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MAINTENANCE OF RAINBOW TROUT IN THE LOWER WAITAKI RIVER WITH HYDRO-ELECTRIC DEVELOPMENT

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Servicing freshwater fisheries and aquaculture

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CONTENTS

TABLES

I. INTRODUCTION

Rainbow trout are a distinctive feature of the unique salmonid fishery of the lower Waitaki River. Previous studies indicated some uncertainty about the long term prospect of maintaining rainbow trout in the proposed residual river, an integral part of the proposed lower Waitaki power scheme (Graybill *et al.* 1988). We have found no evidence from these previous studies to suggest that rainbow trout spawn in the mainstem lower Waitaki. We have no assurance, therefore, that they will spawn in the residual river. The tributaries are likely to be the major source of rainbow trout recruitment for the residual river.

In Section II of this report we summarise the information available on life history of rainbow trout in the lower Waitaki River. This comes mainly from the following Freshwater Fisheries Centre Miscellaneous reports:

Bloomberg, James and Hughes 1990: Rainbow trout spawning migrations in the Awakino river 1987-89. Report No. 80.

James and Bloomberg 1990: An assessment of the abundance, distribution and population structure of adult trout in the mainstem lower Waitaki river, using drift-netting. Report No. 72.

Graybill and Palmer 1991: Juvenile rainbow trout recruitment from lower Waitaki tributaries. Report No. 89.

Palmer, Graybill and Bloomberg 1991: Rainbow trout recruitment from Lake Waitaki. Report No. 93.

Graybill, Palmer and Bloomberg 1991: Juvenile rainbow trout emigration from the Aviemore spawning race. Report No. 96.

Palmer and Graybill 1991: Observations on juvenile rainbow trout and brown trout in the lower Waitaki River 1989-90. Report No. 94.

In Section III we discuss the prospect of maintaining rainbow trout in the proposed residual river as part of the proposed lower Waitaki power scheme.

II. LIFE HISTORY OF RAINBOW TROUT IN THE LOWER WAITAKI RIVER

1. Adults

1.1 Distribution and Abundance

Recent drift-netting studies in the Lower Waitaki River have confirmed earlier indications that the species composition of trout is about 35% rainbow and 65% brown. The proportion of rainbows was higher in the upper half of the river (about 45%), than further downstream.

Adult rainbow trout (between about 40 to 60 cm in length, and three to five years of age) rear mostly in the mainstem Waitaki. Some adults remain in larger tributaries such as the Hakataramea River after spawning, but in the smaller Awakino they apparently move back downstream into the Waitaki soon after spawning.

Sub-adult fish (about 20 to 40 cm and two years of age) are usually only found in the mainstem Waitaki and it's side braids.

The drift-netting studies have shown that adult and sub-adult rainbow trout are considerably more abundant near Kurow, than further downstream near Duntroon and Ferry Road This confirms the view of many experienced anglers that catch rates are highest in the Kurow area. Greater trout abundance near Kurow is thought to reflect increased invertebrate productivity (and thus trout food supply) below the Waitaki Dam, a phenomenon often known as the "lake effect".

This pattern of abundance appears to be variable. There are records from the early 1950s and particularly the early 1970s (WVAS Annual Reports) indicating that there were greater numbers of adult trout available to anglers then, in the middle and lower reaches of the river, than now appears to be the case.

1.2 Movements

About 85% of rainbows tagged in the Awakino River during their spawning migration and later recaptured by anglers, were caught in the upper reaches of the Lower Waitaki River within a few kilometres of the mouth of the Awakino River. The remainder were taken in diminishing numbers downstream towards the mouth. This pattern of recoveries resembles closely the distribution of adults determined from drift-netting studies in the mainstem, and suggests that most adult Awakino rainbows rear in the upper reaches of the Lower Waitaki River after spawning. Only one Awakino fish was later recaptured in the Hakataramea River, which together with the differences in biological characteristics described below, supports the view that some stock differentiation has occurred amongst rainbows in the Lower Waitaki system.

Of migrating rainbows trapped in the Hakataramea and Maerewhenua Rivers in the early 1980s, it is noteworthy that none were subsequently recaptured in the mainstem lower Waitaki River.

Very limited information is available on rainbows tagged in the mainstem Lower Waitaki River. Only one rainbow tagged during the drift-netting surveys in the mid or lower mainstem was recovered, having moved from near Ferry Road in June to the Hakataramea River some 2.5 years later. Several fish tagged in the upper reaches near Kurow were recaptured in the same vicinity or in the Awakino. Of rainbows trapped in the demonstration channels during the early 1980s, several were recaptured in the Hakataramea trap some 27 km upstream shortly thereafter. These observations all support the view that rainbows rear in the mainstem and migrate into the tributaries to spawn.

1.3 Spawning

Extensive spawning and juvenile fish surveys have failed to find any evidence of rainbow trout spawning in the mainstem Lower Waitaki River or side braids (Graybill *et al.*, 1988; Palmer and Graybill, in prep). Spawning is only known to occur in the three main tributaries, the Awakino, Hakataramea, and Maerewhenua Rivers, with the first two being the more important. The geographical location of these two tributaries at the upstream end of the system is probably related to their greater use by rainbow trout for spawning. However, the Maerewhenua rainbow fishery does appear to have declined noticeably over the last decade or more, and it is likely that spawning activity was greater in the past.

Rainbow trout spawners in Lower Waitaki tributaries have been estimated to range from 350 to 850 (mean 550) in the Awakino during the late 1980s, to 90 to 260 (mean 180) in the Hakataramea and 60 to 120 (mean 90) in the Maerewhenua, both during the early 1980s (Table 1). Some experienced anglers believe that angling has improved, and perhaps fish populations have increased in the upper reaches of the Lower Waitaki since the early 1980s, and it may well be that the difference in number of spawners in the Awakino and Hakataramea Rivers is not now as large as these values indicate. In either case, these two upstream tributaries are of major importance for rainbow trout spawning. Without spawning runs into these rivers, it is very likely that the rainbow trout resource in the Lower Waitaki River would cease to exist. Only one fish was trapped in Welcome Stream during two years in the early 1980s. By comparison 448 rainbows entered the Aviemore spawning channel from Lake Waitaki in 1989 (Table 1).

Spawning migrations into the tributaries peaked in August and September. Low numbers of fish were still moving upstream during October, but very few fish appeared to migrate in July. Males moved upstream earlier than females.

The sex ratio was found to be surprisingly variable. Mean values ranged from 39% males in the Awakino to 49% males in the Hakataramea and 52% males in the Maerewhenua (Table 1).

The proportion of repeat-spawning rainbows recaptured in the Awakino trap ranged from 22% in 1988 to 10% in 1989. These values are lower than expected and presumably reflect high levels of mortality from natural causes as well as tagging and angling. The values are still, however, comparable with most other studies such as those reported on by Webb *et al.* (in press).

The length-fecundity relationship was determined for lower Waitaki rainbow. Total egg counts were available for 12 females mostly from the Hakataramea River in the early 1980s (Webb *et al.* in press) and from nine additional females from the Awakino River in 1988 and 1989. Regression analysis indicated that the regression lines for the two sets of data were not statistically different. The two sets were combined and regression analysis gave the following length-fecundity relationships for lower Waitaki rainbows.

$$\text{Ln fecundity} = 2.507 \text{ Ln length (mm)} - 7.220$$
$$(P < 0.01, r = 0.836, n = 21)$$

Using this relationship the fecundity for individual females was calculated and summed to estimate potential egg deposition. These estimates are shown in Table 4.

1.4 Length, Condition Factor, and Age

Mean lengths of spawning fish were very similar in the Hakataramea and Maerewhenua Rivers, but markedly larger in the Awakino River (Table 2). By comparison, spawners were larger again in the Aviemore spawning channel, and generally at least as large (as lower Waitaki fish) in the upper Waitaki system (Table 2).

Condition factor was also found to be noticeably larger for Awakino spawners than for fish from elsewhere in the Lower Waitaki system. Since most Awakino fish appear to rear between the Waitaki Dam and Kurow, the observed increase in condition factor is consistent with published information on the "lake effect", where food and fish production may be considerably enhanced for some distance below a reservoir.

The marked differences in sex ratio and mean length between spawning rainbows in the Awakino and other Lower Waitaki tributaries (together with recapture locality information) suggest that some differentiation of rainbow trout stocks may have occurred in the Lower Waitaki system. However, concurrent trapping of the spawning runs in all tributaries, and preferably a more intensive tagging programme, would be needed to test this hypothesis.

Most rainbow trout spawning in the Awakino River were aged 3+ years, with diminishing numbers of 4+, 2+, 5+, and 1+ aged fish (Table 3). By comparison spawners trapped in the Aviemore spawning channel were mostly 4+, with lesser numbers of 3+, 5+, and 2+ fish. Rainbows captured by drift-netting in the mainstem Lower Waitaki were noticeably younger, being mostly 2+, some 3+, and very few 1+, 4+, and 5+ (Table 3).

2 Juveniles

As rainbow fry emerge from the substrate, some migrate downstream as fry while others remain in the tributaries to rear for in some cases up to a year. The extent to which these behaviours are active or passive is unknown. Some obviously resist the current and remain in the tributary. It seems to relate to density and not to fish size.

