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AN ASSESSMENT OF SMELT MIGRATION OVER THE OHAU CHANNEL FISH PASS

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Front page

View of the right bank of the Ohau Channel control source illustrating the layout of the velocity blocks on the high crest.

Executive Summary

1 Introduction

The purpose of this report is to describe the results of investigations into the ability of fish to migrate over the Ohau Channel control structure. The passage of common smelt *(Retropinna retropinna)* over the fish pass (see photo overleaf) is specifically addressed.

The report concludes with recommendations designed to improve the performance of the fish pass.

2 Monitoring Rationale

Monitoring of the Ohau Channel fish pass was designed to answer the following question:

- Is the fish pass working?
- Is the fish pass selective, i.e. are large smelt using the pass more successfully than small smelt?
- Does the fish pass need to be improved?

3 Results

The following are the main findings of the report;

Fish pass water velocity

- On the high crests velocities are. generally less than the maximum recommended level of 0.3 m s^{-1}.
- Within the artificial riffles built below the high crests, velocity on average exceeds the maximum recommended level of 0.5 m s^{-1}.
- Velocities through the fish pass are highest when the flow in the Ohau Channel is low.

Smelt passage

- The fish pass allows adult smelt to move over the control structure and into Lake Rotorua.

- The fish pass is less effective in allowing the passage of juvenile smelt, particularly those of less than 35 mm in length.
- Very small juvenile smelt (less than 30 mm) appear to be unable to ascend the fish pass.

4 Discussion

It is considered that high velocities in the artificial riffles are the major factor restricting the movement of juvenile smelt over the fish pass. These form the entry to the fish pass and present the greatest velocity barrier to migrating smelt. At present the artificial riffles are not fixed in place and are further prone to being moved by people and through scouring of the underlying sediment. The preferred solution to these problems is to install permanent artificial riffles.

Mr Charles Mitchell, an ecological consultant experienced in fish pass design, has been contracted to advise on the basic design of the permanent artificial riffles. The recommended design is a simple ramp with low vertical sides, which would carry a proportion of the flow from the high crest. The base of the ramp is lined with a regular pattern of velocity blocks. The shape of the velocity blocks and the gentle slope of the ramp are particularly important in reducing water velocities.

Details of the recommended design of the artificial riffles are given in Appendix 6 of this report. Having considered a number of construction options it is proposed to prefabricate the structures in fibreglass.

5 Recommendations

The following recommendations are given to improve fish passage over the Ohau Channel control structure;

(i) A fibreglass artificial rifle of the design described in Appendix 6 should be installed on the right bank of the channel.

(ii) After installation a period of monitoring should be carried out to determine the success of smelt migration over the modified fish pass.

(iii) If successful an identical artificial riffle should be installed on the left bank.

(iv) The fish pass should be regularly inspected and cleaned, particularly during the major migration periods.

In considering the first recommendation it should be noted that the proposed fibreglass artificial riffle represents a rather novel approach to fish pass construction. As explained in Section 5.2 of this report the design has been optimised to slow water velocities as much as possible. Thus provided the structure can be built sufficiently strong there is every confidence that it will function as intended.

1 Introduction

The purpose of this report is to describe the results of investigations into the ability of fish to migrate over the Ohau Channel control structure. The passage of common smelt (*Retropinna retropinna*) over the fish pass is specifically addressed. The report concludes with recommendations designed to improve the performance of the fish pass.

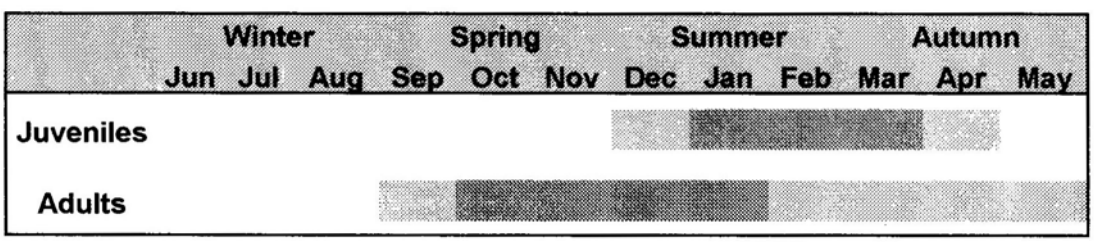
2 Background

2.1 Smelt migrations

Smelt are naturally an anadromous fish-leading a marine planktivorous existence before migrating up rivers as juveniles. The juveniles continue to feed and complete their development in freshwater. In the Waikato River two annual upstream migrations have been identified (J. Boubee, pers. comm.). The first involves juveniles which move upstream from the sea between October and February. Adults migrate upstream between November and February, presumably to spawn. There is some uncertainty as to whether adult smelt are derived from the lower reaches of the rivers or directly from the sea (McDowall 1990). After hatching the larvae drift downstream to the sea to complete the cycle.

Two upstream smelt migrations have also been identified between Lake Rotoiti and Lake Rotorua via the Ohau Channel (Table 1). Sexually mature adults begin to migrate between late September and the middle of October (Mitchell 1988). The second migration comprises shoals of juveniles which begin to appear in the channel between December and the end of January (F. Thompson, pers. comm.).

Table 1: Smelt migration periods in the Ohau Channel. Dark shading indicates major migrations while movement may also occur during the periods indicated by the light shading.



Adult smelt continue to migrate until the end of May although the peak migration period is largely finished by the end of January. Juveniles continue to move through the channel at least until April (Mitchell 1988). It is generally thought that the migrations comprise fish which were hatched in Lake Rotorua and swept into Lake Rotoiti, thus mimicking the life cycle of the river fish. Jolly (1967) considered this a possibility, albeit a "debatable one". Because the migrating adults are sexually mature it is assumed that these subsequently spawn in Lake Rotorua.

The origin of smelt in Lakes Rotorua and Rotoiti is the subject of some debate. Until recently, the accepted view was that smelt were introduced into Lake Rotorua to provide a forage food for the failing trout fishery. Smelt stocks were purported to have been obtained from the lower Waikato River between 1906 and 1909 (Burstall 1980, McDowall 1990). This explanation has been challenged by Strickland (1993) on the basis of a thorough historical review. Strickland contends that smelt were introduced into Lake Rotorua by Maori in pre-European times. Some support for this view comes from a rich oral history, of Maori introductions of freshwater fish into New Zealand lakes (McDowall 1990).

