown to the freezer plant in Cambridge Bay. Harvesting began on September 1 and continued in this fashion until September 10 when the quota was taken. The weir was then removed from the water and stored on the river bank until the next season.

Improvements were made to the design and construction of the weir in 1981 as a result of problems encountered in 1980. Four DFO staff and three Inuit fishermen constructed a conduit pipe weir over a three day period (August 19-21). The wire barrier was rebuilt as described for 1980 and the trap was reused. However, the weir and holding pen followed the design of Anderson and McDonald (1978), with some modifications (see Appendices).

The trap was positioned closer to the shore than in 1980 and a chute, 0.6 m wide and 4.9 m long, was constructed directly upstream from one of the upstream drop gates in the trap (Fig. 4). This led to a holding pen, 7 m x 20 m, one side of which was formed by the river bank. The sides of the chute and holding pen were constructed in the same manner as the wings of the weir. On the upstream side of the holding pen, the conduit pipe was placed in every second hole in the stringers leaving openings of about 5 cm through which the small charr could escape to continue their upstream migration.

Counting, biological sampling and tagging, , as described for 1980, began on August 22 and continued for the duration of the study period. Fishing was carried out in the same manner as in 1980. It began on September 5 and ended September 9 when the quota had been harvested. Following completion of fishing the chute and holding pen were removed from the river. The biological studies continued until September 15 when the weir and trap were removed from the river.

The biological studies were successfully completed in 1981, hence the weir was set up in 1982 for the sole purpose of harvesting the commercial quota. One DFO representative and five Inuit fishermen erected the weir on August 29. Although the same construction techniques were used as in 1981, the design was changed slightly. The wire barrier was erected between the island and the south shore, as had been done in the past. Since the trap was not needed, the wings of the weir were installed such that the apex was located near the north shore (Fig. 5). The south wing was about 65 m long with the north wing about 23 m long. Where the wings joined, an opening 21 cm wide was created by removing six lengths of conduit pipe. The holding pen was formed by extending the long south wing 10 m directly upstream then continuing it in a perpendicular direction 18 m to the north shore. The north wing of the weir formed the downstream side of the holding pen in the shape of a trapezoid.

The weir became operational on August 30 and fishing began on September 5. On September 11, the run appeared to be over and the weir was removed from the river.

Five fishermen set up camp on August 16, 1983, and the weir was operational on the 24th. It was constructed similar to the 1982 operation with one modification. A downstream side was added to the holding pen, reducing its size and changing it to a rectangular shape (Fig. 6). Again the wire barrier was erected between the island and the south shore and the weir itself was constructed. Fishing began on August 30, and ceased on September 5 when the quota was taken. The weir was then dismantled and removed from the river.

## RESULTS

Daily counts of Arctic charr moving upstream began on August 22, 1980. Strong north winds created a storm surge on Jayco Lake shortly thereafter. The resultant increase in water level and velocity in the river proved too much for the weir to withstand. The storm increased the waterborne debris, which clogged the plastic netting. This built up a head of water which eventually resulted in the separation of the mesh from the T-bar posts (see Appendices) and stringer frames along the south wing of the weir. The water level receded and the weir was repaired on August 25. Counting resumed on the 26th. There was no indication that the run had begun at this time, since daily counts were low. On September 1 one load of charr was dressed and transported back to the freezer plant in Cambridge Bay by aircraft (De Havilland Standard Beaver). The following day another load was dressed and shipped in. At this time the daily count of charr moving upstream was steadily increasing indicating the onset of the run. Daily counts and harvest statistics are shown in Table 1. Fishing continued from the 3rd to the 6th. On September 7 a load of fish was dressed, but the aircraft was unable to fly due to bad weather. A storm broke and the resulting high water conditions knocked down the chute and the south wing of the weir that evening. Repairs took place on the 8th so no counting was done. However, there were enough charr in the holding pen to continue fishing. The aircraft arrived and took the catch from the 7th and 8th back to Cambridge 8ay. The holding pen and chute were dismantled on the 9th when freezing conditions were encountered. Counting continued and the commercial fishermen took their catch by dip net from the trap. On September 10 the remainder of the quota was taken and two remaining DFO staff and four Inuit fishermen removed the weir from the river. This took about 3 h.

In total, 33 389 charr were counted moving upstream, of which 830 were tagged and released and biological data were taken from 923. Fishermen harvested 3 680 charr (9 417 kg dressed weight) with a mean length of 64.3 cm (fork length) and mean dressed weight of 2.6 kg.

Counting began on August 22, 1981. Strong NE winds produced storm conditions and high water levels on the 26th. Although the weir accumulated waterborne debris, it did not clog and no damage was sustained. However, the wings and the wire barrier had to be cleaned.

Few charr were counted moving upstream until September 1 when a steady increase indicated the onset of the run. Harvesting began on the 5th (Table 2). Two float-equipped aircraft (De Havilland Standard 8eaver, De Havilland Single otter) were used to transport the catch to Cambridge Bay. The run was nearing its peak and there were ample numbers of charr in the holding pen. Therefore, harvesting was limited only by the amount of work the fishermen could do in a day. By September 9 the quota was filled and fishing ceased. Counting and tagging continued until the 15th. Four DFO staff required about 5 h to dismantle and remove the trap and weir from the river and store it on the riverbank.

A total of 138 795 charr were counted moving upstream, of which 945 were tagged and released and biological data were taken from 2 322. The fishermen harvested 8 402 kg (dressed weight) of charr in a five day period. Mean size was 64.5 cm. Mean dressed weight was 3.0 kg.

In 1982 very few fish entered the holding pen until early September. It was not until September 5 that sufficient charr were available to begin fishing. Fishing continued under the supervision of a DFO Fishery Officer until September 11 when the numbers of charr being captured by the weir began to decline. Approximate daily catches are shown in Table 3. In total 4 570 kg (dressed weight) were harvested. Mean length was 67.5 cm and mean dressed weight was 3.1 kg.

Fishing began on August 30, 1983 when the fishermen shipped 181 kg of charr into Cambridge Bay by float-equipped Cessna 185 aircraft. This was done without first establishing whether it could be handled at the plant or not. In fact, it created some difficulty since the freezer in the plant had malfunctioned and there was a backlog of fish from other areas waiting to be processed. The fishermen were instructed to cease fishing until further notice. The fishery resumed on September 2 under favorable conditions. Under the supervision of a DFO Fishery Officer fishing continued until the 4th when the quota was filled. Daily harvest statistics are shown in Table 3. After fishing ceased, about 4 h were required to remove the weir and holding pen from the river.

In total 5 911 kg (dressed weight) were taken. Mean length was 64.3 cm and mean dressed weight was 2.7 kg.

## DISCUSSION

### WEIR DESIGN

#### Construction techniques

Since one of the objectives of this study was to determine the suitability of using a fish weir for the commercial harvest of Arctic charr, the materials and weir design used initially were chosen for ease of transportation, construction and economy. However, it became evident that durability under storm conditions was a necessity, hence the design had to be modified to complete the evaluation of this technique.

The weir used in 1980 proved to be inadequate both in terms of the material and construction technique used and the layout of the chute and holding pen. As Clay (1961) points out, the use of screen increases the tendency to collect debris. This is indeed what happened on August 23. Much of the debris was algae which clung to the mesh and was very difficult to scrub off. The perpendicular orientation of the face of the weir to the water level (see Appendices) contributed to a buildup in the head of water against the weir, increasing the pressure it had to withstand. The T-rail posts stood alone with no downstream supports and some bent under the load during the storm. In every respect considered here the conduit pipe weir used in 1981-83 proved to be far superior to the plastic netting weir used in 1980. The storm on August 26, 1981, produced high water levels and deposited considerable debris along the conduit weir. It easily withstood these conditions and was much less difficult to clean than the plastic netting. The algae did not cling to the smooth surface of the conduit pipe and often all that was required was to lift each pipe up and down in its position to shed the debris.

According to Anderson and McDonald (1978), the 120° angle (see Appendices) formed between the upstream face of the weir and the river bottom is important since it allows the water to flow slightly up the conduit pipe before passing through, thereby creating more area to dissipate the pressure of the water. Clay (1961) points out that the head of water created by the weir can be lessened by rounding the upstream corners of pickets or using round pickets or bars. Conduit pipe has the desired effect. The stout pipe used as an upright support imparted considerable strength to the weir and was further bolstered by the downstream "two by four" wooden supports. The net result was that the conduit pipe weir functioned very effectively from 1981 to 1983 with no damage due to storm conditions.

A very significant advantage that the conduit pipe weir offered compared with the plastic netting weir was its ability to conform to the irregular river bottom, effectively preventing passage of fish upstream. The skirt and rock arrangement used in 1980 was laborious to install and required constant tending to ensure there were no openings through which fish could pass underneath.

There were some problems with the layout of the weir used in 1980 (Fig. 3). The V-shaped arrangement of the wings creating a 90° angle at the apex enables more water to pass through the fence for a given stream width, thereby reducing the pressure on the weir (Anderson and McDonald 1978). This arrangement effectively led the upstream migrating charr into the trap. However, the chute to the holding pen, which formed an angle to the current (Fig. 3), did not work as well. The charr showed a tendency to hold in the chute and eventually filled it to capacity. They had to be driven into the holding pen. A plywood baffle was placed at the entrance to the holding pen preventing the charr from moving back into the chute. This problem was overcome in 1981 by modifying the layout. The trap was positioned closer to the north shore and the chute led directly upstream into the holding pen (Fig. 4). The holding pen was reduced in width but extended further out into the river. Charr readily moved up into this pen on their own.

Since the trap was needed only for the biological evaluation of the run, the weir design was further simplified in 1982. All that was needed for commercial fishing was the weir itself and a holding pen as shown in Fig. 5 and 6.

Few problems were encountered with the actual harvest of charr using the seine net. The seine was drawn through the holding pen and brought up near shore, although not entirely beached. Fishermen then waded in and captured large charr by hand. No more charr were taken than were required to provide a full load for the aircraft. The rest were released unharmed back into the holding pen. The design used in 1983 included a downstream side to the holding pen (Fig. 6) which reduced its size somewhat but made it easier to seine for a load when there were fewer charr in the pen. This also provided a buffer zone between the pen and the weir so that harvesting activities did not frighten charr that had not yet entered the weir.

Hindrance to migration

The weir is an extremely effective capture mechanism. In fact, when used for enumerative purposes such as was done in 1981, the objective was to capture and count every searun charr migrating upstream during the experiment. This could only be done by extending the weir across the entire width of the channel (Fig. 7, 8). Since DFO personnel monitored the operation, only sufficient charr to fill the commercial quota were harvested and all the rest were released to continue their upstream migration. A fundamental drawback of a weir that extends across the entire channel is the inevitable delay to migration (Clay 1961). This can have serious consequences. There is evidence (Johnson 1980) that non-spawning charr, particularly large ones over 65 cm and some small ones less than 30 cm, may overwinter in streams other than their natal streams. If the weir delays their upstream migration to any extent they may choose to leave the stream and overwinter elsewhere which in itself would probably not be too serious provided they could find a suitable alternate stream. It is not known what effects lengthy delays might have on the remainder of the migrants. These charr could also be forced to go elsewhere. Current year spawners would not be affected since they usually remain in freshwater the summer prior to spawning, as discussed earlier. However, for those intending to spawn the following year, failure to reach their traditional spawning grounds could have disastrous long-term consequences for the stock.

The Fisheries Act (1985) prohibits complete blockage of a stream or river with fishing gear for other than experimental purposes. It states that one-third of the width shall be always left open. Partial-span weirs, covering no more than two-thirds of the width of the river or stream, would comply with existing regulations and allow free passage for the majority of the run. Partial-span weirs would be more than adequate for commercial purposes. Such a weir was constructed on the Koukdjuak River, 8affin Island, by DFO personnel in 1976. The river was 3 km wide at the site although the weir, built between the shore and a small island, was only about 60 m long. A total of 8008 charr were taken in this weir (O.K. McGowan, DFO, Winnipeg, M8, unpublished data). Gillnet fishermen must not block more than two-thirds of the stream yet they have no trouble harvesting the entire quota during a run.

A suggested design for a partial-span weir for commercial fishing is shown in Fig. 9. Less material is required compared with a full-span weir, considerably reducing cost. During years when OFO fisheries management personnel required an enumeration of the run, the weir could be increased to full-span at departmental expense and operated under DFO supervision.