2.1 Outmigration

The timing of fry migration in the Awakino and Hakataramea Rivers extended from late October to mid-December reaching a peak in mid-November. We believe this approximates the emergence period. The timing appeared to be consistent between the two years sampled (1988 and 1989) in the Awakino and between the Awakino and Hakataramea in the first year (1988). In the second year (1989) in the Hakataramea the run appeared to be virtually completed by late November. We are uncertain whether or not this represented an actual shift in timing or generally resulted from the low numbers of migrating fry. We would suspect the latter but without information about the timing and magnitude of the adult run we cannot be sure.

In the Aviemore spawning race the fry migration period extended from late October to late December peaking during mid November to early December.

The fry migration period was shorter than the spawning period in both the Awakino and the Aviemore spawning channel. This occurs because the water temperatures, which control the general rate of embryonic development, are increasing during the incubation period (Graybill *et al.* 1979). Eggs spawned later are able to "catch up" with those spawned earlier because of the progressively increasing water temperature and the overall emergence period is therefore shortened.

After the initial pulse of the fry migration in the Awakino the downstream movement of fingerlings seemed to be associated with freshes but not necessarily consistently. Sampling on a minor fresh (increasing from about 0.4 m^3/s to 1.1 m^3/s) in mid December 1988 yielded only one juvenile rainbow while a larger one (from about 0.6 m^3/s to 1.8 m^3/s) on 14 March 1989 yielded 74 rainbows. At most other times the catches were virtually nil. It is possible that there is some threshold level of fresh that triggers juvenile movement.

The estimated total number of rainbow fry migrating downstream in the Awakino ranged from 32 000 to 69 000 and in the Hakataramea from 7000 to 40 000, and was 448 000 in the Aviemore spawning race (Table 4). We are reasonably confident of the general accuracy of these estimates particularly for the Awakino in 1989 (69 000 fry) and for Aviemore (448 000 fry). Our sampling was reasonably frequent (every third night), trap efficiency was good, and we sampled during the peak hours of movement (2000 hours to 0800 hours).

Almost all fry were observed to migrate at night. In 24-hour trials, 99.6% (out of 14 252 fry) and 99.8% (out of 628 fry) of fry migrated between the hours of 2000 and 0800 in Aviemore and Awakino respectively.

The 7000 fry estimated for the Hakataramea in 1989-90 is a particularly poor result. The reason is not known but is possibly related to low flows resulting from drought conditions in the area. The extremely poor result observed in the Maerewhenua in the first season most likely resulted from the placement of an earthen dam across the entire flow. The potential for both tributaries should be considerably higher than these results indicate.

Our studies suggest that the magnitude of the fry outmigration from each of the three tributaries is in tens of thousands of fry rather than something higher. Under normal conditions we would expect the Awakino and Hakataramea to rank higher than the Maerewhenua.

2.2 Rearing in the Awakino

2.2.1 Seasonal Abundance

The greatest numbers of 0+ rainbows sampled over a 16-month period in the Awakino were captured in January and February 1989 (1988 year class) and December 1989 (1989 year class) (Table 5). This followed the peak migration period, and presumably the peak emergence period, by some 1-3 months. This simply reflects that emergent-sized trout can not be captured effectively using electric fishing. After January/February 1989 when peak numbers were captured the number of juveniles (1988 year class) present declined gradually. Few 1+ rainbows were present after April 1989.

A major flood (about 30 m^3/s) occurred in the Awakino in mid-February 1990. As a result the number of juveniles in the Awakino site declined about 71% (198 to 57) between the February and March 1990 samples (Table 5). This compares to a decline of about 27% (117 to 85) between February and March the previous year. There is little doubt that this flood greatly increased the rate of juvenile trout outmigration. It is interesting, however, that the number of rainbow present in March 1990 (57) following the flood was similar to the number present in April 1989 (60) with no flood. This suggests that the flood reduced the numbers to its "carrying capacity" earlier than it would have without the flood. The fate of those "forced" out of the Awakino is not known. There would be no reason why the majority couldn't have taken up residence in the mainstem lower Waitaki.

The greatest number of 0+ brown trout were captured at the Awakino site in January 1989 (1988 year class) and December 1989 (1989 year class) (Table 5) even though this followed their emergence period by several months. Some 1+ browns were present through to September 1989 becoming 2+ browns in October and remaining in small numbers through December 1989.

2.2.2 Density

Peak 0+ rainbow densities were some three times greater for 1989 year class fish than for 1988 fish (1.23 versus 0.37 fish/m^2) (Table 5). A similar pattern was shown for 0+ browns. At peak densities (and abundance) 0+ browns were consistently present at higher densities than 0+ rainbows through to about January/February. Thereafter, however, their densities were similar.

Densities for both species declined significantly between February and March 1990 as a result of the mid-February flood. Based on these limited data it appears that 0+ browns were affected more by the flood (going from 0.83 to 0.11 fish/m^2) than were rainbows (0.62 to 0.18 fish/m^2).

2.2.3 Total Population Size

The estimated numbers of juvenile rainbow rearing in the Awakino in March 1990 following the flood was some 8000 0+ fish at an overall density of 0.13 fish/m^2. Assuming that the flood had not occurred and that a similar reduction in numbers took place as occurred between February and March 1989, a population estimate of some 14 000 rainbows (0.22 fish/m^2) is obtained. Using the peak density for rainbows as observed in December 1989 (1.23 fish/m^2), gives an extreme maximum estimate of about 79 000 fish. In realistic terms the number of 0+ rainbow trout expected to rear in the Awakino in the first several months following emergence would be in the tens of thousands (perhaps 30 000 to 40 000) rather than something higher.

2.2.4 Length, Weight, and Condition Factor

The lengths and weights of captured fish increased more rapidly during the summer months and less rapidly during the winter months (Figs. 1 and 2). The length-weight relationship (Fig. 3) is described by the equation:

$$\text{Ln Length (mm)} = 0.328 \text{ Ln Weight (g)} + 3.806.$$
$$(n = 981, r = 0.995)$$

Condition factors show seasonal patterns with generally higher condition factors of about 120 in the summer months and generally lower ones in winter months (Fig. 4).

2.3 Size and Condition of Downstream Migrants and Tributary Residents

Fry captured in downstream traps in the Awakino and Hakataramea Rivers and the Aviemore spawning race were typically emergent-sized fish. They were consistently 26-27 mm long, weighed 0.11-0.13 g and had condition factors of about 65-70. These are similar to the lengths, weights, and condition factors of the smallest fish in the electric fishing samples in December.

The only other trapping and electric fishing samples that are directly comparable were from March 1989. The mean lengths, weights, and condition factors for the trapping sample (L = 77, W = 5.6, CF = 117) appeared to be similar to the electric fishing sample (L = 81, W = 6.7, CF = 120) although no statistical tests were done.

In general it appears that emergent fry have condition factors of about 70 which increases quickly to about 120 as the fish puts on initial weight. Condition factors remain at about 120 while the fish are in the tributaries except for the winter months when condition factors are somewhat depressed. Based on these samples there appears to be no difference in size between downstream migrants and tributary resident rainbow trout.

2.4 General Life History Considerations

Although some rainbow trout may migrate downstream into the lower Waitaki river from Lakes Waitaki and Aviemore, most fish probably originate from the Awakino river and other tributaries.

The relative importance to the stocks of either fry migrants from the tributaries or older resident juveniles is unknown. We have indirect evidence from underwater observations that some fry probably survive upon reaching the mainstem Waitaki River. Young-of-the-year rainbow trout were observed in the vicinity of the mouths of the Awakino and Hakataramea Rivers in January/February. We believe that these fish originated from the respective tributaries, as rainbow fry could not be found at this time in middle and lower reaches of the mainstem Waitaki.

Using small mesh gill nets, 1+ rainbow were captured in the vicinity of Kurow, Duntroon, and the mouth. We take from this that 1+ fish rear throughout the mainstem river and from these limited data appear to be distributed throughout the river. We can not be sure whether or not these fish originated from the fry migrations or from fish that reared for a time in the tributaries. Given the observations of fry near the tributary mouths we suspect it is probably from both.

Juvenile habitat in general appears to be limited in the mainstem Waitaki and is of generally low quality. Even so the mainstem has a large area which even at low densities could accommodate substantial numbers of juvenile rainbow trout.

Some of the tributary resident juveniles migrate downstream within several months of emergence (and perhaps earlier). Whether or not there is an annual pattern to this migration is unknown. Some movement was observed to occur on freshes but possibly only those freshes above a certain threshold or perhaps after the juveniles had attained a certain size. Again it is probably density related. As fish grow they require larger territories and with a limited area some have to leave. This fits the general pattern observed, where in the smaller Awakino few 1+ and older rainbow were present, while in the larger Hakataramea a wider range of ages of fish are present that contribute to a recognised river fishery.