Before the introduction of trout, the Ohau Channel supported a traditional fishery based on koaro (*Galaxias brevipinnis*), which were particularly abundant in Lakes Rotorua and Rotoiti. In the Rotorua Chronicle (25 October 1919) Gilbert Mair wrote that these had "formed the principle food supply for the Arawa tribe" and that "for 55 years at least ...[he had] seen the Ngatipikiao tribe netting them in the Ohau [Channel] sun drying them and storing them away for winter use" (McDowall 1987). Following the introduction of trout in the late 1800's concern was expressed by Rotorua Maori over the resultant collapse of the koaro fishery. While common smelt have since replaced koaro as a traditional food source in the Ohau Channel they have apparently never reached a similar level of abundance (Strickland 1993).

The Ohau Channel falls within the Ngati Pikiao robe. Ngati Pikiao refer to smelt as "manga" and use box or elongated cylindrical nets to collect the fish. The nets are fished passively relying on the upstream urge of migratory smelt. The active scoop net method commonly used in the whitebait fishery is generally discouraged. Local fisher people recognise two types of smelt behaviour during the migration. The first of these is termed "running" and involves purposeful swimming with little hesitation up the channel. This behaviour is particularly sought after as the smelt are then easier to catch using the traditional method. The second behaviour is termed "milling around" and as the term suggests involves shoals of smelt with little apparent direction. Experienced smelt fishers inspect the channel frequently when the smelt are thought to be migrating but will usually not attempt to fish if the smelt are milling around.

2.2 The Ohau Channel fish pass

The Ohau Channel control structure was constructed in 1989 to provide control of the level of Lake Rotorua, It is described as a two stage broad crested weir and functions by reducing the volume of water which flows through the Ohau Channel into Lake Rotoiti. The structure has provision for stop logs, which form a false floor allowing further control during periods of low rainfall. The design of the structure is given in Appendix 1 while details of its operation to date are contained in Titchmarsh (1995).

Included in the original right to build and operate the structure (Appendix 2) was the requirement to provide for fish passage following the recommendations of Mitchell (1988). The proposed design of the fish pass included an arrangement of rocks on the high crest which were intended to reduce the water velocity. Following the commissioning of the structure it became apparent that the fish pass was not working as planned. In particular it was observed that smelt were massing below the structure, apparently unable to negotiate the pass.

Two factors contributed to the initial failure of the fish pass. Firstly, and most importantly, the downstream bevel on the high crest recommended by Mitchell (1988) was not included in the final design. As a result there was an abrupt water drop which prevented smelt from gaining access to the high crest during lower flows. Secondly, the original recommendations regarding the placement of rocks on the high crest were not rigorously followed during design. While the concrete blocks which were installed were of the correct size they were too streamlined and set too far apart to be fully effective.

Following recommendations from the Eastern Region Fish and Game Council, the fish pass was improved by placing small rocks and boulders immediately downstream of the high crest. This created an artificial riffle which was expected to lessen the severity of the water drop and therefore reduce the velocity barrier. Rocks were also placed immediately upstream of the high crest to assist in slowing water velocity over the fish pass. Smelt were seen moving through the riffle and over the high crest almost immediately after the rocks were dropped into place. There remained the concern that the arrangement of velocity blocks on top of the high crest was still far from optimum for smelt passage.

To negotiate the fish pass, smelt and bullies must first use "burst swimming" to move through the artificial riffle located downstream of the high crest. Burst swimming is strenuous and can often only be sustained for 4-5 seconds. Peak burst swimming speeds are 0.5 m s^{-1} for smelt and 0.6 m s^{-1} for common bully. Once on top of the high crest "steady swimming" would be used to proceed into the lake. Steady swimming is slower than burst swimming and can be held for longer than 30 seconds before exhaustion. Steady swimming speeds are around 0.3 m s^{-1} for smelt and common bully (Mitchell 1989). Using the above information the velocities within the artificial riffle and on the high crest should ideally be less than 0.5 m s^{-1} and 0.3 m s^{1}respectively.

In June 1994 measurements were taken on top of the high crest and in the artificial riffle to determine whether the velocity exceeded the levels required to allow for fish passage. On the same day temporary blocks were placed in various positions to determine the best method to further slow water velocity. The results of this exercise confirmed that the velocity around the existing blocks was generally too high but that this could be reduced to acceptable levels by the careful placement of additional permanent blocks (see internal memo given in Appendix 3). These blocks were installed in May 1995 (Photo I).

Following this work there remained the need to monitor fish passage over the structure. This report describes the monitoring to date and gives recommendations to further improve the performance of the fish pass.

3 Fish pass monitoring

3.1 Rationale

Monitoring of the Ohau Channel fish pass was designed to answer the following questions;

- Is the fish pass working?
- Is the fish pass selective, i.e. are large smelt using the pass more successfully than small smelt?
- Does the fish pass need to be improved?

As noted in the introduction to this report the movement of smelt over the fish pass was specifically monitored. Juvenile common bullies (*Gobiomorphus cotidianus*) are also known to migrate through the Ohau Channel into Lake Rotorua (F. Thompson, pers. comm.). Common bullies are marginally stronger swimmers than smelt and are able to rest passively on the bottom at water velocities of up to 0.44 m s^{-1} (Mitchell 1989). This adaptation allows resting between bouts of burst swimming and enables bullies to negotiate water velocities which would be impassable to species such as smelt which rely solely on swimming. For this reason it is considered that measures intended to provide for the passage of smelt will also be adequate for bullies.

3.2 Methods

3.2.1 *Fish pass water velocity*

Before measuring velocities, accumulated weed, sediment and debris were noted and removed from the fish pass. Also noted on most occasions was the depth of water on top of the high crest (measured beneath the hand rails) and an estimate of the downstream drop from the high crest to the pools below the control structure.

Velocities were measured on each side of the control structure using a Gurley Pygmy meter. Measurements were carried out 2 3) cm above the base of the high crest at the corners of a series of velocity blocks. These "block corners" provided reference points for future measurements. Up to ten velocity measurements were also taken at random within the artificial riffles on each occasion. Reference points could not be established within the artificial rifles because the rock material was not fixed in position.

3.2.2 *Smelt passage*

Observations of migrating smelt were made directly from the channel banks and by using an underwater viewer fitted with a 45° mirror. Before sampling, notes were taken on the weather and water conditions along with a brief description of smelt movement over the structure.

Smelt samples were collected from two areas on each side of the control structure using a whitebait scoop net. The first area, downstream of the weir crest and artificial rifle, was assumed to contain smelt which were intending to move into Lake Rotorua. These were easily caught as they congregated in the pools below the rifle boulders. The second area was on top of the high crest amongst the velocity blocks. Smelt caught on the high crest were assumed to have negotiated the artificial rifle on their way to Lake Rotorua. More care was required in this area to reduce the chance that the catch included smelt which had moved downstream from Lake Rotorua. In this case sampling was restricted to periods when shoals of smelt were observed to be moving upstream and over the fish pass.