## Size selectivity

Existing regulations prohibit the use of gillnets with mesh size smaller than 139 mm when commercially fishing for searun Arctic charr (NWT Fishery Regulations 1985). This is to ensure that pre-reproductive charr are not recruited into the fishery. The sorting panel used in 1980 was an attempt to achieve size selectivity. The panel functioned like a gill-net. Some small charr were observed to escape upstream through the panel although large charr were caught by the mesh and trapped in it. However, it was soon plugged with fish due to the small size of the panel, thus preventing further escape of the small ones. This problem was effectively solved with the conduit pipe weir simply by removing every second conduit pipe on the upstream side of the holding pen creating gaps through which the small charr easily escaped upstream. No large charr were observed trapped between the pipes.

If the conduit pipe weir construction is used for consnercial fishing, holes for the conduit should be drilled on 3.2 cm centres if 1.3 cm diameter conduit is used. The conduit can then be placed in every second hole when the weir is erected. There are a number of benefits to this. During years when a total count is required for management purposes, the extra conduit can simply be placed in the remaining holes. The added cost of drilling the holes will probably be offset by the reduction in weight of the channels with subsequent reduction in freight costs. A consnercial operation would require only half the conduit needed per linear m that we used to do the total count, significantly reducing cost. Placing conduit on 6.4 cm centres provides a gap of about 5 cm through which the small charr could escape. This should be done along the entire length of the structure. Fishermen would not have to spend time sorting the large charr from the small charr. The weir itself would present less resistance to the current and would be able to withstand greater storm surges, and in all likelihood would accumulate less waterborne debris and be easier to keep clean.

The fishermen in this study selected large charr by eye. Data fran Carder (1983) show that mean fork length of charr taken by gillnet (minimum 139 mm mesh size) from the Jayco River in spring 1981 was 632 mm (N=151) while charr caught in the weir that fall averaged 645 mm (N=181). Concerns regarding the harvest of undersized charr in a weir can be eliminated by establishing a minimum size limit.

## Holding capacity

Arctic charr can apparently tolerate crowded conditions. It has been determined that they can be held without undue stress at a density of 70 $kg \cdot m^{-3}$ for at least two weeks provided they are in flowing water (J. Tabachek, DFO, Winnipeg, M8, personal communication). Holding pens should be built sufficiently large enough to make the operation economical when filled to this density. They should not be overfilled.

# SUITABILITY FOR COMMERCIAL FISHING

## Flexibility

The advantages of the weir for commercial fishing became evident during the four year test period. The greatest advantage of using the weir is that it provides the means to keep the charr alive until such time as expeditious transport to the processing plant/market can be assured (Fig. 10-13). During this study a total of 28 300 kg was harvested using the weir and cullage was nil. The charr were being fast-frozen only 3-4 h after they had been dispatched. This produced a top quality product.

Plant capacity at the Ikaluktutiak Co-op processing plant in Cambridge Bay is limited. Runs in different rivers often occur simultaneously and many loads of charr can arrive at the plant at one time. This was experienced in August, 1983. Since the weir was in operation at Jayco River, a radio call was made to the fishermen requesting that they suspend harvesting until the plant could clear the backlog from the other rivers. Once the plant caught up, fishing resumed at Jayco. Ouring this same period the plant freezer broke down and forced a further suspension of fishing. Once again the flexibility provided by the weir saved the day. On numerous occasions weather in Cambridge Bay grounded the aircraft. A radio message to Jayco River postponed harvesting even though the weather at the fishing site was good. Consequently no charr were lost to cullage due to weather-related transportation problems.

An additional benefit conferred by weirs is species selectivity. Lake trout are sometimes taken as a bycatch in commercial gillnets set for Arctic charr. This species is of far greater value to the sport fishery and can be released unharmed from the weir, thus avoiding conflict between sport and consnercial fishermen.

## Economics

The cost of constructing and operating a weir must be considered in comparison to the conventional gill net fishery.

A breakdown of the cost of material for a conduit pipe weir and holding pen suitable for spanning two-thirds of the Jayco River (50 m width) is shown in Table 4. The price is based on placing the conduit pipes on 6.4 cm centres. Price per linear metre was calculated to be about $43.00 (1985 dollars) F.O.B., Winnipeg, M8. The weight was calculated to be about 20 kg per linear metre. Freight costs, by truck from Winnipeg to Yellowknife via Edmonton, by scheduled air carrier from Yellowknife to Cambridge 8ay, and by float-equipped aircraft from Cambridge 8ay to the Jayco River, would be an additional $44.00 per linear metre. Total cost per linear metre was calculated to be $87.00.

A cost comparison between a conduit pipe weir fishery and a conventional gillnet fishery at the Jayco River site is shown in Table 5. The comparison is for a 10 year period, the expected useful life of a conduit pipe weir. The expected life of boats and outboard motors is five years, gillnets (and seine) about four years (U. Lyall, Ikaluktutiak Co-op, Cambridge Bay, NWT, personal consnunication). All costs are expressed as present values (1985 dollars). Replacement costs have been discounted using a 10% compound interest present worth factor (Grant et al. 1976). Only those items which differ significantly in terms of functions and/ or number required are used in the comparison. Items common to both types of fisheries are excluded. The labour component, four fishermen, is common to both fisheries.

Values for the weir are based on the partial-span design (Table 4, Fig. 9) with conduit placed on 6.4 cm centres. The material, in linear metres, required to construct a two-third span weir with a 90° angle at the apex Is simply equal to the total span of the river at the site chosen. For this example the width of the river is 50 m, thus 50 m of weir material are required. The amount of material required to build the holding pen depends upon the shape of the pen and should be based upon a holding density of 70 $kg \cdot m^{-3}$. For this example a holding pen, square in shape with a mean depth of 0.5 m, one side adjacent to shore (Fig. 9), will require 42 linear metres of weir material. Holding capacity will be 6 800 kg, one half of the entire Jayco River quota. Thus, the total weir material required for this example is 92 linear metres.

The weir appears to be marginally less expensive than a comparable gillnet operation over ten years, as far as capital costs (and freight) are concerned. Operating costs (fuel, etc.) would favour the weir since only one boat and motor is required compared with two for the gillnet fishery.

The most significant financial advantages conferred by the weir fishery are through efficient aircraft utilization and maintenance of high product quality. The weir virtually ensures that 100% of an aircraft's payload capacity can be utilized. Revenue loss due to cullage by the gillnet fishery can be high. A conservative estimate of this cullage is 5% (DFO observations). Applied to the Jayco River example, with a 13 600 kg quota, this represents about 585 kg (680 kg round weight) dressed weight per year, a loss of $2960 (1985 dressed weight price of $\$5.06 \cdot kg^{-1}$, Freshwater Fish Marketing Corporation). Calculated over the 10 year investment period the present value of this lost revenue totals about $20,000, which alone justifies the investment estimated in Table 5.

In some locations using weirs it may be possible to ship the charr to market in fresh condition increasing the value of the product by as nuch as 60%.

Although this analysis is site specific and somewhat simplified it is clear that the weir fishery offers definite financial advantages over a gillnet fishery in some cases. The degree of advantage will be dependent on the size of the quota. The initial high cost of the weir should not be considered a detriment to its use.

Fishing season

Arctic charr are generally in poor condition during the spring downstream migration to the sea since some growth in length takes place in freshwater in winter at the expense of nutritional reserves (Johnson 19BO). Little feeding takes place in winter. This factor, coupled with the high water levels, swift current, ice and waterborne debris characteristic of rivers and streams during spring breakup, precludes using weirs at this time. Fall is the season most suitable for weir fisheries since water levels are low, currents are slow and the charr are in prime condition. Upstream migrations of Arctic charr usually begin during mid to late August in most areas of the NWT.

Licensing

Presently, gillnet fishermen are individually licensed and their financial return depends upon how successful each is in taking a portion of the quota. Since a single weir can easily harvest the largest quota, operating a number of weirs on one system would not be efficient and a mix of weirs and gillnets would result in destructive competition. Changes to the licence system would be needed and some form of restricted entry would be necessary to ensure economic viability.

The use of weirs amongst the Inuit is not a new idea at all. Balikci (1980) briefly describes the operation of the stone weir or 'saputit' which, to a point, involved cooperation amongst the fishermen involved. The Inuit fishermen who participated in this study willingly undertook to pool their efforts during the four years of the fishery's operation. They belong to a fishermen's cooperative which may have helped. For fishermen in other areas this may not be so easy.

Labour component

The use of weirs should not result in a significant reduction in the labour component if they replace gillnet fisheries in certain locations. Large weirs require sufficient labour to erect, maintain and dismantle them. More important is the ability to dress large quantities of charr in a short period of time. If the holding pen is full and transportation of the product can be assured, the speed of the operation is limited only by the time it takes to dress the fish.

It is relatively safe to say that weirs will not completely replace gillnets in the commercial fishery for searun Arctic charr along the coastal NT. Some rivers are suitable for weirs while others are too deep/turbulent for their use. However, the weir fishery offers definite advantages over gillnets at suitable sites.

## SUMMARY

The commercial fishery for searun Arctic charr along the coastal Northwest Territories is beset by rather severe biological and economic constraints. Stocks are widely distributed and harvesting is expensive. Presently the fishery is restricted to gillnets. Fish weirs offer many advantages which hold promise for improving the economics of this fishery. Charr can be held alive in the weir until transportation to freezer facilities/markets can be assured. This reduces loss to cullage and provides greater flexibility in transporting, processing and marketing, vastly increasing the efficiency of the fishery. Perhaps most important, a weir fishery produces a top quality product essential to demand prices necessary to ensure the economic viability of these fisheries.

The conduit pipe weir design described in detail in this report is suitable for these commercial fisheries and its cost of construction compares favorably with gillnet fisheries. Other weir designs may prove to be even more cost effective.

Changes to the Northwest Territories Fishery Regulations will be required to allow the use of weirs for commercial fisheries. Such changes must reflect consideration for biological concerns such as hindrance to upstream migrations and harvest of undersized charr as well as economic concerns such as destructive competition. Fishermen must be prepared to enter into cooperative fishing ventures and licensing policies will need to be changed to provide optimum benefit to such fisheries.

## RECOMMENDATIONS

1. It is recommended that the Northwest Territories Fishery Regulations be amended to allow the use of weirs for commercial fishing for searun Arctic charr along the coastal NUT. These amendments should include measures such as partial-span restrictions to prevent undue hindrance to upstream migrations of Arctic charr. Minimum size limits should be established to ensure escapement of pre-reproductive fish. Holding density and duration should be specified to prevent loss of captive charr.

2. It is recornnended that a licensing policy be developed for a weir fishery to ensure that optimum benefits to the fishery can be realized. The policy should recognize the possibility of destructive competition if fish weirs and gillnets are used simultaneously in a fishery.

## ACKNOWLEDGMENTS

The initial impetus for this study was provided by R.F. Peet and W. Dilk of DFO. The authors extend their thanks to Bill Lyall and staff of the Ikaluktutiak Co-op in Cambridge Bay for their cooperation throughout the study. S.K. Law, R.W. 140shenko, and D.G. Iredale provided continuing support for the project. G.W. Carder coordinated aircraft flights and supplies for the field camp. Field assistants included Carol Read, Marg Meijer, Cindy Douglas, Dave Woudstra, Cheryl Dahl, John Elloit, Morris Oakoak and Gerald Yaremchuk. Fishery Officers E. Sangris and K. Fisher supervised fishing in 1982 and 1983 respectively. Thanks are extended to John Udaloyuk, Dick, Jack and James Ekpakohak, Mathew and David Nakashook and Moses Koihok, the commercial fishermen who were most cooperative. R. Moshenko, P. Thompson, J.W. Clayton and P. Richard reviewed a previous draft and provided many useful suggestions.