Assuming that fry do contribute to mainstem rainbow stocks, it would appear that their contribution is of the same general magnitude as that for later migrating juveniles. Our studies suggested that the fry migration and the "post-fry" population rearing in the Awakino numbered in the tens-of-thousands each.
The relative post fry survival of juveniles rearing in the mainstem and the tributaries is unknown. Based on the electric fishing results possibly 20% of the Awakino resident fish survived to one year of age. There are no data on the survival rates of outmigrant fry in the lower Waitaki River but because of the less suitable habitat available it is likely survival rates were lower.

Survival rates in the lower Waitaki River from one year of age to maturity are unknown but are probably in the range of 5 to 40% to account for the numbers of spawning fish observed from 1987 to 1989.

3. Competition Between Rainbow and Brown Trout

Although knowledge of the interactions between these two trout species was identified as important for the purposes of predicting whether rainbow trout can be maintained in a modified river, it was also acknowledged that to conduct meaningful studies on this subject within the time and resources available, was not possible. Fortunately a recent publication from North America by Gatz *et al.* (1987), has considerable relevance to this topic, and concludes some competition does occur.

The authors compared habitat availability and use by rainbow trout, when sympatric and allopatric with brown trout. They considered that if both resource overlap and niche shifts in sympatry were found, it would be sufficient evidence to conclude that competition was occurring.

They measured water depth, water velocity, substrate, distance to overhead vegetation, sunlight and surface turbulence, both where they collected trout and for the streams in general. This enabled them to separate the effects of habitat availability from possible competitive effects. Fish collected were separated into two age groups, 0 and ≥ 1, and the habitat data analysed separately for each group.

They concluded that there was strong evidence for interspecific competition. Habitat use varied significantly between allopatric and sympatric rainbow trout in 68% of the comparisons made. For all the variables measured except sunlight, rainbow trout used their preferred habitats less in sympatry with brown trout than in allopatry if brown trout also preferred the same habitats. Rainbow trout aged ≥ 1 occupied more areas with moderate to high velocity, coarser substrates, further from overhead vegetation, and offering less shade when in sympatry with brown trout than in allopatry.

Niche shifts by rainbow trout away from the preferences of brown trout were common. Thus strong evidence existed for interspecific competition of the two types derived from niche theory - resource overlap and niche shift in sympatry. They also found some evidence of reduced biomass and production in the sympatric streams to be evidence for ongoing competition.

They speculated that the mechanism was that interference competition occurred in which behaviourally dominant brown trout induced habitat shifts by rainbow trout. Brown trout would have forced rainbow trout into areas having some combination of the following deficiencies: higher water velocity, greater distance from cover, and lower food availability.

III. MAINTENANCE OF RAINBOW TROUT IN THE LOWER WAITAKI RIVER WITH HYDROELECTRIC DEVELOPMENT

1. Introduction

Hydroelectric development will result in the creation of a small impoundment between Waitaki Dam and the upper end of the power canal, floodway, and residual river. This impoundment will replace between 5 km and 9 km (depending on the development option) of the mostly single channel Waitaki River that presently exists in this area.

Of the three options proposed, that with the power canal on the south bank is shown as having an impoundment about 9 km in length, almost twice the length of that proposed for the other two options (Electricorp, 1989). The impoundment created will have a width of about 100 m immediately below the Waitaki Dam increasing to about 400 m a short distance upstream of Kurow. With the south bank option the lower half of the impoundment would be contained within parallel embankments 400 m apart, and there would be a maximum water depth of about 30 m at the lower end. Water velocities through the impoundment have not been calculated, but indications are that the new impoundment would probably resemble a very sluggish river in the enlarged lower section, but have an increasingly noticeable current as one nears the Waitaki dam. Velocities about 0.5 km below the dam are likely to reduce somewhat from 1.7 to 2.0 m/sec at present to about 1.4 to 1.5 m/sec (Works Consultancy Services estimates). Between about 2 km and 5 km below the dam velocities are expected to reduce from 1.5 m/sec to about 0.5 m/sec. At the lower end of the reservoir, some 9 km below the dam, water velocities are expected to be only 0.05 m/sec, compared with 1.5 m/sec at present.

It seems appropriate to consider the upstream impoundment and the closely connected Awakino River and power canal, as a largely separate system from the residual river, tributaries, lower river system for two reasons. First fish access between these systems for most species, but particularly salmonids (rainbow and brown trout, and chinook salmon) will be difficult if not impossible in many cases. Second, the two systems will have some very different physical and biological characteristics. The most obvious difference will be the presence of relatively slow flowing water in the impoundment compared with the residual river. This could result in considerable differences in species composition and abundance of invertebrates and fish in the two systems.

2. Upstream Impoundment, Awakino River, and the Power Canal

2.1 Aims

A major aim of fisheries studies on the lower Waitaki River has been to attempt to find ways in which the various fisheries and fish resources could be maintained if a hydro scheme is built.

With development the upper reaches of the river will be converted into a small impoundment, resulting in marked changes to the fishery and fish resources in this system. Because modification of the river in this area will be so extensive, it is likely that it will be impossible to maintain some of the trout resources and fisheries currently present. The following sections consider in some detail the potential for maintaining trout, particularly rainbow trout in this system if the scheme proceeds.

2.2 Spawning and Recruitment

The Awakino River appears to be the most important spawning tributary for rainbow trout in the lower Waitaki River, with runs averaging about 500 spawners per year. This river would be the only spawning area for rainbow trout in the new upstream impoundment/power canal system. Presently there is a small amount of additional spawning by fish held in channels at a camping ground above Kurow, but this area would be inundated with development.

Access for spawning rainbow trout migrating between the new impoundment and Awakino River should not deteriorate if development is undertaken carefully.

Recruitment from the Awakino River will be the main source of fish to support a rainbow fishery in the upstream impoundment. It is possible that some recruitment originates from Lake Waitaki through Waitaki Dam but its extent and reliability is unknown. The recruitment will occur in two components. The first is the migration of fry that occurs from late October to mid December, peaking in mid November. The second is the migration of fingerlings that rear in the Awakino for up to a year before migrating to the mainstem Waitaki. The latter appear to move mainly on the freshes.

The yield of fry from the Awakino to the mainstem is likely to number in the tens of thousands of fish. The initial population of fish remaining to rear in the Awakino will also number in the tens of thousands. The yield to the mainstem from this latter component would be substantially reduced to an unknown level after experiencing mortalities over the tributary rearing period. It is likely that recruitment from the Awakino would be sufficient to support fish stocks in the proposed impoundment if there are not significant losses into the floodway or residual river.

2.3 Adult and Juvenile Rearing

Awakino River rainbow trout appear to return to the lower Waitaki River soon after spawning. Based on angler recaptures of tagged fish, most Awakino adult rainbows appear to rear in the area between Kurow and the Waitaki Dam, with a small number of fish moving further downstream.

With hydroelectric development, adult rainbows from the Awakino River would most likely remain in the upstream impoundment and power canal. Some may make their way downstream into the residual river or the floodway, but such fish would be lost to this system.

Lakes are used widely by rainbow trout for adult rearing, as is apparent from their presence in other lakes on the Waitaki system. The relatively small area of the upstream impoundment and power canal would obviously limit the trout population that could be supported.

Juvenile rainbow trout would presumably rear in the new impoundment, as they are presently known to rear in Lake Waitaki for example. Population levels, however, can not be predicted. Some juveniles would likely enter the residual river, floodway, or power canal but the numbers and proportions to each can not be predicted. Juveniles entering the residual river and floodway would be lost to the Awakino/upstream impoundment/canal system. Rearing of small trout in the power canal would be negligible because of the paucity of suitable habitat. Small trout were found to be very uncommon in the Ohau canal when it was dewatered. Juveniles could move downstream through the power canal and power station/s. Again these would be lost to the system in question.

The power canal particularly, would be poor habitat for trout. Most of the length of the canal in the South Bank Option is shown as being concrete lined with water velocities of 2.5 m/sec (Electricorp, 1989), and this would have negligible habitat value. In common with the upper Waitaki hydro canals, typical food producing areas such as riffles would be absent, and there would be no cover apart from depth. It seems likely that trout in the new power canal would be in no better and probably worse condition than the generally very poor conditioned fish observed in the cobble-lined and less turbid Ohau Canal.

Invertebrate food production in the new impoundment and canal would probably stabilise at a level considerably less than that found in the upper reaches of the lower Waitaki River at present. This is because the 10 or so kilometres of river below the Waitaki Dam, which at present has relatively high invertebrate and fish production (the lake effect), would mostly cease to exist. Increased production in such areas is considered to result from the large numbers of filter feeding zoobenthos (usually hydropsychid caddisflies) which feed upon lake-derived seston, and are in turn fed upon by fish. It is possible that a limited amount of this invertebrate production may still occur at the upstream end of the new impoundment, where water velocities will probably remain sufficiently high. It is also possible that some lake effect may appear in the section of river below the power scheme, but at best it would probably take many years for suitable substrate conditions to develop there. The retention of this zone of high productivity is not assured and should be regarded as a bonus if it occurs.

2.4 The Floodway

Floods in the main river could carry considerable numbers of juvenile and some adult trout out of the upstream impoundment and into the floodway. Any trout entering the floodway will be lost to the Awakino system as no salmonid fish passes are planned to allow upstream movement from either the floodway or residual river back into the upstream impoundment. Such losses could have a major impact on trout stocks, particularly rainbow trout, in the Awakino system.