Samples containing at least 100 smelt were preserved in 10% formalin. Each fish was weighed, measured (fork length) and sexed (adults) using the distinguishing morphological features described by McDowall (1990). The gonads (egg mass) of at least 20 adult females from each sample were dissected out and weighed to give an indication of maturity. The diet of a small sample was also investigated by dissecting out the stomach and identifying the prey species under a binocular microscope.

4 Results

The key findings of the monitoring are described here. Within this section reference is frequently made to data which is presented in graphical form. These ‘figures’ follow the Bibliography.

4.1 Fish pass water velocity

It was usually necessary to remove sediment, weed and other debris from the fish pass before measuring velocities. On at least one occasion access for smelt to the high crest was blocked by extensive accumulation of weed on the artificial rifles and hand rail supports. As discussed later in this report a small amount of weed may actually assist smelt in moving over the fish pass (see Section 4.2).

Velocities on the high crests varied widely with approximately 35% of the readings at the block corners exceeding 0.3 m s^{-1} (Figs 1-3). Figure 1 indicates that many of these high velocities occurred around the blocks closest to the right bank[1]. Within the artificial riffles velocity on average exceeded 0.5 m s^{-1} (Fig. 4). In general velocities were greater on the right bank fish pass than on the left bank (Figs 3 and 4). Table 2 suggests that velocities through the fish pass were highest when the flow in the Ohau Channel was low.

Table 2: Comparison of mean velocities measured on the fish pass (right and left bank data combined) with Ohau Channel flow and Lake Rotorua level.

Date	Crest (m s^{-1}')	Riffle (m s^{-1})	Flow (m s^{-1})	Lake level (m)
9/11/95	0.31	No readings	17.11	279.900
23/11/95	0.33	0.75	15.43	279.850
5/2/96	0.21	0.64	16.72	279.890
9/2/96	0.26	0.56	18.49	279.940

4.2 Fish passage

Shoals of migrating smelt were observed to move up the Ohau Channel in a deliberate fashion, pausing infrequently. This "sustained swimming" was sometimes interrupted by feeding behaviour which involved short steadying movements followed

[1] Right bank refers to the right hand side of the channel when looking downstream.

by darting attacks. On encountering the control structure the shoals were often seen to turn downstream and circle within the deep scour pools. Smelt swam rapidly over the fish pass during short periods (less than 15 minutes) of concentrated movement. This movement was often signalled by the frenzied feeding behaviour of gulls which congregate around the structure.

Observations with an underwater viewer highlighted that smelt are adept at choosing low velocity zones. In moving over the fish pass smelt typically favoured the slack water nearest the bank. Movement over the artificial riffles was aided by clumps of weed which hang off the hand rail supports. Smelt were often seen too move along the edge of these clumps using the thin boundary layer of low velocity to gain access to the high crest. Local people sometimes take advantage of this behaviour when fishing for smelt. The fish are encouraged to swim along the side of a net placed within the artificial riffle but are swept into the net when they reach the mouth which is faced upstream.

Smelt sampling was carried out during five days in November 1995 (adult run) and during three days in February 1996 (predominantly juveniles running). Field notes and summary statistics from the sampling are given in Appendix 4 and 5. Smelt formed the majority of the catch with a small number of bullies and the occasional juvenile trout (Appendix 5). An interesting part of the catch were two juvenile koaro which were easily distinguished by their slender form and golden-yellow colouration. One was caught downstream of the control structure and the other on top of the fish pass.

Ohau Channel smelt varied widely in size with a length range of 21 to 62 mm and a weight range of 0.08 to 1.66 g. An analysis of the length versus weight relationship is given in Figure 5. This exponential relationship may be described by the following regression equation:

$$\text{Weight (g)} = 11\times10^{-7}\ \text{Length}^{3.464}\ \text{(mm)}\ (r^2 = 0.725).$$

This relationship illustrates the proportionally greater increase in weight which occurs during the transition from the juvenile to the adult body form. For example, in growing from 30 to 60 mm a lake smelt would have doubled its length but increased its weight by a factor of at least ten (from 0. 14 g to 1.6 g).

Relative frequency histograms have been used to inspect and present the data on smelt size. In order to provide simple visual comparisons the graphical information has been overlaid. This method is preferred over a simple statistical comparison of the means as it provides information on the spread of the data (e.g. the range of sizes) as well as its central tendency (mean, or median for non-normal or skewed data). As an example Figure 6 indicates the clear separation between the migration periods of adult and juvenile smelt. The mean lengths for these two periods (47.6 and 36.8 mm respectively) are close to those which would be estimated by inspection of the frequency histograms.

The size distribution of smelt which moved over the fish pass in November 1995 was the same as that for those which were present immediately downstream of the control structure (Fig. 7). Male smelt were generally larger than female smelt (Fig. 8). With the exception of 30 November, the ratio of males and females which moved over the pass was similar to that present downstream. Overall there tended to be slightly more males than females in the population (Fig. 9). The mean size of adult smelt moving through the channel increased over the November 1995 sampling period. This was accompanied by a marked increase in sexual maturity as indicated by female gonad weights expressed as a. percentage of body weight (Fig. 10).

Juvenile smelt began 1:o run through the Ohau Channel on 23 December 1995 (F. Thompson, pers. comm.). Sampling of the juvenile run did not commence until 5 February 1996. Compared to the samples collected downstream of the fish pass proportionally fewer of the smaller juvenile smelt were caught on the high crests (Fig. 11). While approximately 4% of the smelt present downstream were 30 mm or less in length these comprised just 0.5% of those caught on the high crests (Table 3). A less severe but nonetheless significant difference was found for the 30.5-35 mm size class. The high proportion of larger smelt on the high crests reflected their success in ascending the fish pass compared to the smaller size classes.

Table 3: Juvenile smelt size classes and their proportions (%) downstream and on top of the high crests. "All" represents the downstream and high crest data combined.

Size class	Downstream	High crest	A11
<30.5mm	4.2	0.5	2.2
30.5-35 mm	52.8	23.8	37.2
35.5-40 mm	29.13	57.3	45.7
> 40 mm	13.4	18.4	14.9

Diet analysis supported the observation that migrating smelt continue to feed actively while moving through the channel. Most fish contained large numbers of zooplankton which were easily identifiable and therefore likely to have been eaten a short period before the fish were caught. A preliminary assessment suggested that the dominant prey species were two cladocerans, *Bosmina longirostris* and *Ceriodaphnia dubia*. Small numbers of a copepod, *Calamoecia lucasi*, and littoral chydorids were also present in the diet. These species all occur in Lake Rotorua (Chapman 1973. Jolly 1977) and were probably caught by smelt as plankton drifting through the Ohau Channel.