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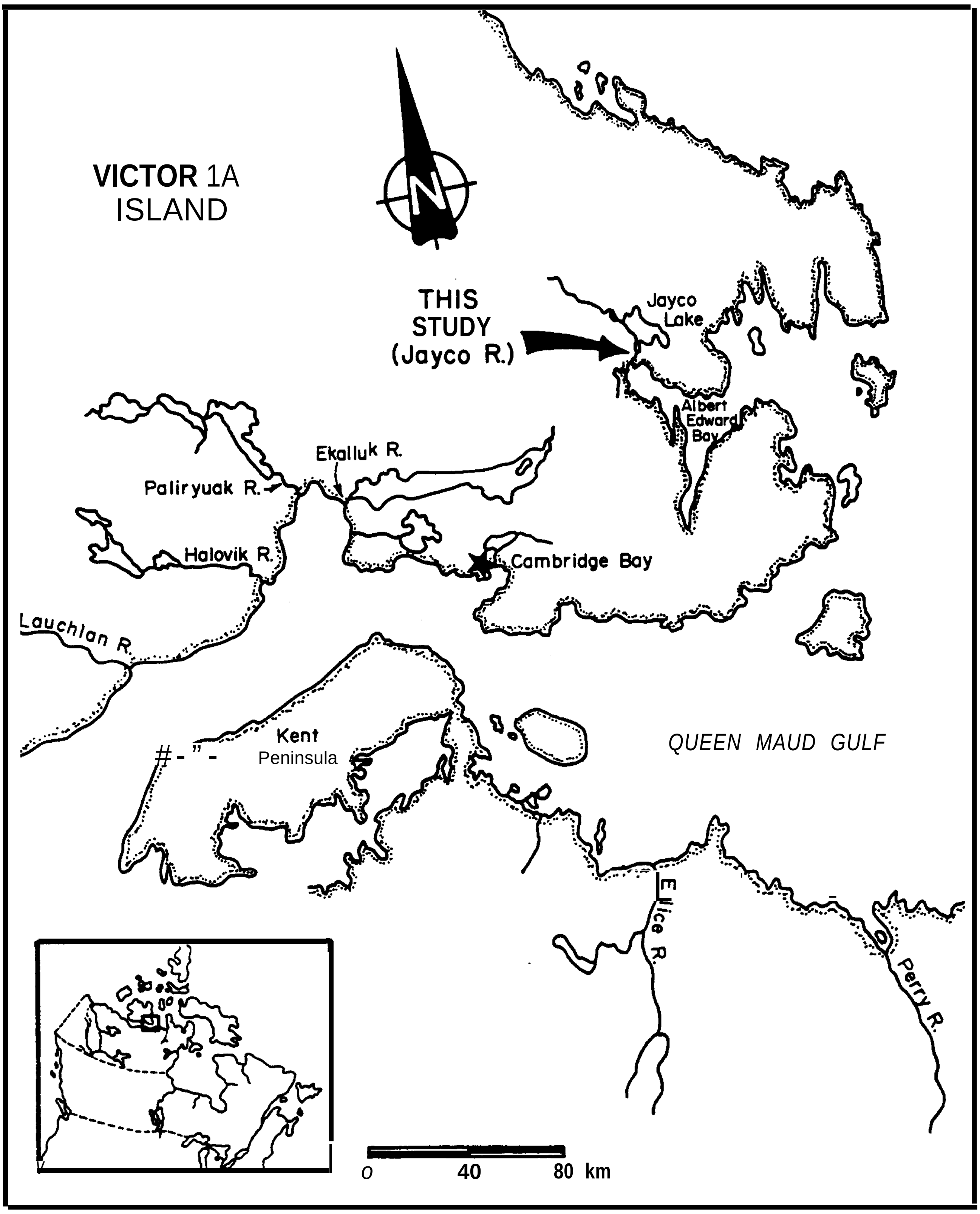



Fig. 1. Map of the Cambridge Bay area showing the location of the study site at Jayco River.

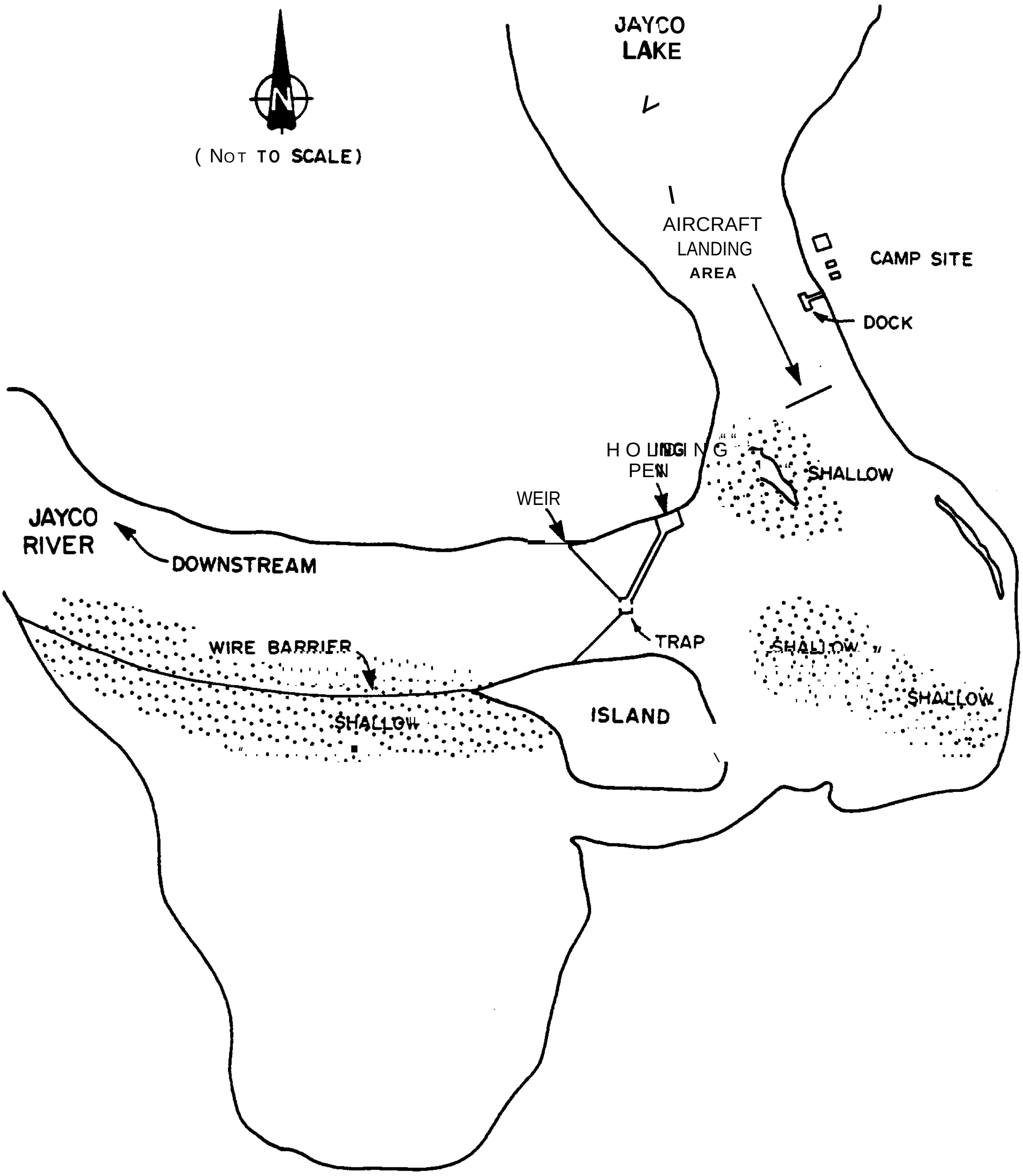



Fig. 2. Detailed map of the study area showing the location of the weir and campsite at Jayco River.

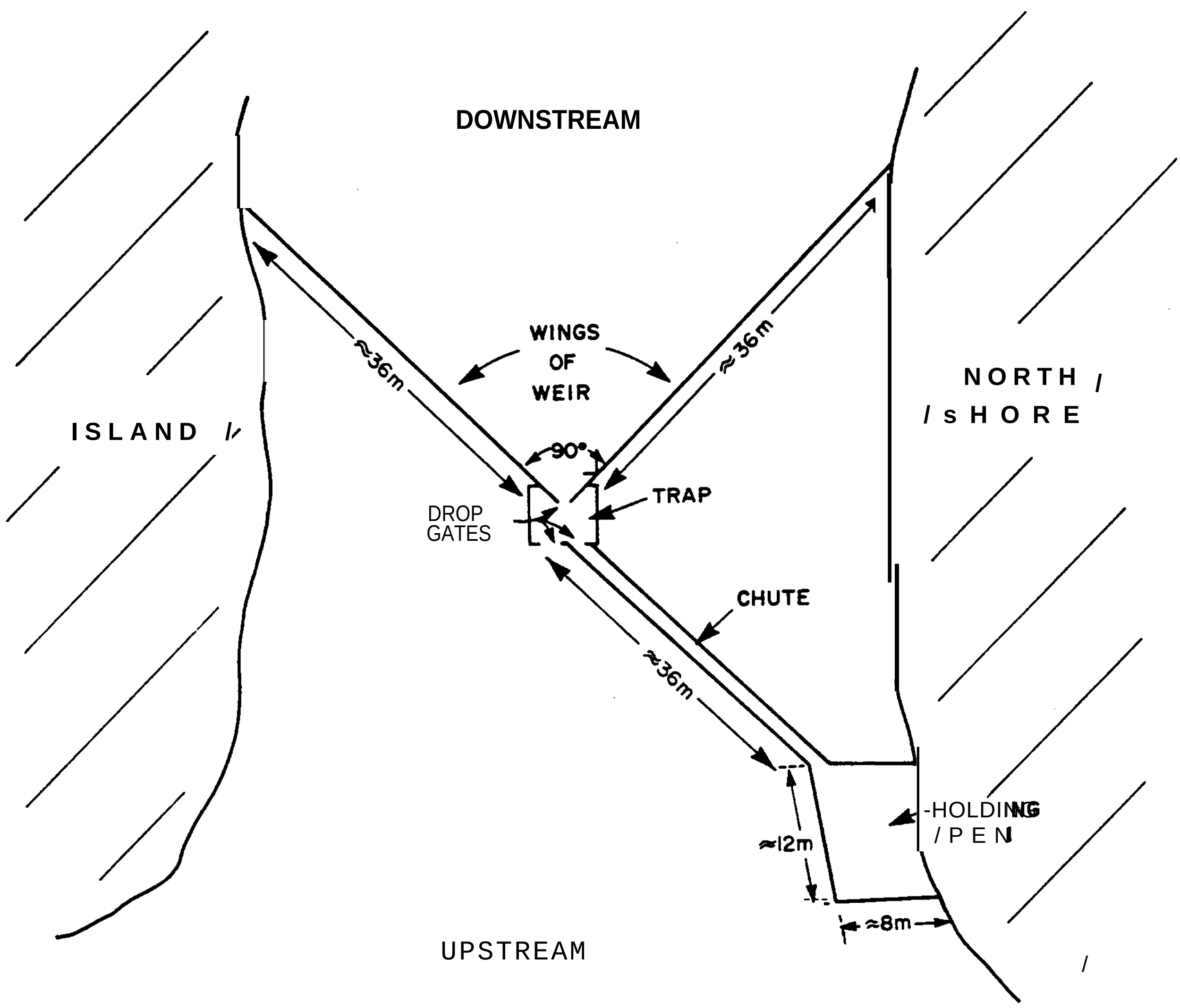



Fig. 3. Layout of plastic netting weir and trap used for counting and commercial fishing in 1980, showing dimensions of structures.