The potential loss of juveniles through being carried into the floodway during a flood is difficult to predict. It would depend on such things as the time of year and the duration and magnitude of the flood. Obviously, larger and longer lasting floods would have greater potential impact than lesser ones. Floods in November/December would have the greatest potential impact on fry as this coincides with their migration out of the Awakino.

Although it is impossible to predict the numbers of trout that could enter the floodway, some provision should be made for dealing with this situation. If there is some residual flow from seepage in the floodway (perhaps several cumecs), and the fish barrier at the lower end allows for downstream passage, then many of these fish could survive and re-enter the Waitaki River downstream of the project. If there is insufficient residual flow, then it seems likely most fish would be lost. The Comprehensive Report (Electricorp, 1989) states that the floodway would be little modified from the present river bed, in which case salvage of stranded fish would be virtually impossible. An assessment of likely residual flow (if any) in the floodway is obviously of major importance in assessing fish losses.

2.5 The Fishery

The trout fishery in the upstream impoundment will be markedly different from that presently existing in the upper reaches of the lower Waitaki River.

The fishery in this area around and above Kurow has been very popular with anglers for many years. Catch rates by diarists in the 1970s were considerably higher here than elsewhere on the lower Waitaki River. Recent studies have confirmed that the abundance of large well conditioned trout is greatest in these upper reaches, with many of the larger rainbows in the lower Waitaki River appearing to rear here. Because riverine populations of large rainbow trout are very limited in the South Island, particularly on the East Coast, this area is very attractive to anglers. Rainbow trout have an added attraction over brown trout for many anglers as they are usually hooked more easily, and fight more spectacularly.

If invertebrate food production in the new impoundment declines as a result of the disappearance of the lake outlet effect, then trout numbers, size and condition of fish would also be reduced, perhaps markedly.

At present a variety of angling methods are used for trout in these upper reaches. Most common is spinning, followed by the various forms of fly fishing (nymph, sedge, dry, and lure), with very little live bait. Following development and the change from a river to an impoundment fishery, sedge fishing at night would largely disappear. There may be some increase in live bait angling, but other methods would probably continue to be used in much the same proportions as at present.

If hydro development proceeds then management of the fishery in this system would require close attention, because of the difficulty of predicting the size of the trout stocks that might occur, and the angling effort they could sustain. At present high numbers of Awakino rainbows are taken by anglers in the Waitaki River following spawning, and it could be useful to reduce this catch. Adult trout in the new impoundment may be even more vulnerable to angling than at present, because there will be fewer inaccessible areas. Angling from boats could well become very popular on the new impoundment, but would have to be carefully managed so as to prevent overexploitation of the trout resource.

Since the present trout fishery in the upper 10 km of the lower Waitaki River is very highly regarded by anglers, most are likely to view it's conversion into a probably much less productive small impoundment fishery with considerable concern.

A limited fishery for rainbow and brown trout may develop in the upper 5 km or so of the power canal on the south bank which is shown as earth (rather than concrete) lined. Provided access is available, some anglers will utilise this area, as they do on the upper Waitaki power canals. However, we are of the view that for most anglers, the quality of the fishery in the canal will in no way compensate for or equal that found in the upper reaches of the lower Waitaki River at present.

2.6 Summary

It is difficult to make accurate predictions about how well the rainbow trout fishery and resource can be maintained in the upstream impoundment/Awakino River/power canal system. There will continue to be rainbow (and brown) trout spawning runs into the Awakino River, supported by fish rearing in the new impoundment, but the size of the runs and the population in the impoundment cannot be predicted. It seems likely that populations will be smaller than currently exist in the upper reaches of the lower Waitaki River. The Awakino River will be the only source of rainbow trout recruitment for this system.

Certainly the type of fishery will be completely different with the conversion from a large river to a narrow impoundment. The loss of one of the few remaining very productive lake outlet type river fisheries would be of great concern to many anglers. The evening sedge (or caddis) fishery typical of lake outlets and highly regarded by expert anglers, would greatly diminish and possibly disappear. Angling techniques will change, with those methods more suited to lakes being used.

3. Residual River, Tributaries, and Lower River

3.1 Aims

The overall consideration of the lower Waitaki fisheries study has been to maintain the existing fish stocks and fisheries of the lower Waitaki. Our recent studies have been directed at assessing whether or not rainbow trout can be maintained in the proposed residual river. Rainbow trout in the lower Waitaki are part of a unique salmonid fishery consisting of a good mixed fishery for brown and rainbow trout and one of the major chinook salmon fisheries. The residual river has been proposed as a way of maintaining this unique salmonid fishery and the native fish stocks of the lower Waitaki if hydro-electric development was to proceed. All three development options (in-river, north bank power canal, and south bank power canal) include a residual river.

The residual river concept was extensively discussed in the Residual River Report (Graybill *et al.* 1988), which gave detailed recommendations for its development. In that report it was concluded that fish stocks and fisheries for brown trout, chinook salmon, and native fish should be maintained with a residual river as part of the development but some concern was expressed for rainbow trout.

In this section we consider the system comprising the residual river, tributaries, and lower river and the potential for maintaining its rainbow trout stocks and fisheries.

3.2 Spawning and Recruitment

Rainbow trout spawning runs into the Hakataramea and Maerewhenua Rivers in the early 1980s were estimated at about 170 and 90 fish respectively. This compares with recent estimates of about 500 fish migrating into the Awakino River.

Several adult rainbows which were trapped in the demonstration channels were recaptured in the Hakataramea River shortly thereafter, presumably during a spawning migration. None were recaptured in the Maerewhenua River. It is notable that no rainbow trout have been recaptured in a tributary other than that in which they had previously spawned with the exception of one fish, an Awakino fish recaptured in the Hakataramea. This indicates that adults have a strong homing ability and that rainbow populations in the Hakataramea, Maerewhenua (and Awakino) Rivers are largely separate.

Thus in order to maintain rainbow trout in this system, it will be essential that there be easy access for spawning adults between the residual river and Hakataramea River, and between the Maerewhenua and the mainstem river.

Maerewhenua River rainbow runs appear to have diminished markedly in recent years, probably because of water abstraction and an absence of fish screens, and it seems likely that the low numbers of rainbows, particularly adults, in the lower Waitaki River is a consequence of this problem. With attention to this and suitable connection to the main river, runs into the Maerewhenua should be able to be rebuilt.

Recruitment to the residual river will come mainly from the Hakataramea River, the major north bank tributary located near the upstream end of the residual river. The timing (late October-mid December) and magnitude (tens of thousands of fish) of the fry migration from the Hakataramea will be similar to that of the Awakino. Also like the Awakino, the Hakataramea will contribute older fish that have reared for a time. The size of this contribution is unknown, but it will probably be larger than that of the Awakino because the Hakataramea is larger than the Awakino and has more juvenile rearing habitat.

Additional juvenile recruitment could come from the upstream impoundment. Its magnitude however, can not be predicted. In relative terms it could be at least 10% of the fish leaving the upstream impoundment as on average 10% of the flow will enter the residual river outside of times when the floodway is used. Its possible it could be a larger proportion than 10% since juveniles are generally distributed along river margins and the residual river intake will be on the north bank.

Another potential source of juvenile recruitment could be from fish that pass through the power canal and power station/s or through the floodway into the lower river and re-enter the residual river from the downstream end. This source is, however, unreliable. We indicated above some of the problems for fish in the floodway. For fish that pass through a power station/s there would be associated mortalities that would increase as the number of stations increased (5, 3, and one power stations for in-river, N-bank, and S-bank options respectively) and the size of fish increased. Overall this source of recruitment should be discounted as too unreliable. If it does occur, it would be a bonus.

The Maerewhenua River, on the south bank near Duntroon, is the other spawning tributary and source of recruitment to the mainstem lower Waitaki at the present time. Its production has been virtually nil for the past several seasons probably because of an earthen dam across the total flow and the general low flow conditions (from drought) in recent years. Even so its fishery, in its own right, and its potential contribution to mainstem rainbow stocks can not be discounted.

We had suggested in the Residual River Report that it may be impractical to "connect" the Maerewhenua to the residual river on the north bank. Such a connection would be complicated and costly with little assurance that it would work as desired for migrating adults (upstream) and particularly juveniles (downstream). Any alternative must maintain the biological connection between the Maerewhenua and the mainstem Waitaki and protect the presently poor, but potentially locally important fishery of the Maerewhenua.

In this event we recommend that the Maerewhenua be connected to the mainstem by an extension on the south bank that runs parallel to the power canal/floodway and joins the mainstem river downstream of the proposed project. This extension would need to be 6-8 km long depending on the option chosen. It would not require the intensive attention to instream habitat as required for the N-bank residual river.

Structures would still be needed to connect the Maerewhenua to the floodway (and/or possibly the power canal depending on the option chosen) to discharge excess flow and sediment. A fish pass may be required to allow for upstream migration of adult trout into the Maerewhenua. With this the Maerewhenua would remain a viable spawning stream for rainbows and a source of recruitment to the lower river. Some juveniles originating from the Maerewhenua could enter the residual river via the lower river but this would be an unreliable source.