5 Discussion

5.1 Fish passage

The monitoring results presented in this report suggest that the fish pass does not prevent the movement of adult: smelt into Lake Rotorua. It is clear that the fish pass presents a partial barrier to juvenile smelt, particularly to those of less than 35 mm in length. For example, in February 1996 the 30.5-35 mm size class comprised 5 3% of the smelt found downstream of the weir and 24% of those caught on the high crest. Because a significant proportion of these juveniles were found on the high crest it is considered that they are not completely excluded from moving into Lake Rotorua. A more likely explanation for the differing proportions is that they are delayed in their attempts to move over the fish pass and are therefore over-represented in the downstream population.

Juvenile smelt can be expected to have a lower swimming performance than the adults. As with most fish the body weight of smelt, and hence muscle mass, increases at a proportionally much greater rate than length. Adult smelt are rounder in profile and have a deeper body than the juveniles. This can be expected to translate into higher burst and steady swimming speeds. While the very small juvenile smelt (less than 30 mm) made up a minor proportion of the migrating population (2.2%) it is notable that they appeared to be unable to ascend the fish pass. Ingram (1989) found that an increase in the percentage of myotomal red muscle occurred in lake smelt at a length of 25-30 mm. This change corresponds with a transition from the anguilliform swimming mode to the more efficient sub-carangiform swimming mode. Thus it appears that the smaller juveniles are limited by a lower proportion of the more powerful red muscle and a less efficient swimming mode compared to the larger fish.

The design of fish passes for lake smelt is hampered by a lack of information on their swimming performances. The maximum velocities recommended by Mitchell (1989) were determined using juvenile river smelt of 56-67 mm in length. Lake smelt are smaller-of the adults caught in the Ohau Channel, less than 1% were more than 55 mm in length. Because adult lake smelt are able to ascend the fish pass it is assumed that their swimming performance is pat least equal to that of juvenile river smelt. Given the likely lesser swimming performance of juvenile lake smelt it is perhaps surprising that any are able to negotiate the fish pass. It is possible that the fish are utilising low velocity zones which are difficult to measure using a standard velocity meter.

It is considered that high velocities down the artificial riffles are the major factor restricting the movement of juvenile smelt over the fish pass. Velocities in this area are closely related to the flow management regime in the Ohau Channel. During low flow periods the installation of the stop logs in the control structure further lowers the volume and therefore the depth of water flowing through the channel (Titchmarsh 1995). Under these conditions water velocities within the artificial riffles are increased because the acceleration of water is greater when it is allowed to drop some distance over the end of the high crest. Velocities on top of the high crest are also increased because of the greater head differential between the upstream and downstream ends of the control structure.

5.2 Options to improve fish passage

Improvements to the fish pass should focus on the artificial rifles. These form the entry to the fish pass and also present the greatest velocity barrier to migrating smelt. At present the artificial riffles are composed of rocks and boulders which were dropped into position. This material is not fixed in place and is further prone to being moved by people and through scouring of the underlying sediment. The removal of just one boulder from the area can reduce the effectiveness of the entire riffle by creating a high velocity fall of water.

The preferred solution to the above problems is to install permanent artificial riffles. The riffles must slow water velocity sufficiently to allow the passage of juvenile smelt which are assumed to be weak swimmers. Unfortunately there is no established research experience which can be used as a guide in designing fish passes for juvenile lake smelt. The approach that has been taken in this case is to optimise the design to slow velocities as much as possible. The Ohau Channel control structure presents some special challenges for fish passage and to be effective in this situation the artificial rifles should be;

- operative over the allowable range of lake levels
- long enough to allow for low flows and the resulting low channel depth
- gently sloped to reduce water velocities
- wide enough to carry sufficient flow to attract smelt into the fish pass
- smoothly butted to the high crest.

Mr Charles Mitchell, an ecological consultant experienced in fish pass design, has been contracted to advise on the basic design of the artificial rifles. The recommended design is a simple ramp with low vertical sides which would carry a proportion of the flow from the high crest. The base of the ramp is lined with a regular-pattern of velocity blocks. The shape of the velocity blocks and the gentle slope of the ramp are particularly important in reducing water velocities. Details of the recommended design are given in Appendix 6.

A number of options have been considered to construct the artificial riffles. Because of difficulties in diverting water it is not feasible to cast a concrete structure into place. A prefabricated concrete structure. was considered but this option was discarded due to the weight of the structure and likely problems with lifting it into position. A further option was to confine a ramp of compacted gravel fill against the channel banks using vertically driven sheet piling. Concrete velocity blocks would be attached together in the appropriate pattern using wire cable and this arrangement would be laid over the top of the fill. While feasible this option is considered to be very expensive and there are concerns that the fill material would be quickly scoured out.

The final and preferred option is a prefabricated fibreglass structure. Using this option the ramp would first be constructed of plywood which is used as a former. Velocity blocks would be moulded in fibreglass and fixed to the ramp. Fibreglass mat is then laid over the entire structure, impregnated with resin and cured. The advantages of fibreglass are that it is light weight and can be made sufficiently strong to resist blunt or point impacts. There are uncertainties regarding the service life of a fibreglass structure given the weight of water which would flow along its length. In particular longitudinal stresses would need to be considered during construction and in finalising the method of fixing the structure to the high crest.

There is a concern that freshly cured fibreglass emits small quantities of styrenes which may inhibit fish passage. To minimise this it is proposed to coat the entire structure with a water-based vinyl sealant. The sealant would contain a dark pigment to reduce damage from ultraviolet light. The final structure would be dark grey or black reducing its visual impact and the potential for predation by gulls.

6 Recommendations

The following recommendations are given to improve fish passage over the Ohau Channel control structure;

(i) A fibreglass artificial riffle of the design described in Appendix 6 should be installed on the right bank of the channel.

(ii) After installation, a period of monitoring should be carried out to determine the success of smelt migration over the modified fish pass.

(iii) If successful an identical artificial rifle should be installed on the left bank.

(iv) The fish pass should be regularly inspected and cleaned, particularly during the major migration periods.

In considering the first recommendation it should be noted that the proposed fibreglass artificial riffle represents a rather novel approach to fish pass construction. As explained in 5.2 the design has been optimised to slow water velocities as much as possible. Thus provided the structure can be built sufficiently strong there is every confidence that it will function as intended.

Bibliography

Burstall, P.J. 1980: The introduction of freshwater fish into Rotorua lakes. In Rotorua 1880-1980, D. Stafford, R. Steele, and J. Boyd (eds). Rotorua and District Historical Society, Rotorua. Pp 1 15-121.

Chapman, M.A. 1973: *Calcinioecia lucasi* (Copepoda : Calanoida) and other zooplankters in two Rotorua, New Zealand lakes. *Internationale Revue des Gesamtes Hydrobiologie 58*: 79-104.