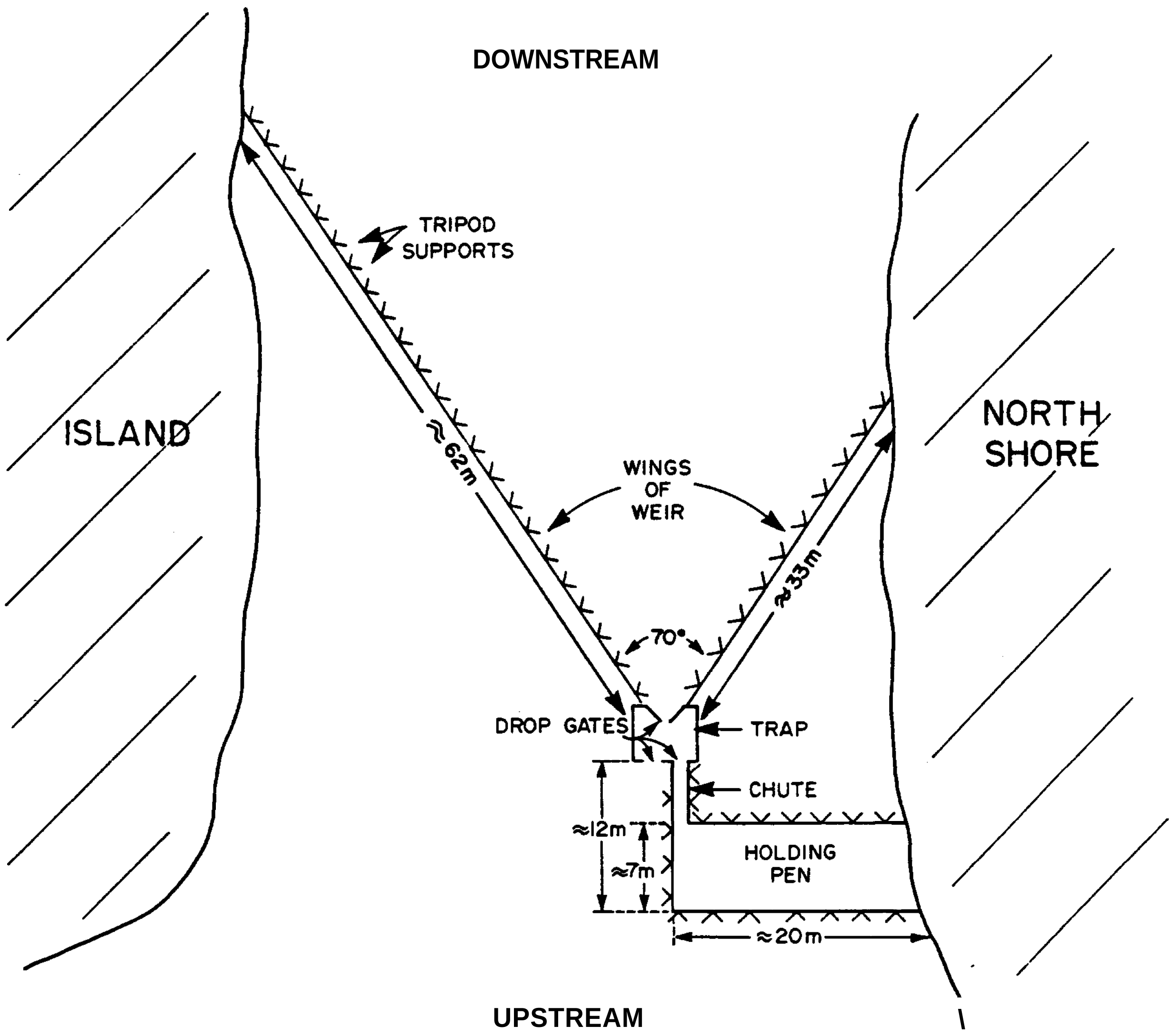



**Fig. 4.** Layout of conduit pipe weir and trap used for counting and commercial fishing in 1981, showing dimensions of structures.

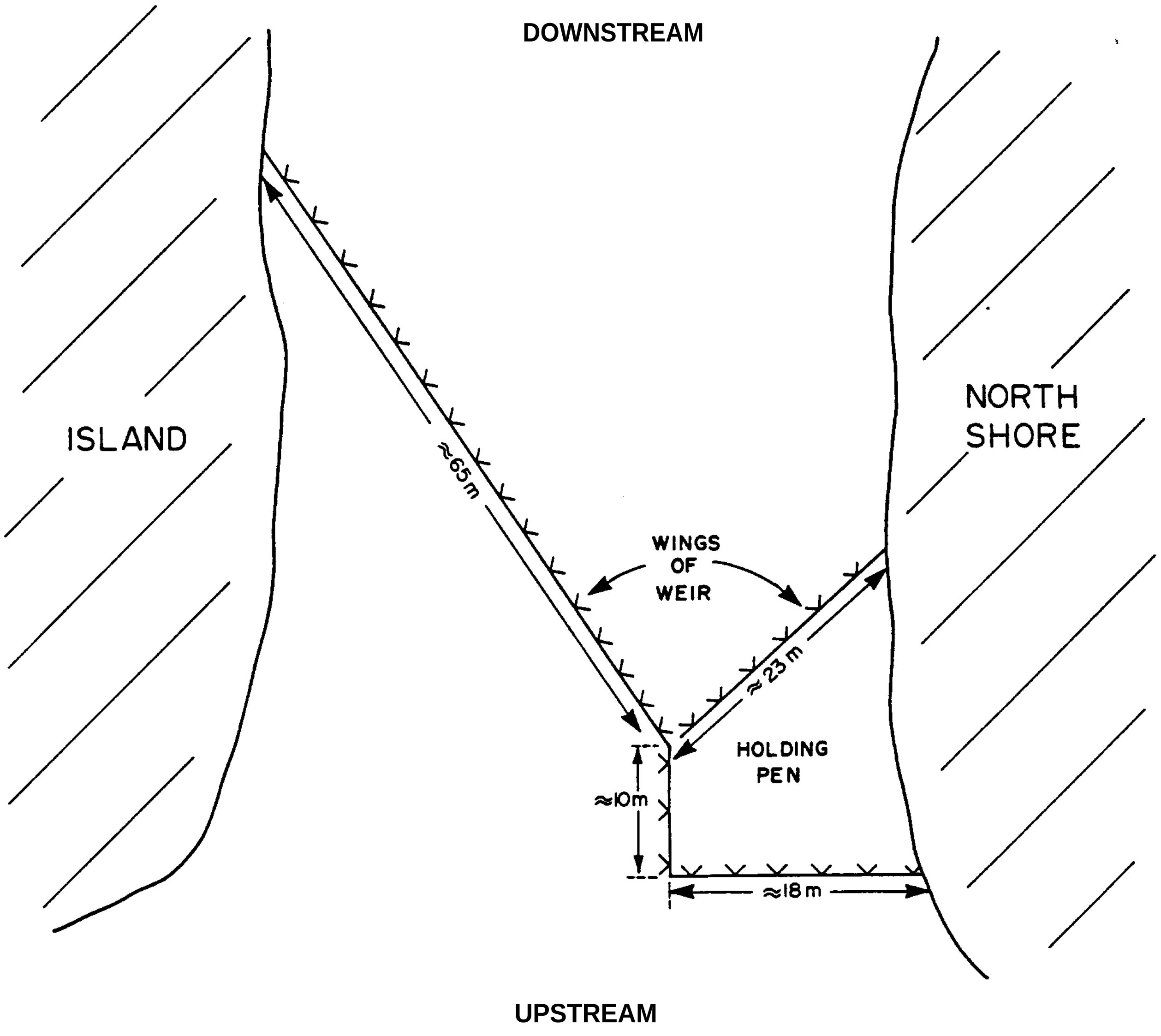



Fig. 5. Layout of conduit pipe weir used for commercial fishing in 1982, showing dimensions of structures.

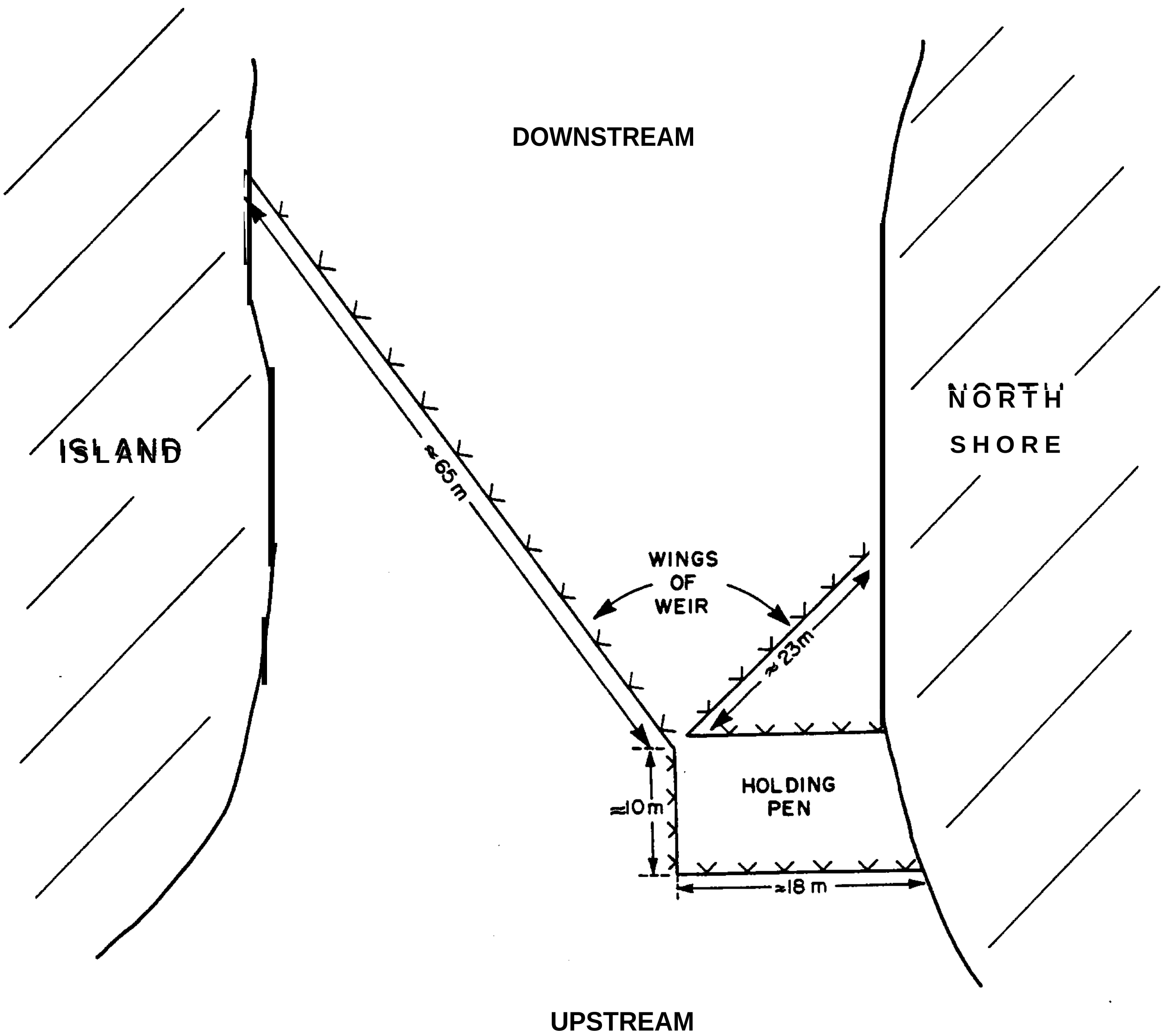



Fig. 6. Layout of conduit pipe weir used for commercial fishing in 1983, showing dimensions of structures.