3.3 The Need for Spawning Channels and/or Hatcheries

At the present time the three major tributaries, the Awakino, Hakataramea, and Maerewhenua Rivers, provide recruitment to the rainbow stocks of the mainstem lower Waitaki River. With development the Awakino and Maerewhenua will be largely isolated from the residual river. The Maerewhenua has also been shown in recent times to be an unreliable source. This leaves the Hakataramea as the major source of rainbow recruitment for the proposed residual river. Even here production can be variable. Fry migration in the Hakataramea ranged in our studies from 7000 to 40 000 fish. The estimate of 7000 fry from the Hakataramea compares to nearly 70 000 fry for the Awakino in the same year. It is likely that these figures reflect natural variability. With this sort of variability the Hakataramea can not be relied upon as the major source of recruitment given the perturbations of development, not the least of which is construction. As insurance we recommend that a spawning channel be built as part of the hydro-electric development of the lower Waitaki. It is not meant to replace the natural production of the Haka but to complement it. In part it will compensate for lack of a direct connection between the Maerewhenua and residual rivers and counteract some adverse construction effects.

We believe there is no need to consider a hatchery as a way of supplementing rainbow trout production. Spawning channels have been shown to be effective by our work in the Aviemore spawning race.

3.4 The Need for Fish Passes

In the Residual River Report we recommended that movement of salmonids from the residual river to the upstream impoundment be restricted (presumably by velocity barrier). We confirm that recommendation here. It is desirable to "hold" as many spawners as possible in the residual river and divert them into the Hakataramea. This is particularly true for chinook salmon. There would be little spawning habitat for them, even in the Awakino. Any salmon production that did occur there would be diminished by losses into the power canal and/or floodway. Such losses would be unsatisfactory.

A fish pass will be needed to allow migration of native fish species from the residual river to the upstream impoundment. This would be mostly for eels, but facilities could be required for other species such as koaro if the need arises.

3.5 Juvenile and Adult Rearing

Major emphasis was given to juvenile and adult rearing habitat in the Residual River Report. It remains of prime importance.

From our recent observations of rearing juveniles in tributaries such as the Awakino and Hakataramea and in the mainstem lower Waitaki we have drawn some general conclusions. Juvenile densities were considerably higher in the tributaries (and in a small river like the Tekapo) than they were in the mainstem lower Waitaki. Even so a substantial number of juveniles could rear in the mainstem because it is so large (65 km long and 6-9 braids on average). Brown and rainbow trout juveniles were observed rearing together in the tributaries with no apparent segregation by species. Similar generalisations can not be made for the mainstem because densities were so low. Habitat in the tributaries was considerably more diverse than that in the mainstem.

Competition studies (Gatz *et al.* 1987), as well as drift diving (Jowett and Teirney, 1990) and angling observations, suggest that where the two species occur together, adult rainbow trout are often found in areas with less instream cover and higher water velocity than are brown trout. It will thus be important for the maintenance of rainbow trout stocks to ensure that there is sufficient habitat of this type in the residual river.

Rainbow trout are also generally restricted to large rivers or to river/lake systems. Since rainbows in the lower Waitaki River have no direct access to a lake, it may be that their continued presence is associated in some way with the large size of the river. With hydroelectric development the size of the river down to Black Point will be reduced to about one ninth of its present size. In addition this area has been envisaged as having several smaller channels more suited to spawning and the rearing of juvenile salmonids. Although we think it unlikely, this major reduction in river size, and a possible associated increase in competition between rainbow and brown trout, could see rainbow trout stocks in the residual river much smaller than at present.

From this we conclude that our emphasis on habitat diversity in the Residual River Report was justified. We believe that diverse habitat, produced by recognised stream enhancement techniques if necessary, will allow juvenile and probably adult brown and rainbow trout to cohabit the residual river.

3.6 Hakataramea River Restoration

The Residual River Report considered the Hakataramea River an integral part of the residual river. For instance, unrestricted access for fish between the two systems was considered essential, and the Hakataramea will be the only major spawning and rearing tributary directly connected to the residual river. We believe that the better the Hakataramea River is for fisheries, the better the residual river will be.

The Hakataramea River at present looks rather different from about 90 years ago when the salmon hatchery was established there (Fig. 5). The photo shows extensive tussock cover on the valley floor, stable banks and no visible large areas of open gravel river bed. Based on literature accounts and observations of other rivers, the Hakataramea River at the turn of the century would have provided markedly more fish habitat than exists at present. There would have been more bankside vegetation, more undercut banks and less shallow gravel margins, larger substrate, narrower channels, deeper holes, reduced water temperatures, less evaporation, and a more consistent flow.

There are several observable consequences for fisheries of this reduction in fish habitat. First is the restriction of salmon spawning runs in some years to the lowermost reaches of the river. This is because the river in many places now has a wide gravel bed, which with low flows becomes too shallow for salmon to migrate upstream. Although L. F. Ayson established the first salmon runs from a hatchery on this river (Fig. 5), it is difficult to imagine the site being considered very suitable nowadays.

Secondly studies have shown that juvenile trout rear in the Hakataramea, but at relatively low densities compared with some other rivers.

Thirdly, the river produces a considerable amount of sediment (MWD 1984), sufficient to require special structures and long-term maintenance aimed at preventing the accumulation of sediment at the confluence of the Hakataramea River and residual river. Sediment yield is normally much reduced where stable banks are present (Evans, 1979; Debano and Schmidt, 1989), and a reduction in sediment input could reduce engineering difficulties and long-term maintenance. It could also possibly reduce the frequency and magnitude of flushing flows in the residual river, flows which will be at the expense of power generation.

The residual river will be largely isolated from tributaries other than the Hakataramea following the construction of a power scheme. Thus restoring fisheries habitat in the Hakataramea River through increasing bankside or riparian cover, will increase the likelihood that the residual river will be successful.

Riparian cover could best be improved by excluding stock or severely restricting stock access to the river bed and riparian zone (Evans, 1979; Myers, 1989; Platts, 1989). This can be achieved by fencing off these areas. Natural regeneration of vegetation and streambanks will occur, but additional restoration (poplar plantings, instream structures, boulders) after stock exclusion should also be considered. Such enhancement would only be successful if it was part of a coordinated programme involving interested parties such as Electricorp, landowners, Canterbury Regional Council, South Canterbury Fish and Game Council, anglers and angling clubs, and MAF Fisheries. Consideration of a restoration programme would be timely as the Canterbury Regional Council intends developing a draft Water Management Plan for the Hakataramea River by 1993. It may be possible to follow overseas examples, and involve interested parties such as landowners and anglers in undertaking some of the labour-intensive work, with Electricorp purchasing materials. Such rehabilitation programmes in North

America have been very successful, benefitting both instream users and landowners, and provided sponsors with good PR.

We recommend that Electricorp contribute to fencing off of riparian areas in the Hakataramea River, so that fisheries habitat is restored, and the residual river has an increased chance of being successful.

3.7 The Fishery

One of the major aims in proposing the residual river concept was to maintain the existing fisheries of the lower Waitaki. Under the originally proposed hydro-electric scheme with a 55 km residual river, the upper 30-35 km (above Black Point) of the residual river was to provide for trout fishing, and the lower 20-25 km primarily for salmon fishing. This conformed to the general distribution of salmon and trout anglers. Only a small proportion of salmon angling was done above Black Point.

Under the currently proposed scheme the residual river would be about 30 km long extending down to Black Point. In line with previous recommendations this 30 km residual river should be maintained for trout fishing. This would leave the lower river downstream of the scheme (approximately 30 km) largely unchanged.

The lower river should adequately accommodate the salmon fishery, that portion of the trout fishery that occurs there now, and the fisheries for native species that occur mostly near the mouth.

Within the proposed residual river we would reasonably expect the rainbow fishery to be maintained along with the brown trout fishery. This will be dependent, however, on development of high diversity habitat that includes a variety of water types, including runs and riffles, meanders, and areas of deep water.

We would expect the trout fisheries in the Hakataramea River to carry on largely as they are now. It has always been assumed that the Hakataramea would be an integral part of the residual river system. The Maerewhenua is more problematic. We were surprised to see the reference in the Comprehensive Report that the Maerewhenua under all three options was to be connected to only the floodway and not the residual river. We have no assurance that fish stocks will be viable in the floodway as discussed earlier. We believe that the Maerewhenua must be part of the residual river/tributaries/lower river system to prevent the decline of its trout fisheries including the possible elimination of its rainbow fishery.

It will be important that the fisheries of the residual river/tributaries/lower river system are monitored before, during, and after development. This will provide a basis for recommending changes in construction practices, management principles, or fishing regulations/restrictions that may be needed to protect or possibly enhance fisheries in this system.

3.8 Summary

The Hakataramea River will be the major spawning tributary and source of rainbow trout recruitment to the residual river. The Awakino and Maerewhenua Rivers will be largely isolated from the residual river and any input from them will be unreliable. We recommend that the Maerewhenua River be connected to the lower river via a 6-8 km extension along the south bank of the power canal/floodway. This biological connection is needed to supplement trout production in the lower river and to allow for a viable trout fishery in the Maerewhenua itself. Without it, it is likely that the rainbow fishery would be eliminated from the Maerewhenua.