Ingram, J.R. 1989: Growth dynamics and effects of migration on the myotomal musculature in lacustrine and riverine forms of the common New Zealand smelt *(Retropinna retropinna R.*). Unpublished M.Sc thesis, University of Waikato, Hamilton.

Jolly, V.H. 1967: Observations on the smelt *Retropinna lacustris* Stockell. *New Zealand Journal of Science 10*: 331-355

Jolly, V.H. 1977: The comparative limnology of some New Zealand Lakes. Part 2: Plankton. *New Zealand Journal of Marine and Freshwater Research 11:* 307-340.

McDowall, R.M. 1987: Impacts of exotic fish on the native fauna. In Inland waters of New Zealand, A. B.Viner *(ed).* DSIR Science Information Publishing Centre, Wellington. Pp 333-348.

McDowall, R.M. 1990: New Zealand freshwater fishes: A natural history and guide. Heinemann Reed, MAF Publishing Group. 553 p.

Mitchell, C.P. 1988: Environmental assessment of` the proposed Lake Rotorua control structure. MAFFish, Fisheries Research Centre Report. 17 p.

Mitchell, C.P. 1989: Swimming performances of some native freshwater fishes. *New Zealand Journal of Marine and Freshwater Research* 23:181-187.

Strickland, R.R. 1993: Pre-European transfer of smelt in the Rotorua-Taupo area, New Zealand. *Journal of the Royal Society of New Zealand 23*: 13-28.

Titchmarsh, B.R. 1995: Lake Rotorua and Lake Rotoiti Report on the technical issues and effects to be considered in the application for resource consents. Environment BOP Operations Report 95/5 (December 1995). 78 p

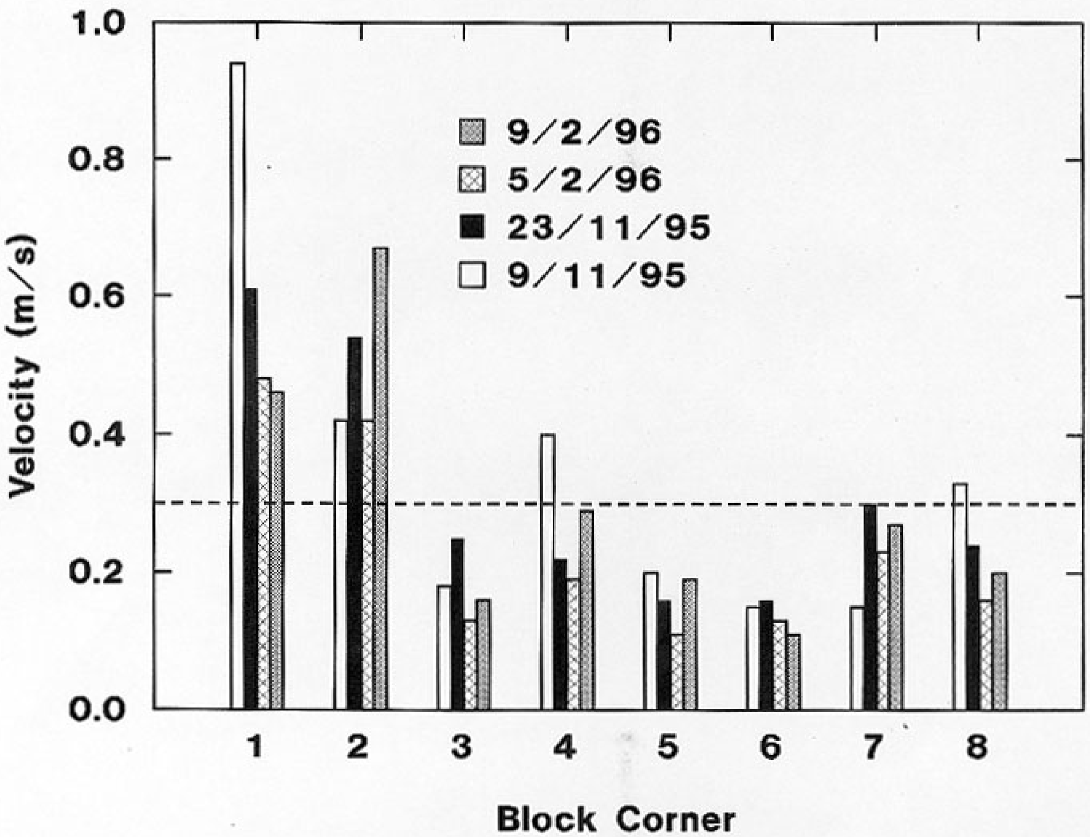
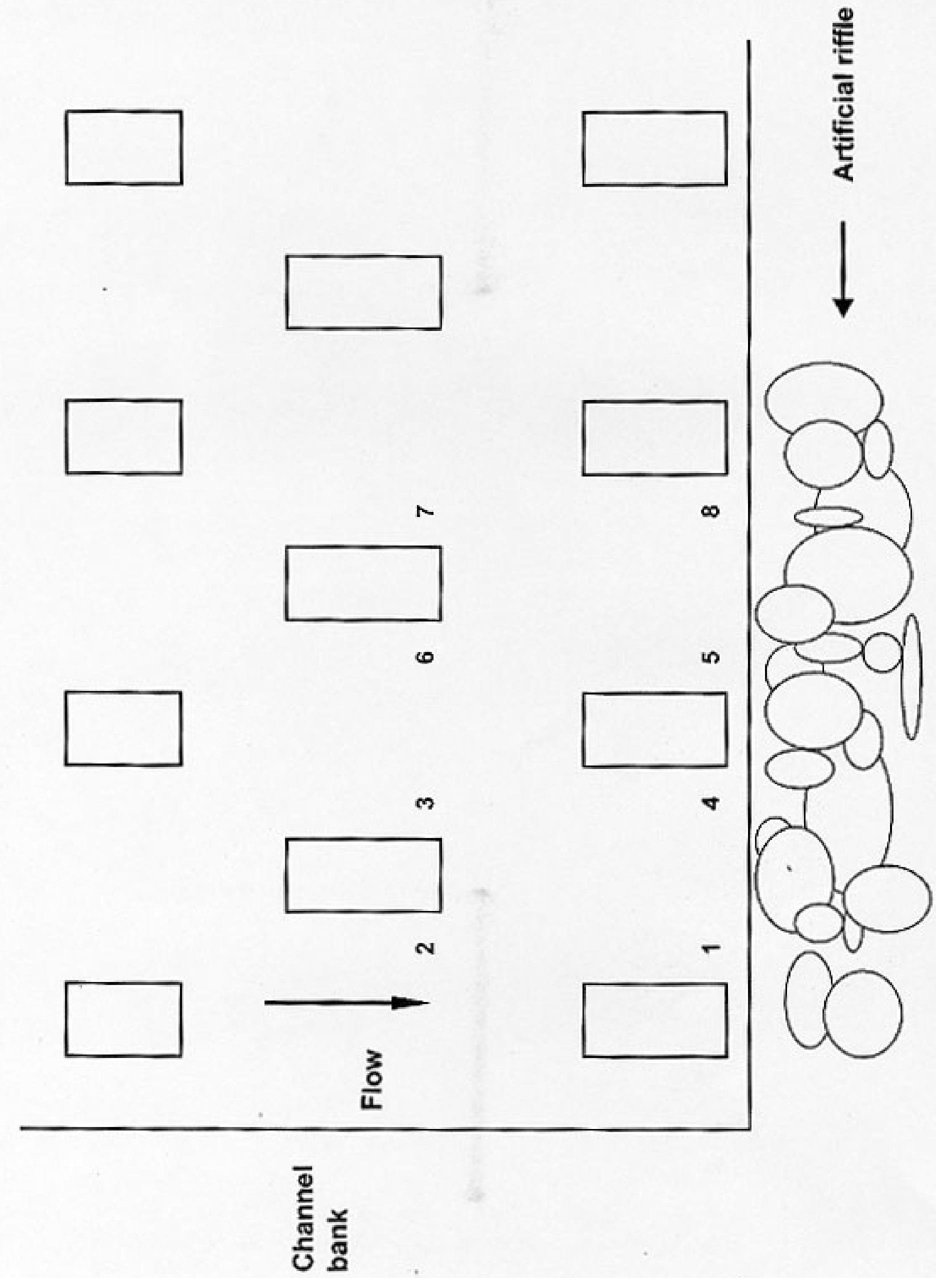