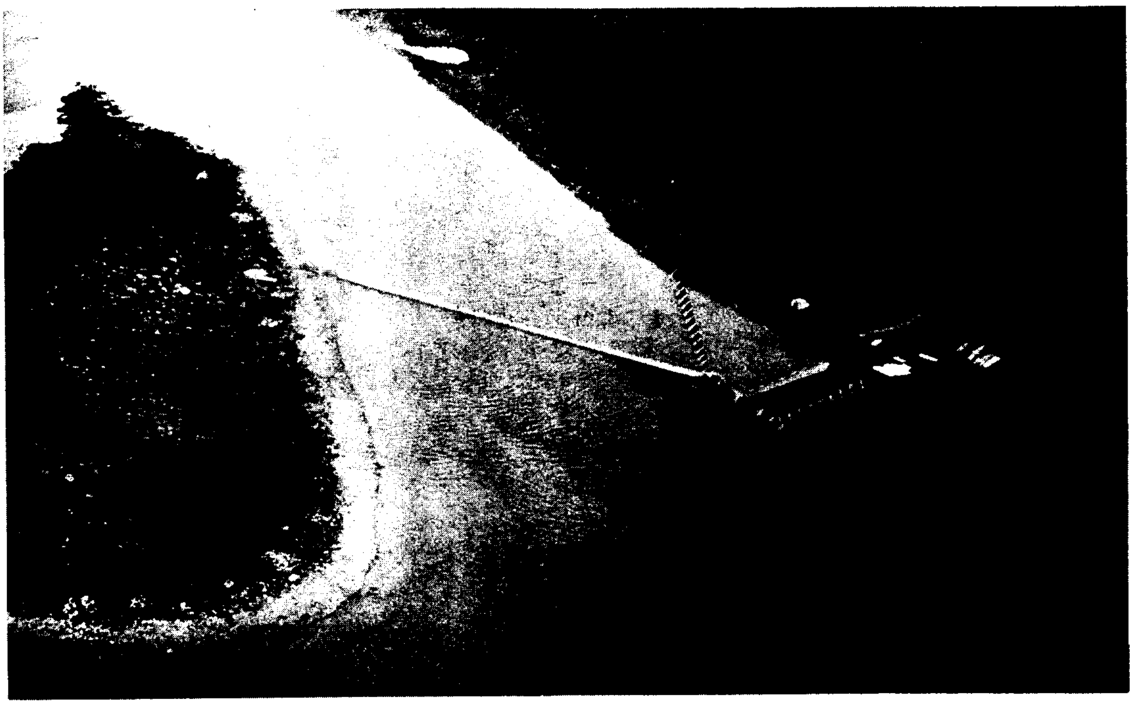
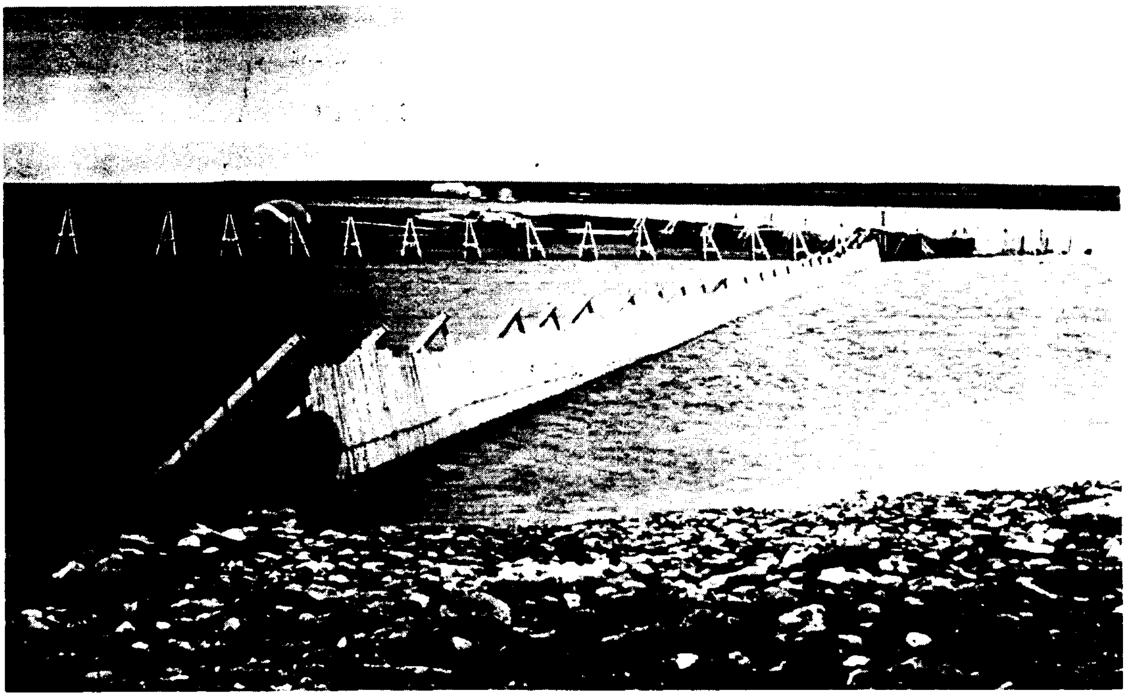


Fig. 7. **Aerialview** of the conduit pipe weir and trap used for counting and commercial fishing in 1981.



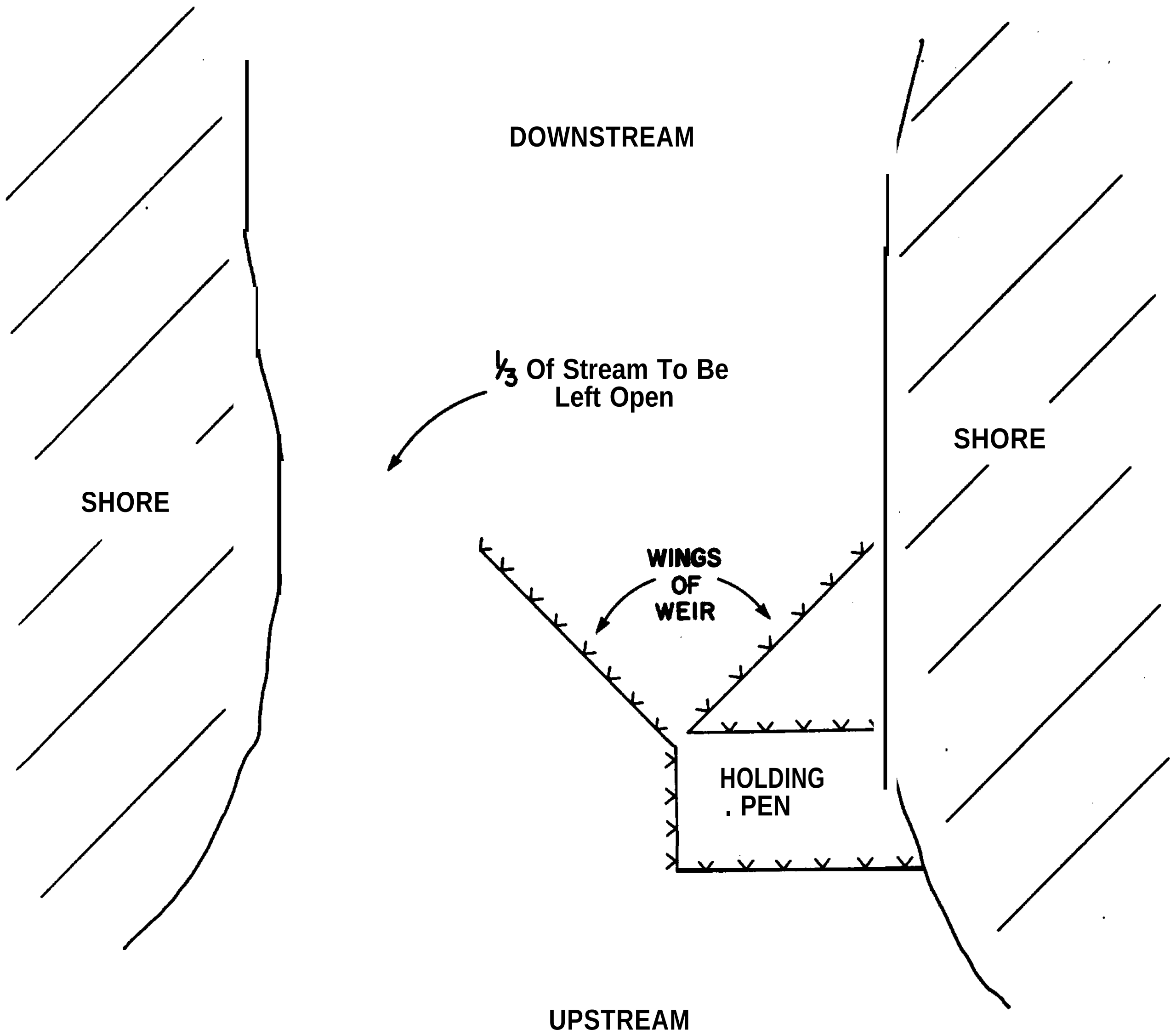



Fig. 9. Suggested layout of weir and holding pen for a commercial searun Arctic charr fishery. Heir must not span more than two-thirds of river.

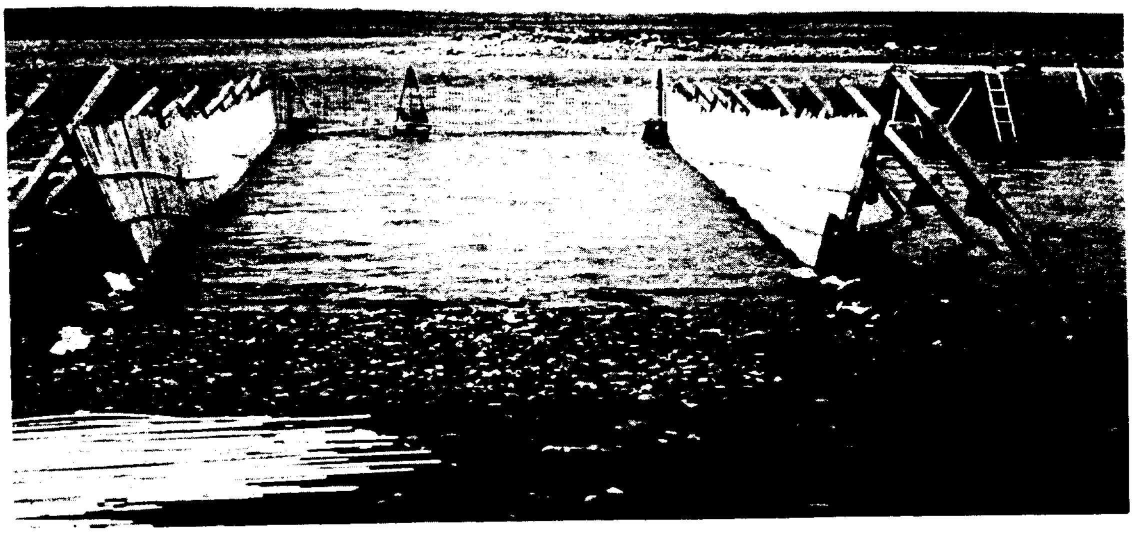


Fig. 10. View of conduit pipe holding pen from shore, 1981.

Fig. 11. Arctic charr in holding pen. Note gaps in foreground created by removing every second conduit pipe to allow small charr to escape.

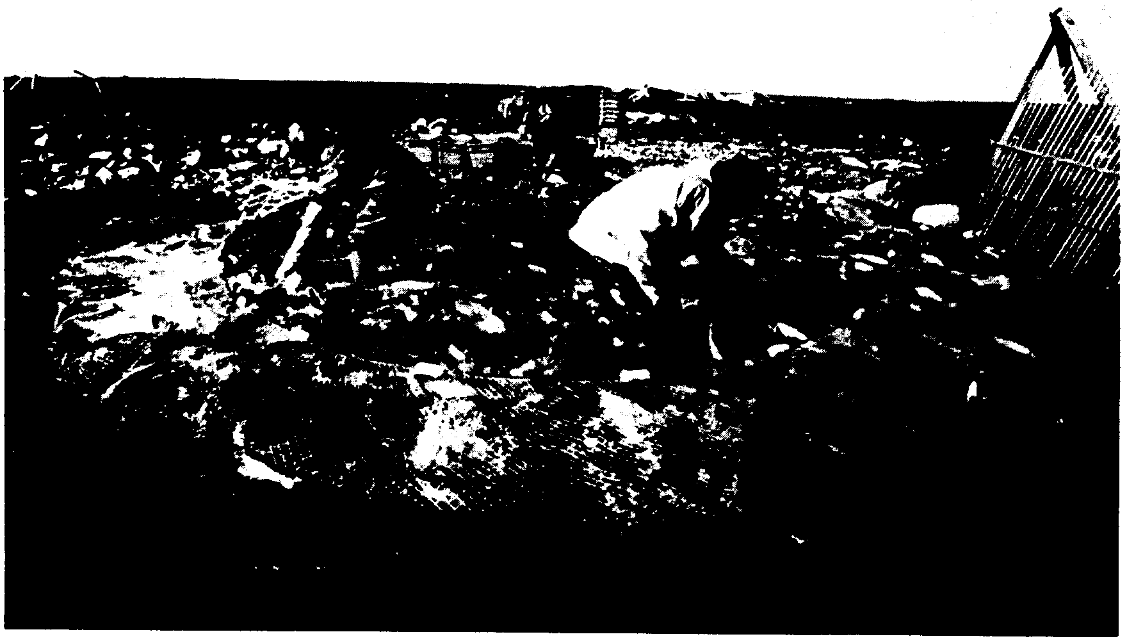


Fig. 12. Commercial fishermen harvesting charr with seine net, 1983.

Fig. 13. Commercial fishermen loading charr onto aircraft for transport to Cambridge Bay.