Because of the variable production from the Hakataramea, we recommend that a spawning channel be build as part of the lower Waitaki power scheme. This will serve to complement (not replace) the natural production from the Hakataramea, partially compensate for the lack of a direct connection between the Maerewhenua and residual river, provide rainbow recruitment to the lower river, and counteract some of the adverse effects of construction.

We would expect a rainbow fishery to develop in the residual river along with a brown trout fishery. The former will be dependent, however, on developing habitat with high diversity using recognised stream enhancement techniques. We believe the trout fisheries in the Hakataramea will be largely unchanged as will those of the Maerewhenua if it is connected to the lower river.

The lower river should adequately accommodate the salmon fishery, that portion of the trout fishery that occurs there now, and the fisheries for native species that occur mostly near the mouth.

We recommend that the fisheries and fish stocks of the residual river, tributaries, and lower river be monitored before, during, and after development to prevent adverse effects from construction activities and ensure that the overall functions (goals) of the residual river are met.

4. Recommendations

Detailed recommendations were made in the Residual River Report (Section 7) to meet the functions (Section 1) of the residual river for fisheries. Some of the recommendations remain unchanged but others need to be modified in light of the last three years of studies that concentrated on rainbow trout in the lower Waitaki.

4.1 Location (Section 7.2.1 in the Residual River Report)

We confirm the recommendation that a residual river be located on the north (true left) bank as an extension of the Hakataramea River. In addition we recommend that the Maerewhenua River be connected to the lower river via a south-bank extension. This will provide a biological link between the Maerewhenua and the lower river ensuring that potential fish production from the Maerewhenua reaches the lower river and that fish stocks and fisheries of the Maerewhenua will remain viable.

4.2 Tributary Connections (7.2.2)

We confirm the recommendation that the residual river be connected to the Hakataramea River, and to all of the north-bank tributaries between the Hakataramea and the downstream end of the power scheme. We recommend that the Maerewhenua River be connected to the lower river via a 6-8 km extension along the south bank.

We had originally recommended that the Maerewhenua be connected to the residual river. Such a connection was considered to be complicated and costly and we questioned that it would work as desired.

The Comprehensive Report suggested that the Maerewhenua be linked to the floodway only. We have no assurance that flow conditions in the floodway will allow viable conditions for fish stocks. Even if a permanent residual flow from seepage should develop, there would be massive disruptions from flood flows in the floodway. Such a connection would probably result in the demise of the rainbow fishery in the Maerewhenua and eliminate any potential contribution to rainbow stocks of the lower river or residual river. It is imperative that the Maerewhenua have a biological link to the lower river/residual river system. A south-bank extension seems the most reasonable way to do that. It should be added that the contribution of the Maerewhenua in the future, will depend in part on actions by other agencies in relation to irrigation diversions.

4.3 Structures (7.2.3)

We confirm the recommendation that the residual river be linked to the Waitaki River and the Hakataramea River by two major structures: a downstream barrier and the upstream facilities. As discussed above the Maerewhenua would be connected to the lower river via a 6-8 km extension. A structure would be required to allow flows several times the mean annual flow of the Maerewhenua to enter the extension, and to discharge excess flow and sediment into the floodway and/or power canal. Structures would also be required for the spawning channel and the native fish pass.

4.4 Configuration (7.2.4)

We recommend that the 30 km residual river consist of three dominant channels. The characteristics of the approximately 30 km mainstem Waitaki downstream of the power scheme will remain largely unchanged. This conforms to the general distribution of salmon and trout anglers on the existing lower Waitaki River. Other considerations for the residual river remain the same.

4.5 Flow and Flow Regime (7.2.5)

We confirm the recommendation that the residual river have a base flow of 40 m^3/s, with a flushing flow of about 120 m^3/s every 2.5 weeks and the 100 year "design" flood of about 400 m^3/s. This reference to the 100 year "design" flood is as discussed in Section 6 of the Residual River Report but corrects the error in Section 7.2.5 that referred to an annual flood of 400 m^3/s.

With regard to the floodway, we make a new recommendation that the extent of residual flows in the floodway be calculated, so that its value as fish rearing (and wading bird) habitat can be evaluated.

4.6 Measures to Increase Diversity (7.2.6)

This recommendation remains unchanged, viz. : That measures be implemented to increase the diversity of instream habitat for fish.

4.7 Angler Requirements (7.2.7)

This recommendation remains unchanged, viz. : That vehicle access to the residual river and foot access along the residual river be provided. We believe that most angler requirements will be met by making adequate provision for fish stocks.

4.8 Construction (7.2.8)

This recommendation remains unchanged, viz : That the residual river be constructed in stages, in parallel with the construction of the power scheme. The stages of pre-excavation and channel formation would be followed by periods of adjustment, reinforcement, and evaluation. Fish passage must be maintained throughout this sequence and the fish stocks must not be harmed by the effects of construction, such as the discharge of sediment-laden water.

4.9 Management Plan (7.2.9)

This recommendation remains unchanged, viz. : That a comprehensive management plan be developed so that the residual river will have the greatest possible benefit for the fisheries.

4.10 Spawning Channel

We recommend that a spawning channel be built as part of the residual river development. It is meant as insurance to complement the presently variable juvenile production from the Hakataramea and to partially compensate for lack of direct connection between the Maerewhenua and residual rivers and counteract some adverse construction effects.

4.11 Restoration of the Hakataramea River

We recommend that Electricorp contribute to fencing off of riparian areas in the Hakataramea River, so that fisheries habitat is restored, and the residual river has an increased chance of being successful. This work would have a beneficial effect even if hydro construction did not proceed, and should be started as soon as possible. It would require a concerted effort by all parties involved.

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TABLE 1. Number of rainbow trout trapped during spawning runs in tributaries of the lower Waitaki system between 1981 and 1989, and in the Aviemore spawning channel in 1989.

Location	Year	Number trapped	Estimated run size	% male
Welcome Stream				
	1981	1	0	0
	1982	0	0	-
Maerewhenua River				
	1981	39	60	54
	1982	78	120	51
	Mean	59	90	52
Hakataramea River				
	1981	52	90	52
	1982	239	260	49
	1983	165	200	44
	Mean	152	183	49
Awakino River				
	1987	422	450	33
	1988	328	350	44
	1989	817	850	40
	Mean	522	550	39
Aviemore Spawning Channel				
	1989	448	448	43

TABLE 2. Mean length, condition factor, and sex ratio of rainbow trout trapped in the Waitaki system. (- = no information.)

	No. of years trapped	Mean length (mm) M	F	Mean C.F. M	F	% males
Lower Waitaki system						
Welcome Stream (a)	2	-	-	-	-	-
Demonstration channels (b)	2	437	403	114	118	49
Maerewhenua River (a)	3	435	434	110	117	52
Hakataramea River (a)	3	437	421	117	123	49
Awakino River (c)	3	481	474	122	129	39
Aviemore Spawning Channel (d) (Lake Waitaki)	2	519	501	117	129	47
Tekapo system						
Maryburn Stream (e)	3	489	481	114	118	63
Tekapo River (e)	3	494	482	113	119	55
Ohau River (f)	1	459	441	112	128	33
Scotts Creek (g) (Lake Alexandrina)	2	559	561	-	-	36

a = Webb, Dungey and Graynoth, in prep.
b = Palmer 1986.
c = Bloomberg and James, in prep.
d = Graybill, Palmer and Bloomberg, in prep.
e = Bloomberg, in prep.
f = McCarter and Bloomberg, in prep.
g = Hayes 1984.

TABLE 3. Age composition (%) of spawning rainbow trout trapped in the Awakino River from 1987 to 1989, and the Aviemore spawning channel in 1988 and 1989; and non-spawning fish captured at three sites in mainstem lower Waitaki River in 1988/89.

Year/ locality	Sex	N	Age (years) 1+	2+	3+	4+	5+
Awakino River							
1987	M	137	0.7	12.1	60.2	26.5	0.5
	F	283	0.0	11.6	58.7	26.4	3.3
1988	M	143	2.8	15.1	55.0	26.4	0.7
	F	172	0.0	8.0	61.5	26.8	3.7
1989	M	324	1.3	6.4	59.8	32.0	0.5
	F	492	0.0	10.1	63.5	23.6	2.8
Aviemore Spawning Channel							
1988	M	9	-	-	33.3	33.3	33.3
	F	17	-	-	17.6	76.5	5.9
1989	M	86	-	5.8	24.4	61.6	8.1
	F	87	-	3.4	26.4	54.0	16.1
Lower Waitaki River							
Kurow	-	55	7.3	54.6	27.3	7.2	3.6
Duntroon	-	22	4.5	59.1	36.4	0.0	0.0
Ferry Road	-	17	0.0	82.4	17.6	0.0	0.0

TABLE 4. Life History information for lower Waitaki rainbow trout.