Figure 1: Velocities at the block corners on the right bank. Dashed line indicates the steady swimming speed of smelt. Positions of the block corners are identified on the facing page.

Positions of the block corners given in Figure 1 (Right bank).



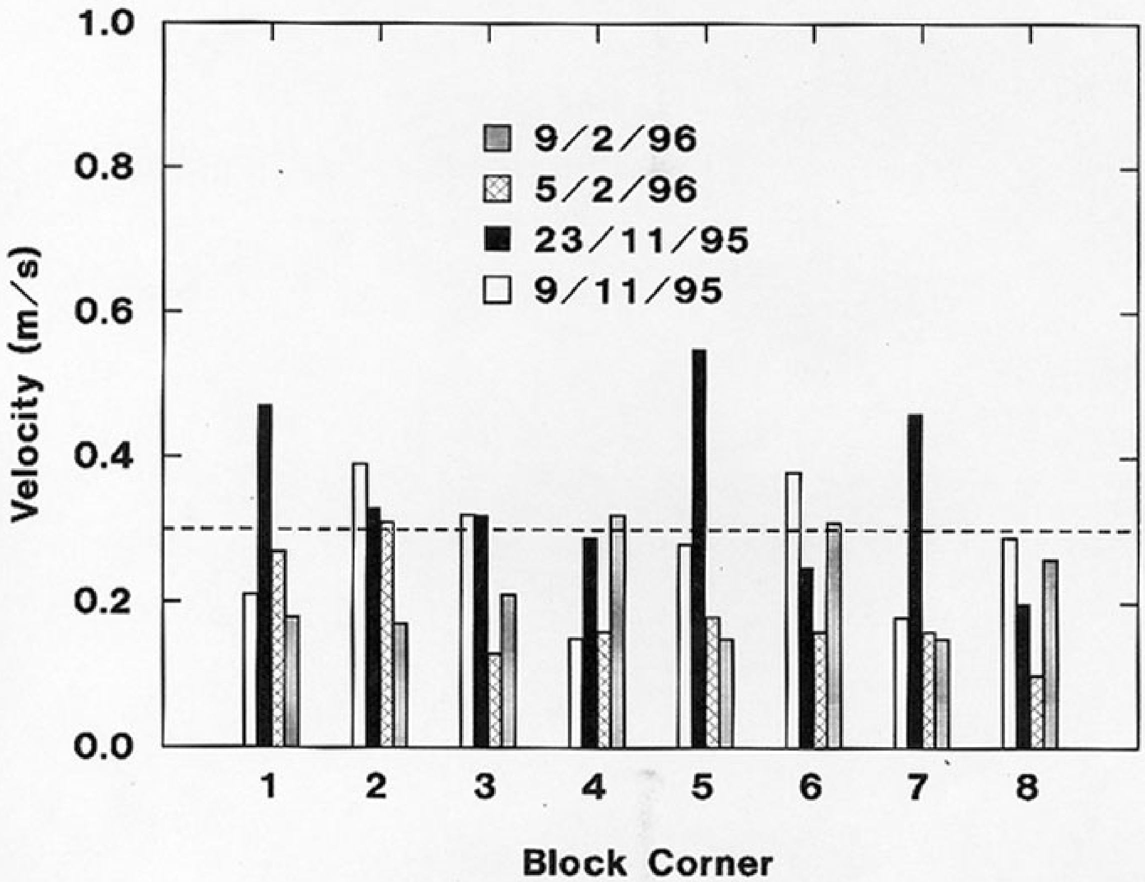
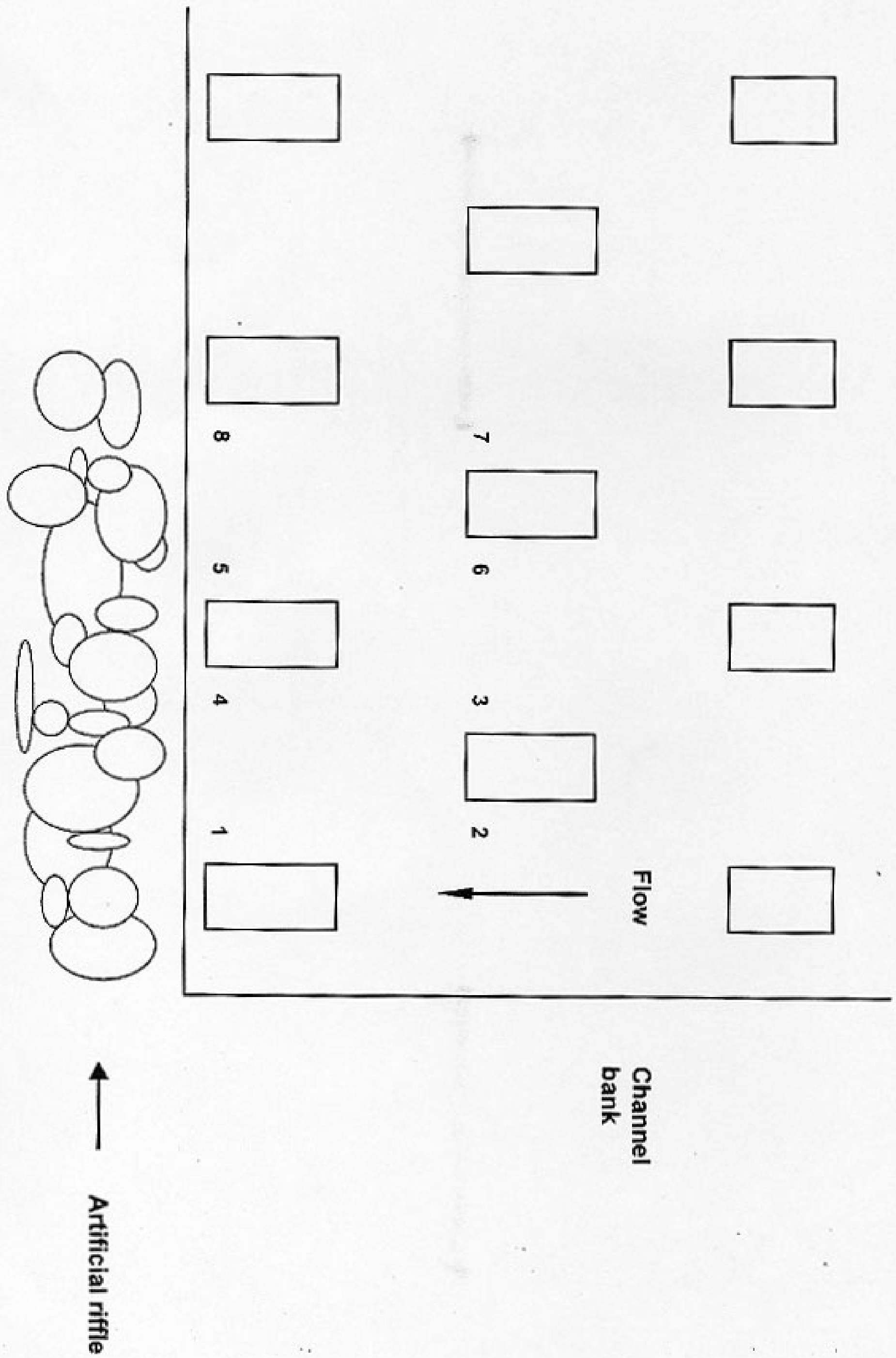