Table 1. Daily count of Arctic charr migrating upstream in the Jayco River and daily commercial harvest statistics using the weir, 1980.

| Date | Daily Count | Harvest | |
|---|---|---|---|
| | No. Charr | No. Charr | Dressed Wt (kg) |
| August | | | |
| 22 | 48 | | |
| 23 | 46 | | |
| 24 | W.O.[a] | | |
| 25 | W.O.[a] | | |
| 26 | 123 | | |
| 27 | 169 | | |
| 28 | 269 | | |
| 29 | 479 | | |
| 30 | 752 | | |
| 31 | 451 | | |
| September | | | |
| 1 | 617 | 193 | 442 |
| 2 | 750 | 123 | 275 |
| 3 | 1 655 | 494 | 1 175 |
| 4 | 2 066 | 468 | 1 102 |
| 5 | 5 607 | 570 | 1 511 |
| 6 | 8 586 | 209 | 542 |
| 7 | 8 244 | | |
| 8 | W.O.[a] | 347 | 890 |
| 9 | 2 147 | 823 | 2 081 |
| 10 | 1 380 | 453 | 1 399 |
| Total | 33 389 | 3 680 | 9 417 |

[a]Weir washed out due to high water and storm conditions.

Table 2. Daily count of Arctic charr migrating upstream in the Jayco River and daily commercial harvest statistics using the weir, 1981.

| | Daily Count | Harvest | |
|---|---|---|---|
| Date | No. Charr | No. Charr[a] | Dressed Wt (kg) |
| **August** | | | |
| 22 | 41 | | |
| 23 | 53 | | |
| 24 | 75 | | |
| 25 | 55 | | |
| 26 | 66 | | |
| 27 | 106 | | |
| 28 | 152 | | |
| 29 | 224 | | |
| 30 | 462 | | |
| 31 | 277 | | |
| September | | | |
| 1 | 760 | | |
| 2 | 941 | | |
| 3 | 1 436 | | |
| 4 | 6 778 | | |
| 5 | 5 413 | 205 | 627 |
| 6 | 12 292 | 460 | 1 397 |
| 7 | 14 816 | 580 | 1 757 |
| 8 | 17 337 | 745 | 2 264 |
| 9 | 19 683 | 775 | 2 357 |
| 10 | 22 716 | | |
| 11 | 12 430 | | |
| 12 | 9 625 | | |
| 13 | 6 763 | | |
| 14 | 4 268 | | |
| 15 | 2 026 | | |
| Total | 138 795 | 2 765 | 8 402 |

[a] Number calculated by dividing daily total dressed weight by mean dressed weight per charr (N=181).

Table 3. Daily commercial harvest statistics for Arctic charr taken by the weir in the Jayco River, 1982 and 1983.

| Date | 1982 Harvest-Dressed Wt (kg)[a] | 1983 Harvest Dressed Wt (kg) |
|---|---|---|
| August | | |
| 30 | | 181 |
| 31 | | |
| September | | |
| 1 | | |
| 2 | | 1 053 |
| 3 | | 2 179 |
| 4 | | 1 782 |
| 5 | 780 | 716 |
| 6 | 580 | |
| 7 | 870 | |
| 8 | 860 | |
| 9 | 840 | |
| 10 | 370 | |
| 11 | 270 | |
| Total | 4 570 | 5 911 |

[a] Approximate weight.

Table 4. Materials and costs for a conduit pipeweir and holding pen (92 m). Prices are 1985 dollars, F.O.B. Winnipeg, MB.

| Materials | Unit | Quantity | Unit cost ($) | Extended cost ($) |
|---|---|---|---|---|
| Conduit, thin-walled galvanized, 1.27 cm diam. | 1.52 m | 1443a | 0.85 | 1226.55 |
| Aluminum channel, 2.54 cm x 5.72 cm x 2.54 cm x 0.47 cm, pre-drilled | 4.88 m | 38 | 46.50 | 1767.00 |
| Standard pipe, 4.83 cm diam., pre-drilled | 2.13 m | 20 | 23.50 | 470.00 |
| Lumber, construction grade, 5.08 cm x 10.16 cm | 3.05 m | 40 | 2.40 | 96.00 |
| Angle Iron, 8.89 cm x 6.35 cm x 0.64 cm, cut and pre-drilled | 15.24 cm | 40 | 5.40 | 216.00 |
| U-bolts, galvanized, 5.08 cm x 0.95 cm | ea. | 40 | 1.35 | 54.00 |
| Carriage bolts, plated, 1.27 cm x 17.78 cm C.W. nuts and washers | ea. | 20 | 1.20 | 24.00 |
| Jute bags, 283 g. 53.34 cm x 91.44 cm | ea. | 70 | 0.50 | 35.00 |
| TOTAL | | | | $3888.55 |

[a] Conduit placed at 6.4 cm centres along aluminum channel.

Table 5. A comparison of the capital expenditures for a weir fishery and a gillnet fishery for searun Arctic charr at the Jayco River, NWT. prices are 1985 dollars, F.O.B. Winnipeg, MB. and include freight to the fishing site. Period of operation is 10 years.

| Item | Fishery (conduit pipe) ($) | Gillnet Fishery ($) |
|---|---|---|
| Material for 92 m conduit pipe weir | 8004 | |
| Beach seine, replaced every 4 years | 860 | |
| 200 m gillnet, replaced every 4 years | | 1397 |
| 6.7 m freighter canoe | (Xl) 3600 | (X2) 7200 |
| Replace canoes after 5 years | (Xl) 2235 | (x2) 4470 |
| 40 hp outboard motor | (Xl) 2600 | (X2) 5200 |
| Replace motorS after 5 years | (xl) 1614 | (x2) 3228 |
| TOTAL | $18913 | $21 495 |

Appendix 1. Construction details of the trap used to enumerate the upstream migration of Arctic charr in the Jayco River, 1980 and 1981.

Rectangular in shape the frame consisted of lengths of aluminum handy angle (6.4 cm x 3.8 cm x 0.5 cm) fastened together with stainless steel hex-head machine bolts (0.6 cm x 20 x 2.5 cm), lockwashers, flatwashers and nuts (Fig. A1l). The trap was lined on the inside with plastic netting (du Pent Vexar, 9.5 mm mesh). The netting was held in place by strips of aluminum (2.5 cm x 0.3 cm) bolted to the frame of the trap. The floor was made of plywood, 0.6 cm thick. A plywood drop gate, 15 cm x 1.9 cm x 2.4 m long, was located at the head of the V-shaped entrance. Aluminum channel (2.54 cm x 5.72 cm x 2.54 cm x 0.47 an) was used for the jambs. As well, two drop gates were fitted to the upstream end of the trap. Each was constructed of aluminum handy angle and covered with 9.5 mm plastic netting. The drop gates were 0.6 m wide and 1.0 m deep. Aluminum channel formed the jambs. A deck of plywood, 1.6 cm thick, covered the downstream half of the top of the trap. Rocks were placed on this deck to provide ballast, once the trap was in position in the river. Burlap sacks, filled with rocks and tied shut, were hung over the frame of the upstream end of the trap to provide additional ballast. A ladder, constructed of aluminum handy angle with aluminum channel rungs, was assembled to provide personnel with access to the inside of the trap. The wings of the weir could be fastened to each side of the V-shaped entrance to the trap by means of gudgeon-type hinges and aluminum rods dropped down through the holes in the hinges.

Appendix 2. Construction details of the plastic netting weir used in 1980 and the wire barrier used in 1980-83.

The wings of the weir were made with standard T-rail posts (snow fence stakes), 2.4 m In length, driven part way into the river bottom every 3"m in a straight line extending downstream from the entrance of the trap to each bank of the river. The T-rail posts were then joined by two rows of stringers attached on the upstream side with plastic fasteners (Tyrap). The stringers were made from 3 m lengths of galvanized conduit pipe (2.5 cm diameter). One row was fastened about 0.3 m above the river bed while the other was located at water level (Fig. A2.1). This structure was covered with 25 mm mesh plastic netting (Vexar), attached to the entrance of the trap (Fig. A2.2) and unrolled from a boat onto the upstream side of this framework. The netting, 1.5 m wide, was attached to the T-rail posts and stringers with plastic fasteners leaving a 0.4 m skirt at the bottom. Rocks were piled on this skirt to ensure that no fish could pass under the weir. Since the water depth did not usually exceed 0.8 m, this left about 0.3 m of plastic netting extending above water level.

To build the wire barrier T-rail posts were driven into the river bed at 3 m intervals and welded wire fabric (25 mm mesh), bent to form a 90° angle, was attached to the upstream side with plastic fasteners (Fig. A2.3). Since the water was shallow (0.3 m), a 0.8 m width of welded wire fabric provided sufficient material to form a 0.3 m skirt leaving 0.2 m of mesh extending above water level. Rocks were placed on the skirt to prevent fish from swimming under it.

Appendix 3. Construction details of the wire mesh sorting panel used in the holding pen, 1980.

The sorting panel was made of woven wire, 6 mm thick, mounted in an aluminum handy angle frame which measured 0.9 m x 1.2 m (Fig. A3.1). The wire in the panel formed diamond-shaped openings similar to that in a hanging gillnet. Five panels were made with mesh openings of 89, 102, 114, 127 and 139 mn, respectively. The largest size represented the minimum gillnet mesh size presently allowed in the commercial fishery. Each panel could be dropped into place between two aluminum channel jambs held upright by T-rail posts driven into the river bed.

Appendix 4. Construction details of the conduit pipe weir used in 1981-83.

Tripod supports were constructed by fastening the end of two 2.4 m lengths of 5.0.3 cm x 10.16 cm (two by four) lumber to the end of a 2.1 m length of standard 4.83 cm pipe with a 1.27 cm x 17.78 cm carriage bolt (Fig. A4.1). A 0.6 m length of two by four lumber was nailed to the two wooden supports to form a cross-member. This provided rigidity and separation for the wooden legs.

Two pieces of angle iron, 8.89 cm x 6.35 cm x 0.64 cm, were fastened to the front of the standard pipe leg by means of U-bolts. The lower piece was attached about 40 cm from the bottom and the upper piece was located about 60 cm above it. Each piece of angle iron had four pre-drilled holes across the horizontal face. The holes were 2 cm in diameter and 3.2 cm centre to centre. Two rows of aluminum channel stringers, each 4.88 m in length, rested on these angle iron seats and thus joined the tripod supports together. Holes, each 2 cm in diameter, were drilled along the length of these channels and spaced 3.2 cm centre to centre. The stringers were attached to the angle iron seats by inserting two 1.52 m lengths of 1.3 cm diameter EMT thin-walled galvanized conduit pipe through the last two holes in the stringer and the corresponding holes in the seat. Subsequent studies have revealed that drilling five holes in the angle iron seat, instead of the four described above, results in a better design. The stringers are attached to the outside two holes on each end, as described, but a single piece of conduit is inserted in the middle hole to fill the gap. This prevents binding of the stringers during construction.

Once the trap was positioned and anchored in the stream, the tripod supports were set up in the river, 2.4 m apart. The pipe leg of each tripod support faced upstream with the wooden legs downstream. The position of the wooden legs was adjusted such that the pipe leg formed an angle of about 120° with the upstream river bed (Fig. A4.1, A4.2). Once in position the tripod supports formed a V-shaped pattern with the apex at the entrance to the trap (Fig.' A4.2). Burlap sacks, filled with rocks were hung over the cross-members between the wooden legs to provide ballast and anchor the tripod in position. The stringers were then fastened between the tripods supports and the weir was completed by Inserting 1.52 m lengths of the galvanized conduit pipe in all the remaining holes. Plastic netting (25 mm mesh Vexar) was used at the junction of the wings of the weir and the trap.