	Awakino		Aviemore	Hakataramea	
	1988	1989	1989	1988	1989
No. female spawners	173	492	255	-	-
Potential egg deposition	666 000	1 857 000	1 116 000	-	-
No. migrant fry	32 000	69 000	448 000	40 000	7000
No. resident fry (potential)	30 000 to 40 000	30 000 to 40 000	Nil		
Total post-emergent fry	62 000 to 72 000	99 000 to 109 000			
Egg to post-emergent survival(%)	9 to 11	5 to 6	40		

TABLE 5. Estimated population size and juvenile trout density (fish/m^2) at the Awakino River site during 1988-90.

Date	Rainbow trout 0+		Rainbow trout 1+		Brown trout 0+		Brown trout 1+		All trout 0+		All trout 1+		Total	
14.12.88	43	0.13	24	<0.10	156	0.49	54	0.17	200	0.63	79	0.25	281	0.88
12.01.89	113	0.35	12	<0.10	172	0.54	42	0.13	286	0.89	53	0.17	338	1.06
22.02.89	117	0.37	11	<0.10	98	0.31	31	0.10	212	0.66	41	0.13	253	0.79
21.03.89	85	0.27	5	<0.10	73	0.23	19	<0.10	159	0.50	24	<0.10	184	0.58
12.04.89	60	0.19	2	<0.10	54	0.17	12	<0.10	117	0.37	14	<0.10	133	0.42
16.05.89	42	0.13	0	-	39	0.12	9	<0.10	74	0.23	9	<0.10	90	0.28
15.06.89	40	0.13	0	-	33	0.10	6	<0.10	73	0.23	6	<0.10	79	0.25
18.07.89	18	<0.10	0	-	20	<0.10	6	<0.10	38	0.12	6	<0.10	44	0.14
16.08.89	21	<0.10	1	<0.10	26	<0.10	6	<0.10	47	0.15	7	<0.10	54	0.17
18.09.89	28	<0.10	1	<0.10	32	0.10	3	<0.10	60	0.19	4	<0.10	64	0.20
20.10.89	30	<0.10	1	<0.10	0	-	30	<0.10	30	<0.10	31	0.10	62	0.19
21.11.89	31	0.10	0	-	450	1.41	30	<0.10	481	1.50	30	<0.10	513	1.60
19.12.89	394	1.23	5	<0.10	577	1.80	19	<0.10	957	2.99	24	<0.10	980	3.06
18.01.90	224	0.70	0	-	390	1.22	9	<0.10	615	1.92	9	<0.10	622	1.94
13.02.90	198	0.62	0	-	266	0.83	2	<0.10	463	1.45	2	<0.10	466	1.46
06.03.90	57	0.18	0	-	34	0.11	2	<0.10	91	0.28	2	<0.10	93	0.29

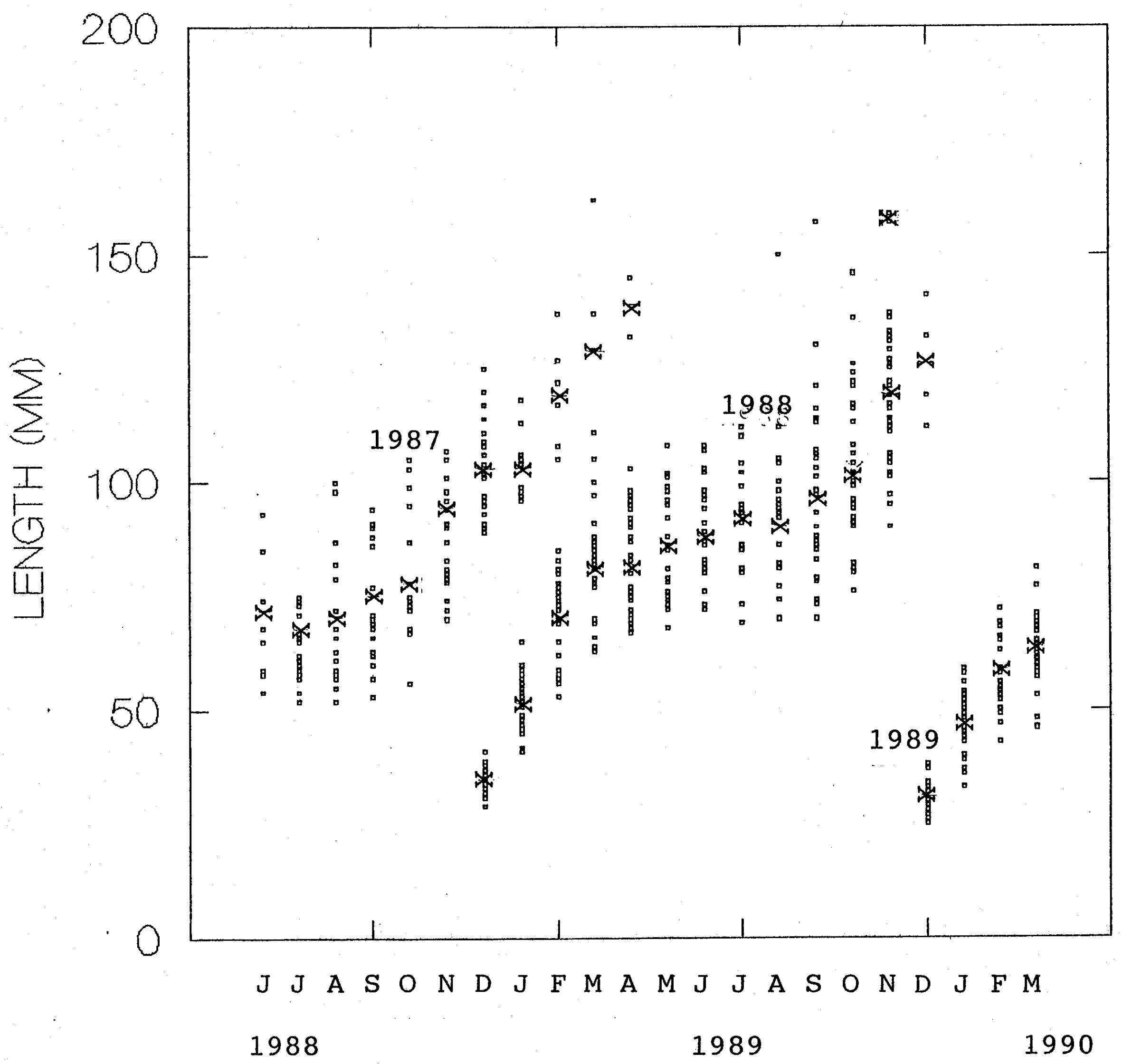

FIGURE 1. Length of juvenile rainbow trout from the 1987, 1988, and 1989 year classes captured by electric fishing in the Awakino River, 1988-90. X = mean length.

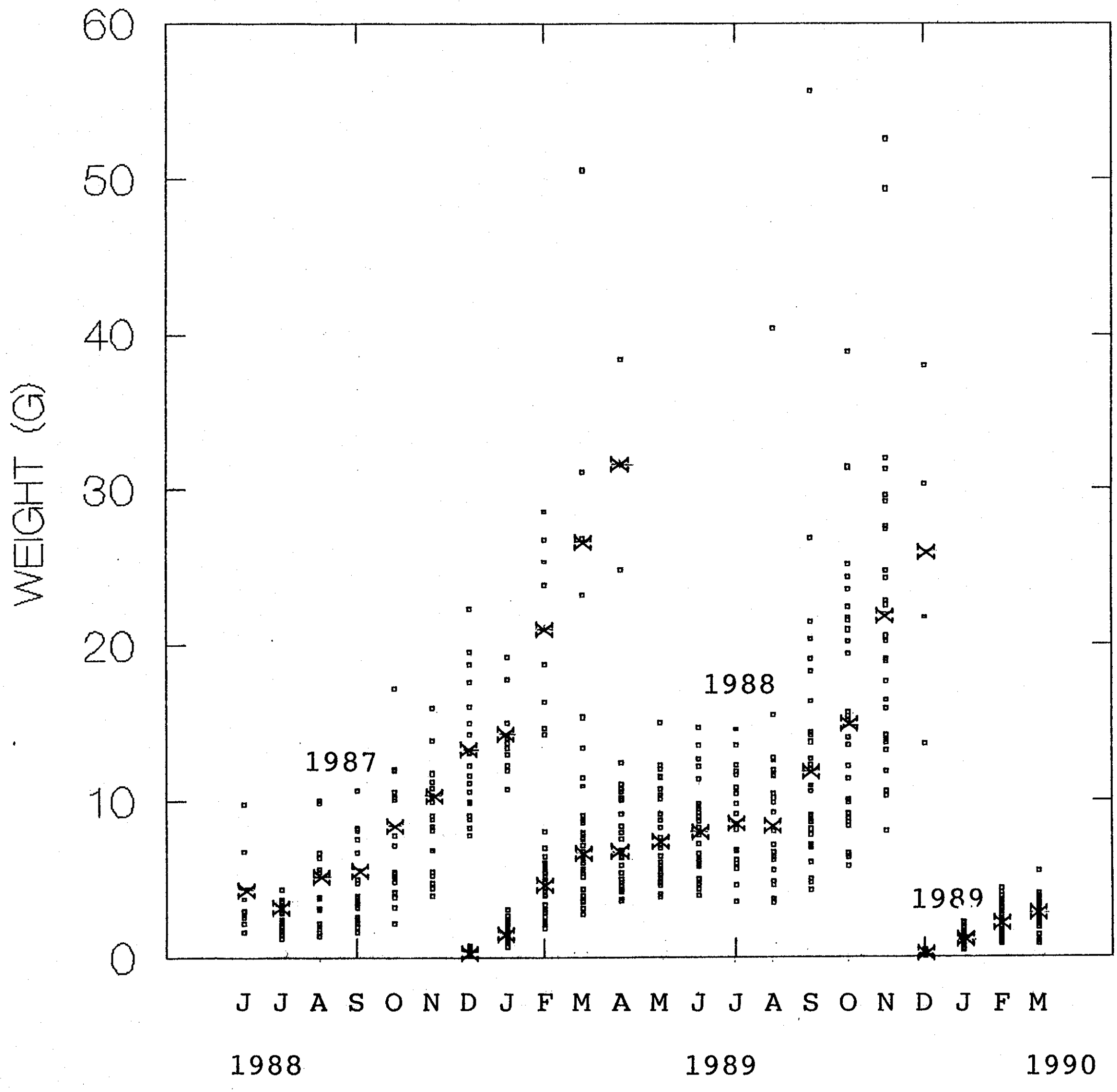

FIGURE 2. Weights of juvenile rainbow trout from the 1987, 1988, and 1989 year classes captured by electric fishing in the Awakino River, 1988-1990. X = mean weight.