Figure 2: Velocities at the block corners on the left bank. Dashed line indicates the steady swimming speed of smelt. Positions of the block corners are identified on the facing page.



Positions of the block corners given in Figure 2 (Left bank).

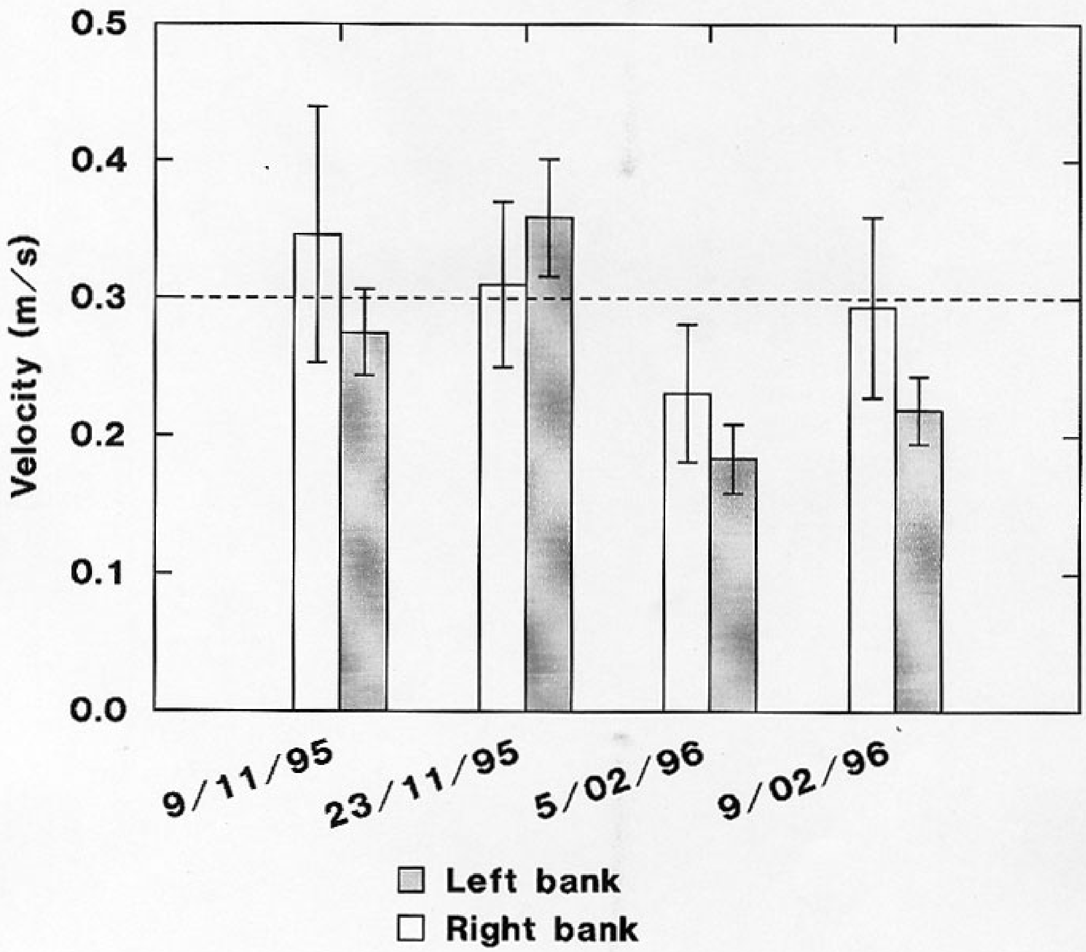


Figure 3: Mean velocities (+/- SE) on the high crests. Dashed line indicates the steady swimming speed of smelt.