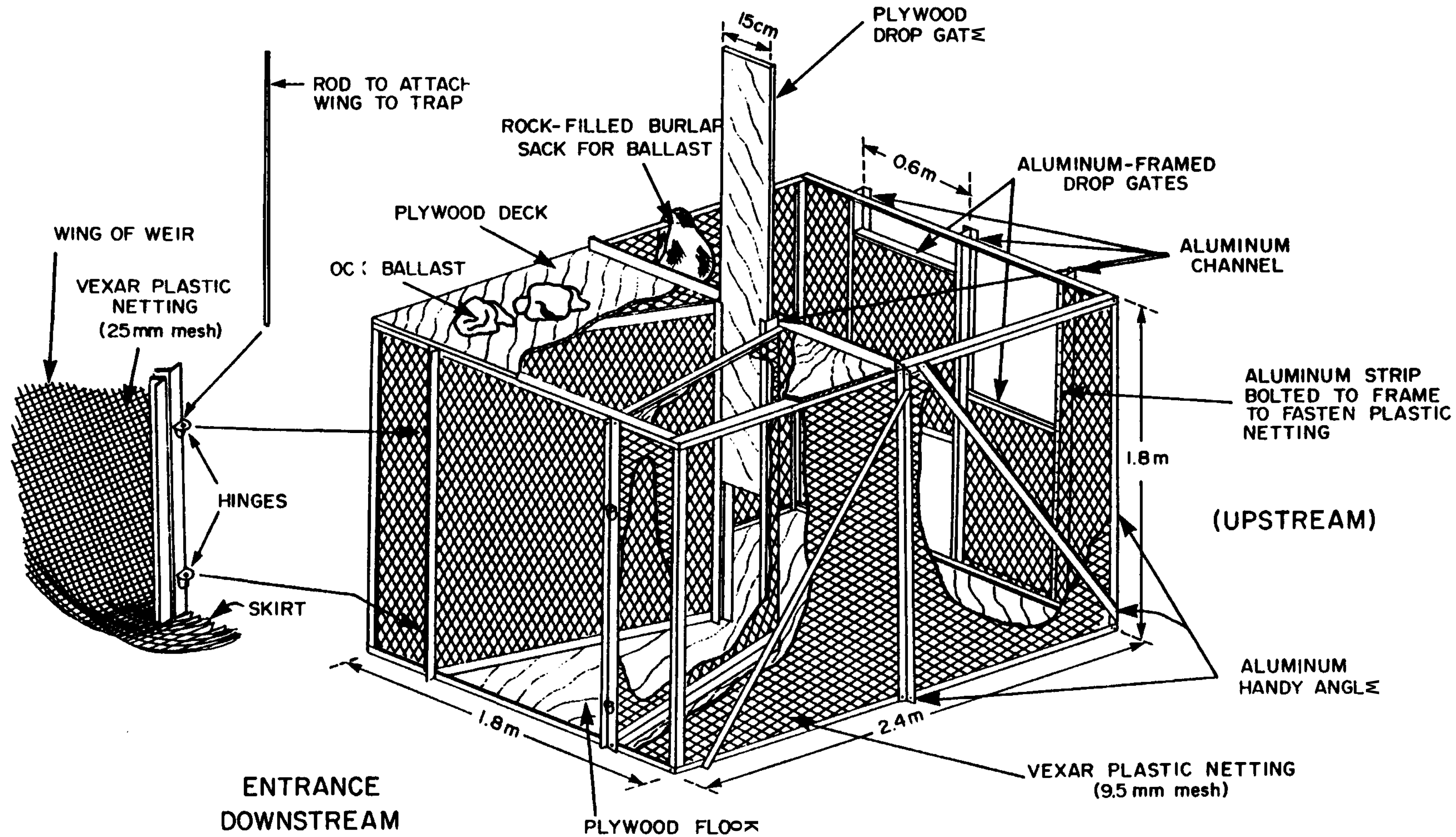



Fig. 5.1.1. Construction details of the trap used to enumerate the upstream run of charr.