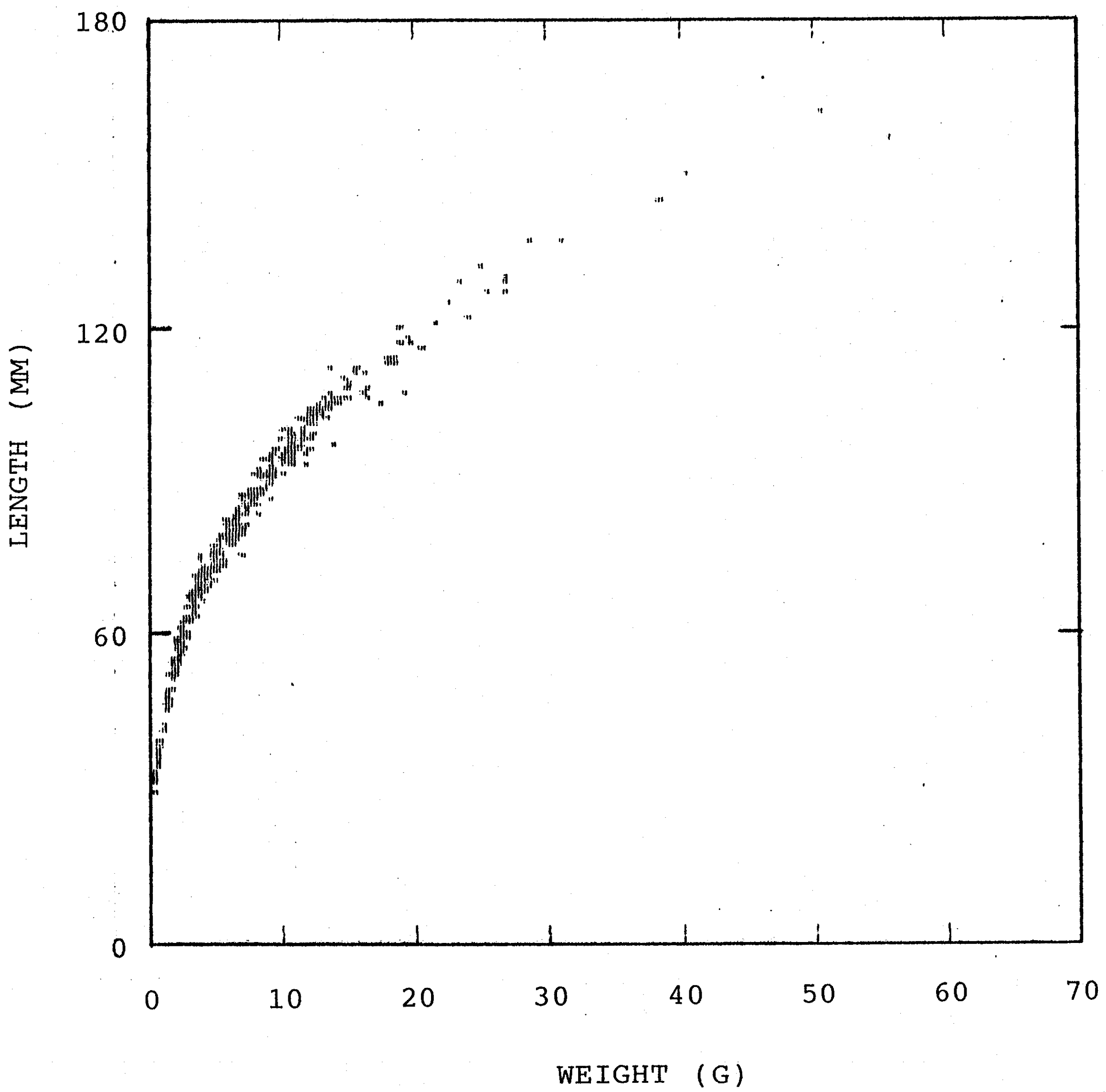

FIGURE 3. Length-weight relationship for juvenile rainbow trout captured by electric fishing in the Awakino River, 1988-90. (n=981, r=0.995)

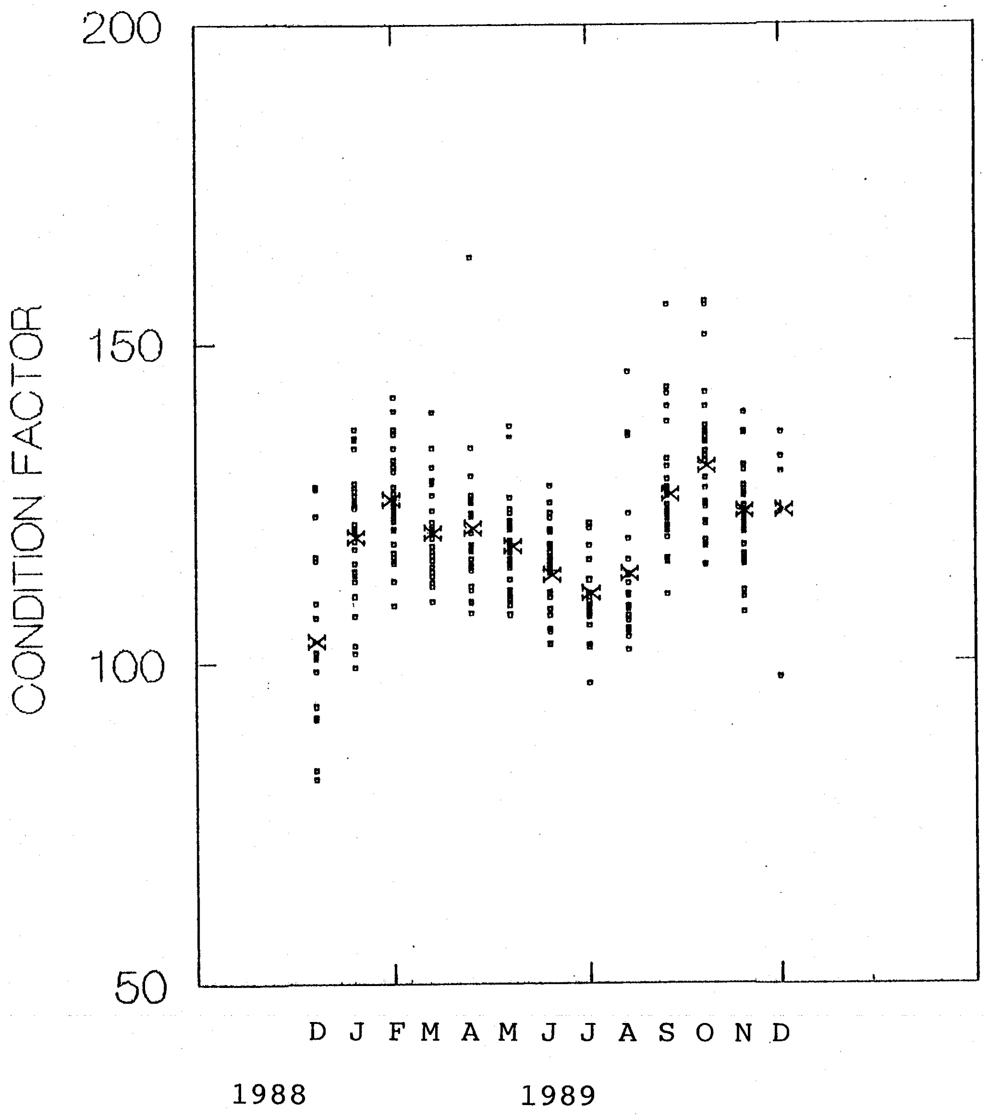

FIGURE 4. Condition factors of juvenile rainbow trout from the 1988 year class captured by electric fishing in the Awakino River, 1988-89. X = mean condition factor.

FIGURE 5. The Hakataramea River and hatchery in about 1900.