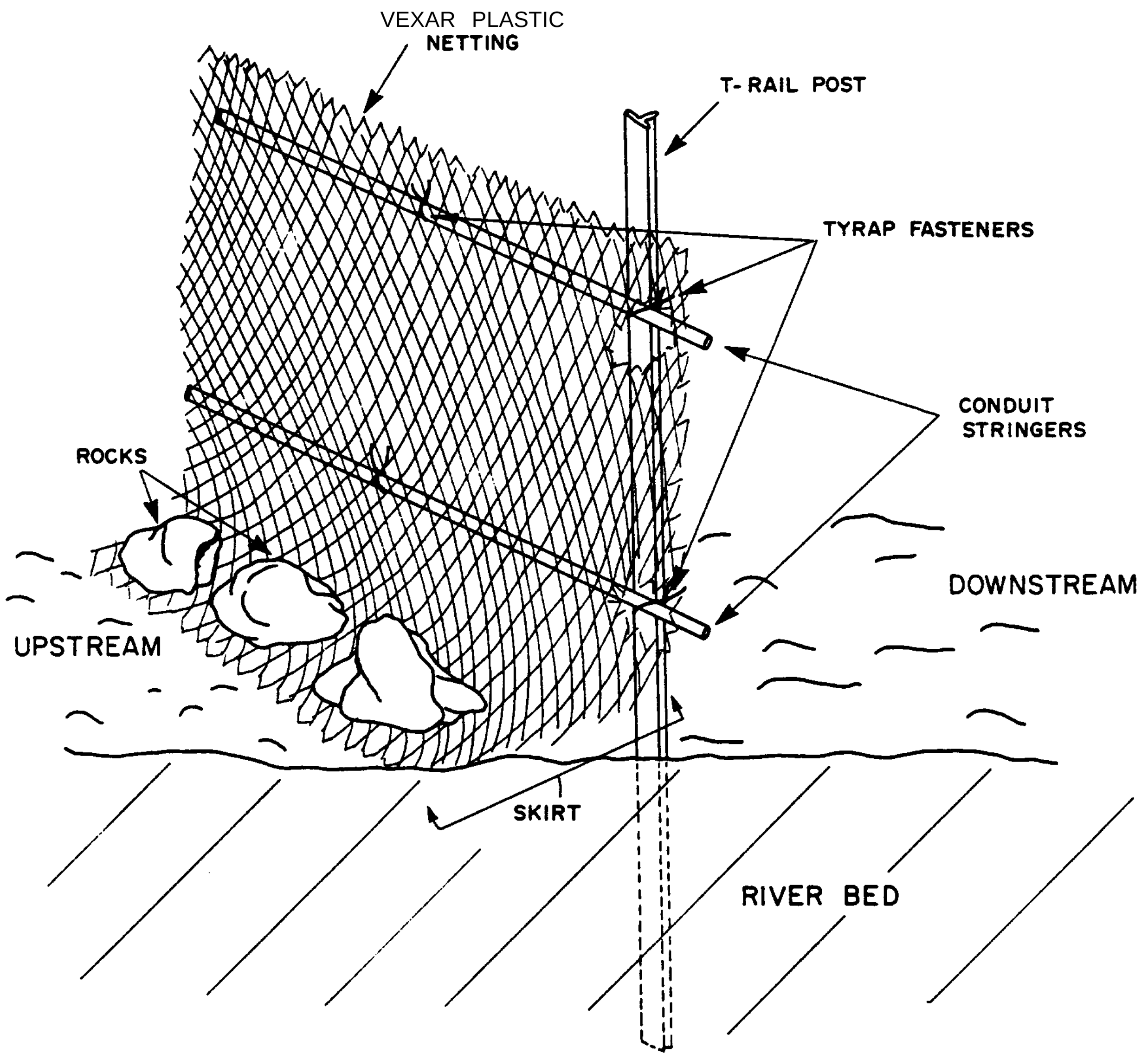



**Fig. A.2.1.** Construction details of the wings of the 'plastic netting weir used in 1980.

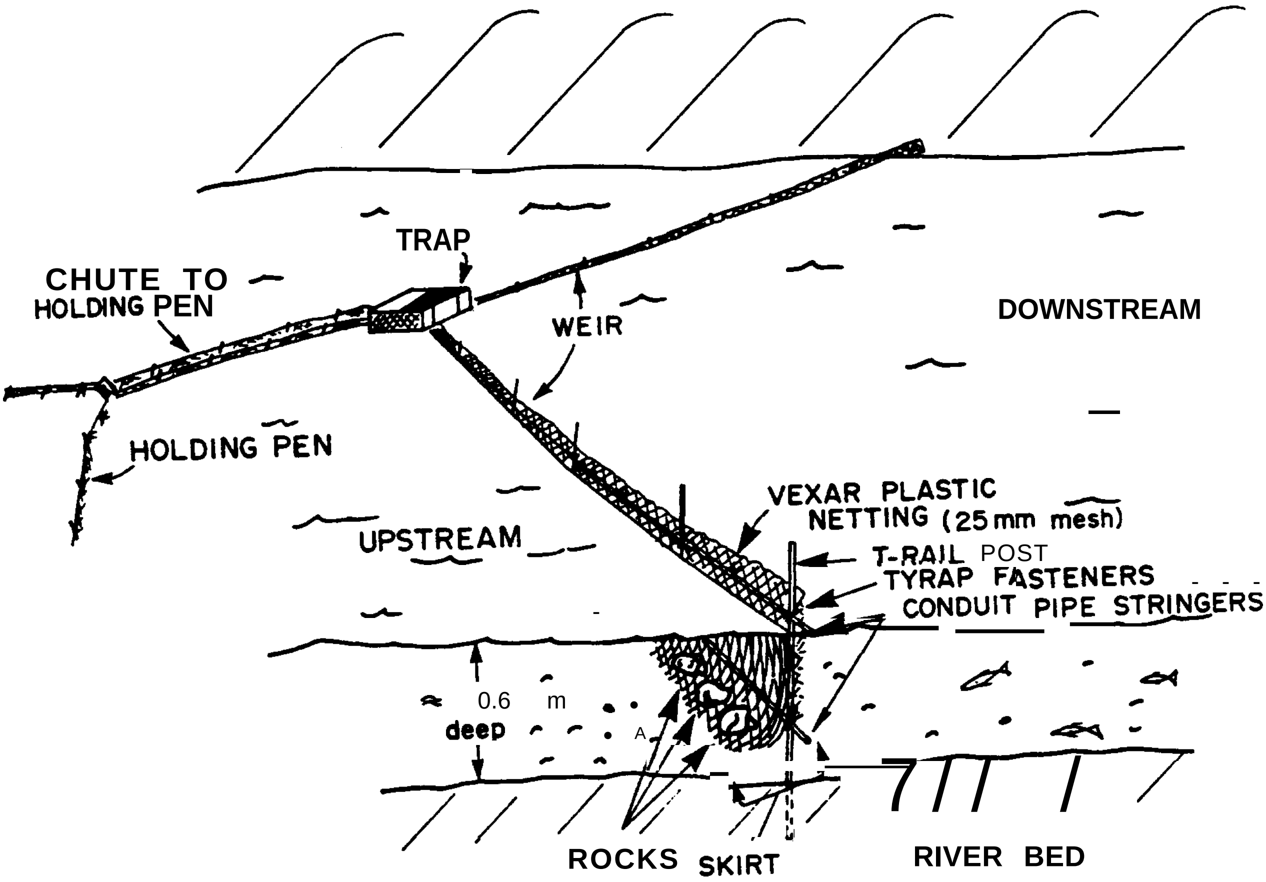



**Fig. A.2.2.** **Side view of layout of plastic netting weir used in 1980 showing underwater details.**

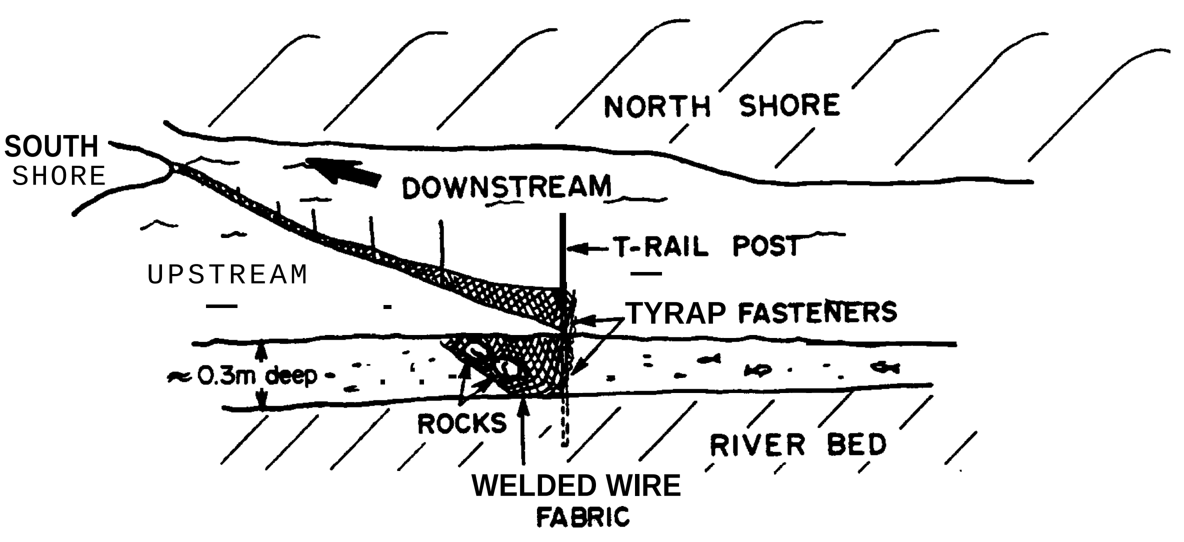



**Fig. A.2.3.** Side view of wire barrier erected between island and south shore, 1980-83, showing underwater details.

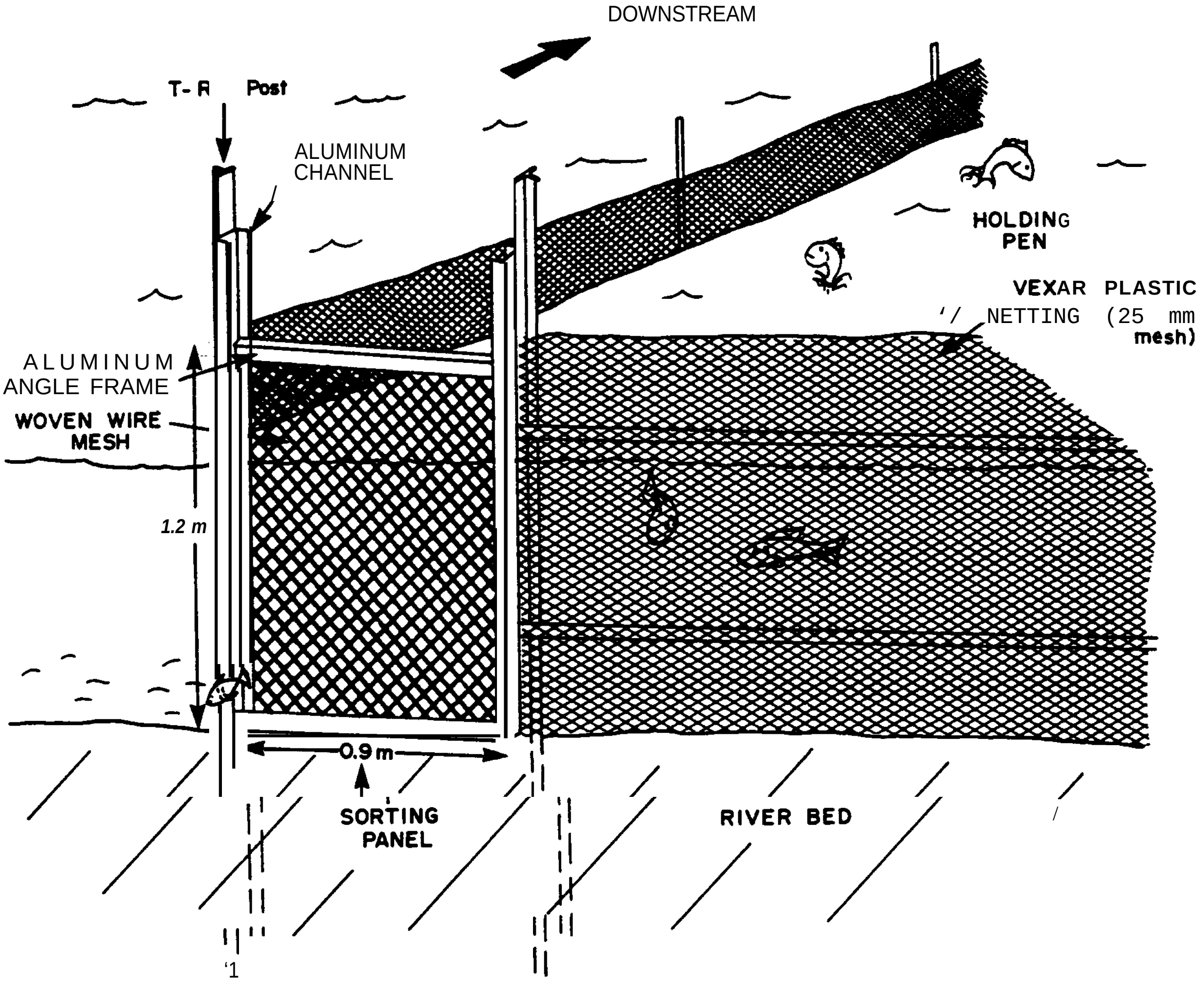



Fig. A.3.1. Construction details of wire mesh sorting panel instal led in holding pen, 1980.

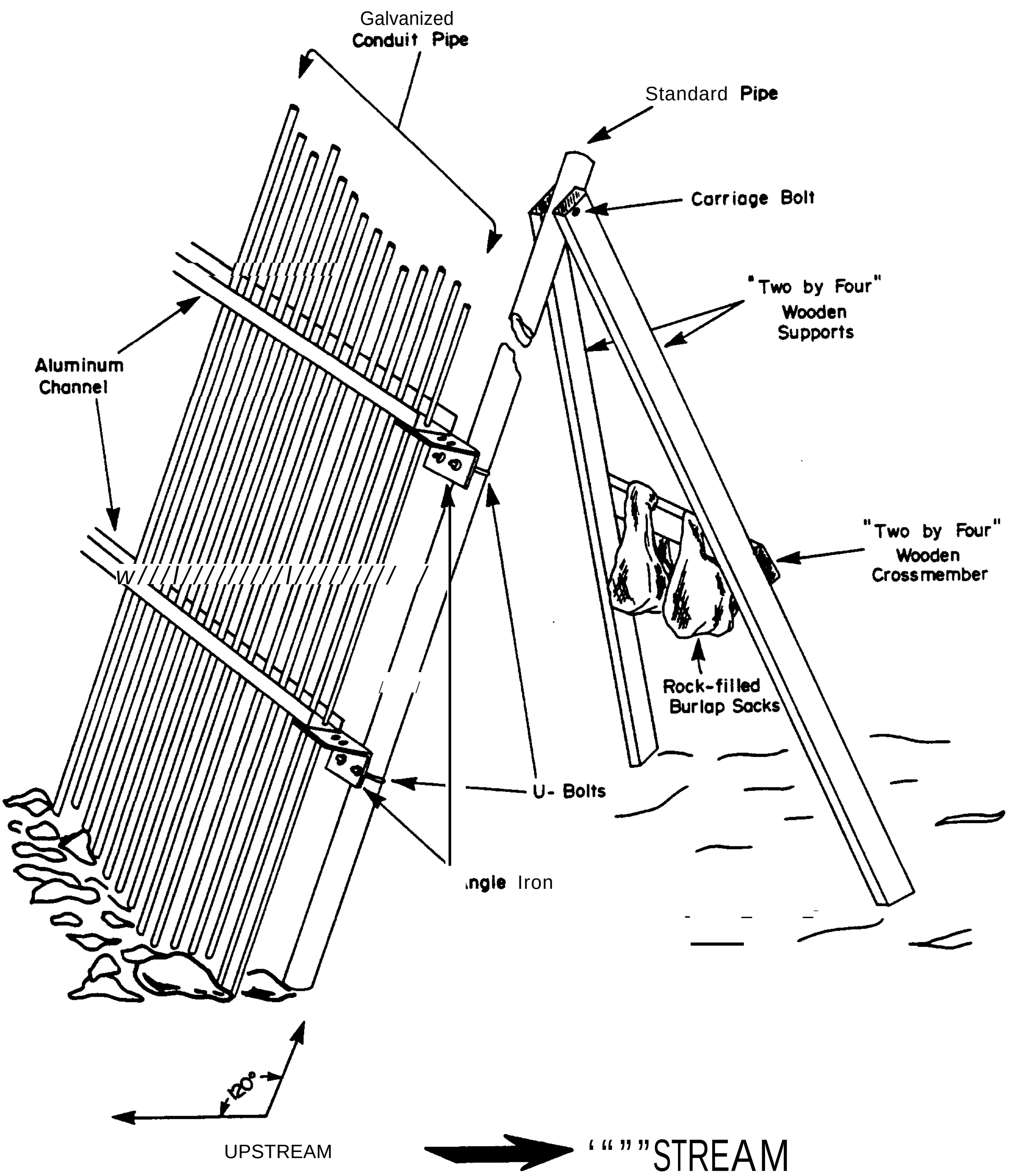



Fig. A.4.1. Construction details of wings of conduit pipe weir used in 1981-83.

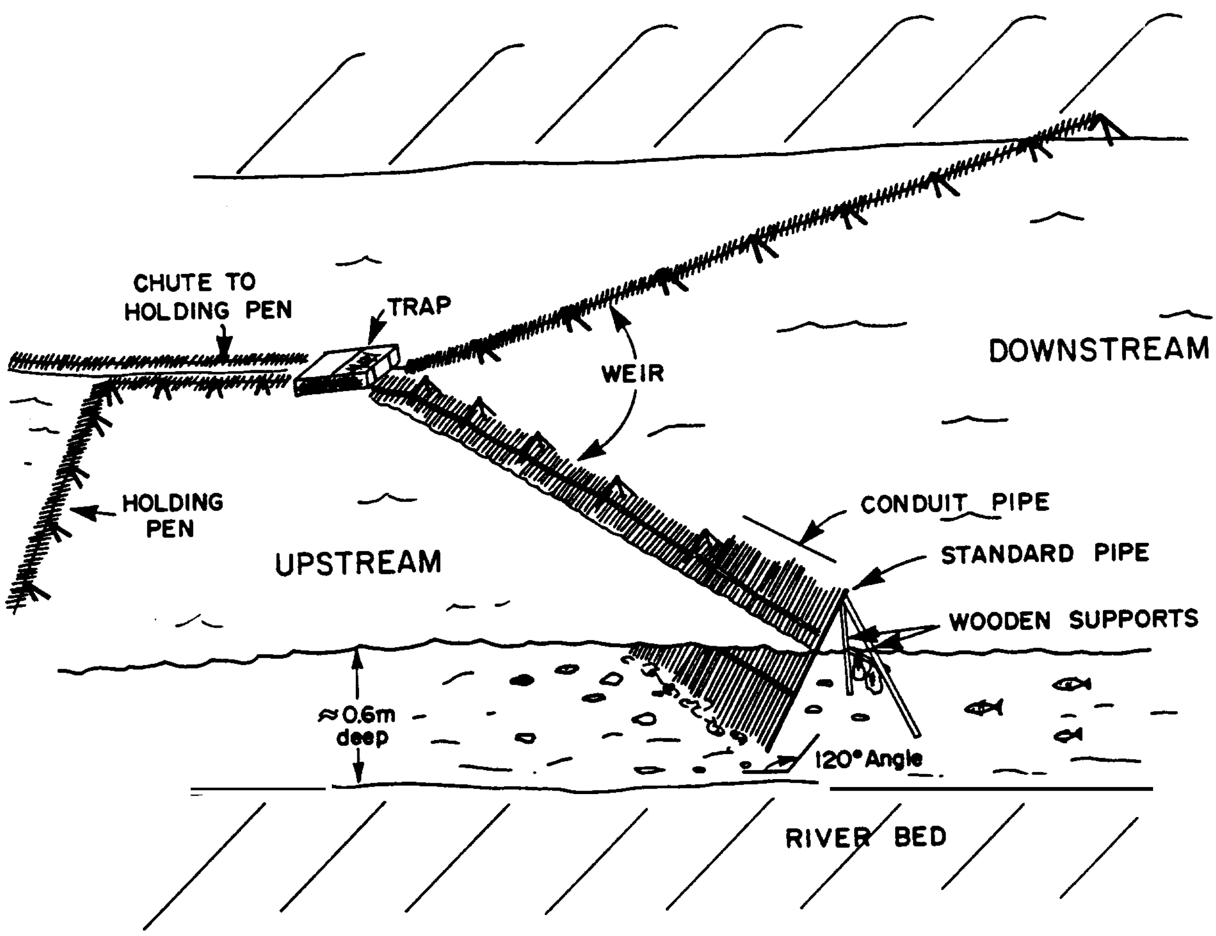



Fig. A.4.2. Side view of layout of conduit pipe weir used in 1981 showing underwater details.