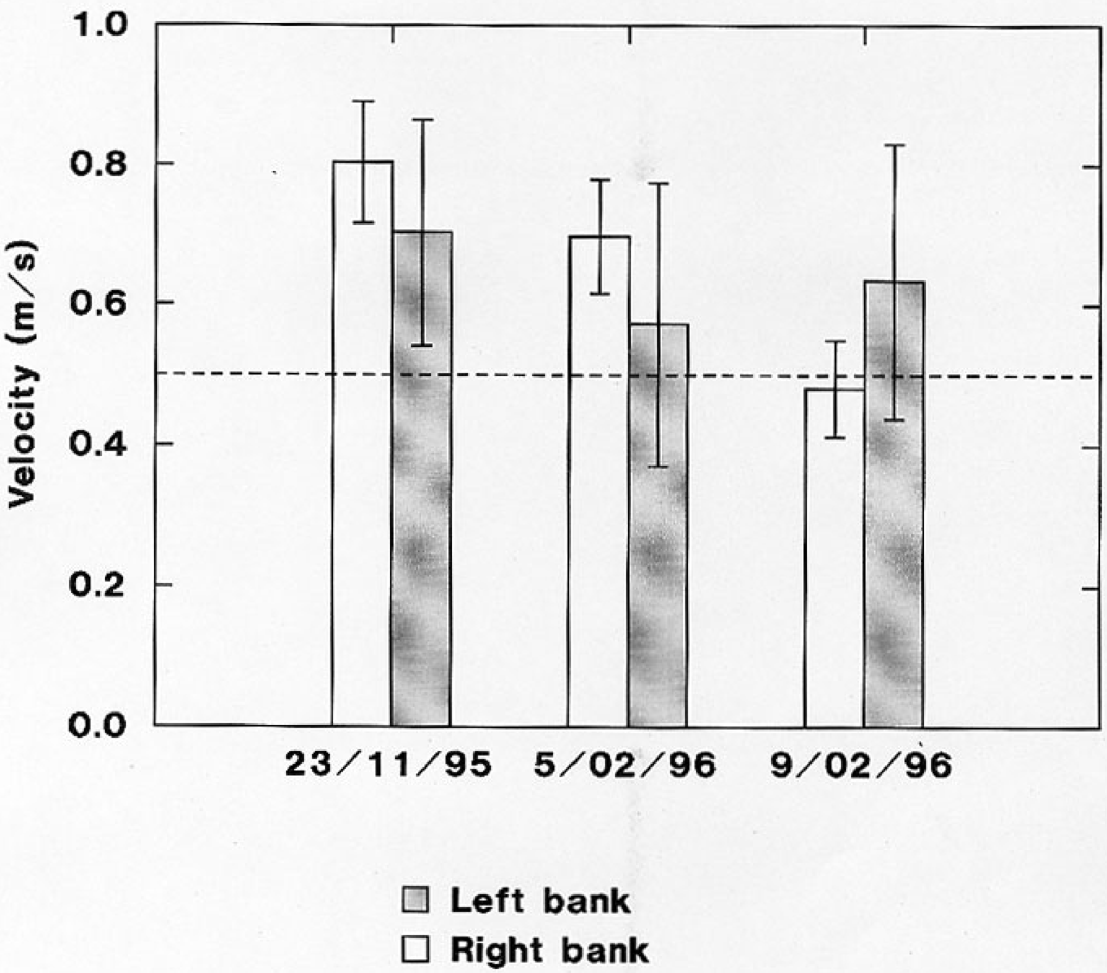


Figure 4: Mean velocities (+/- SE) in the artificial riffles. Dashed line indicates the burst swimming speed of smelt.

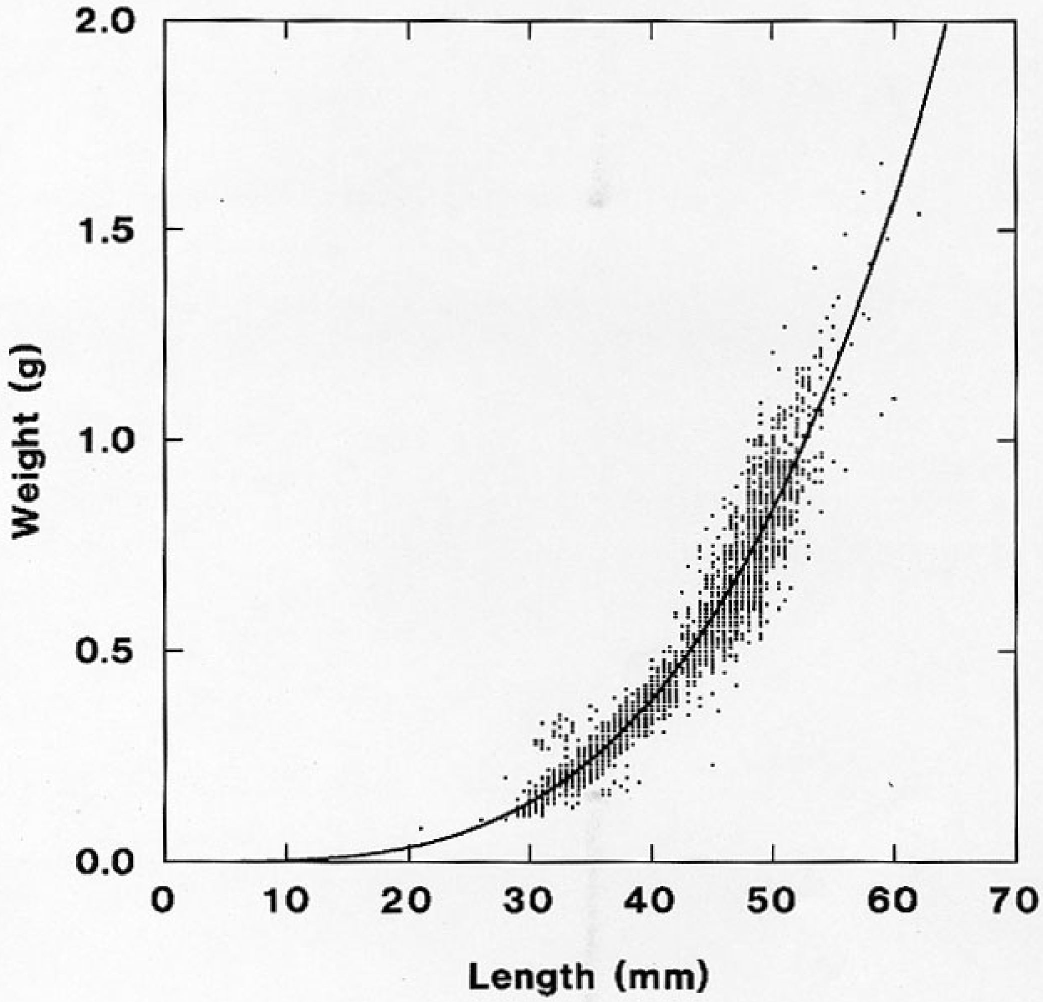


Figure 5: Length-weight relationship for smelt collected in the Ohau Channel. Fitted line is derived from the regression model described in the text.

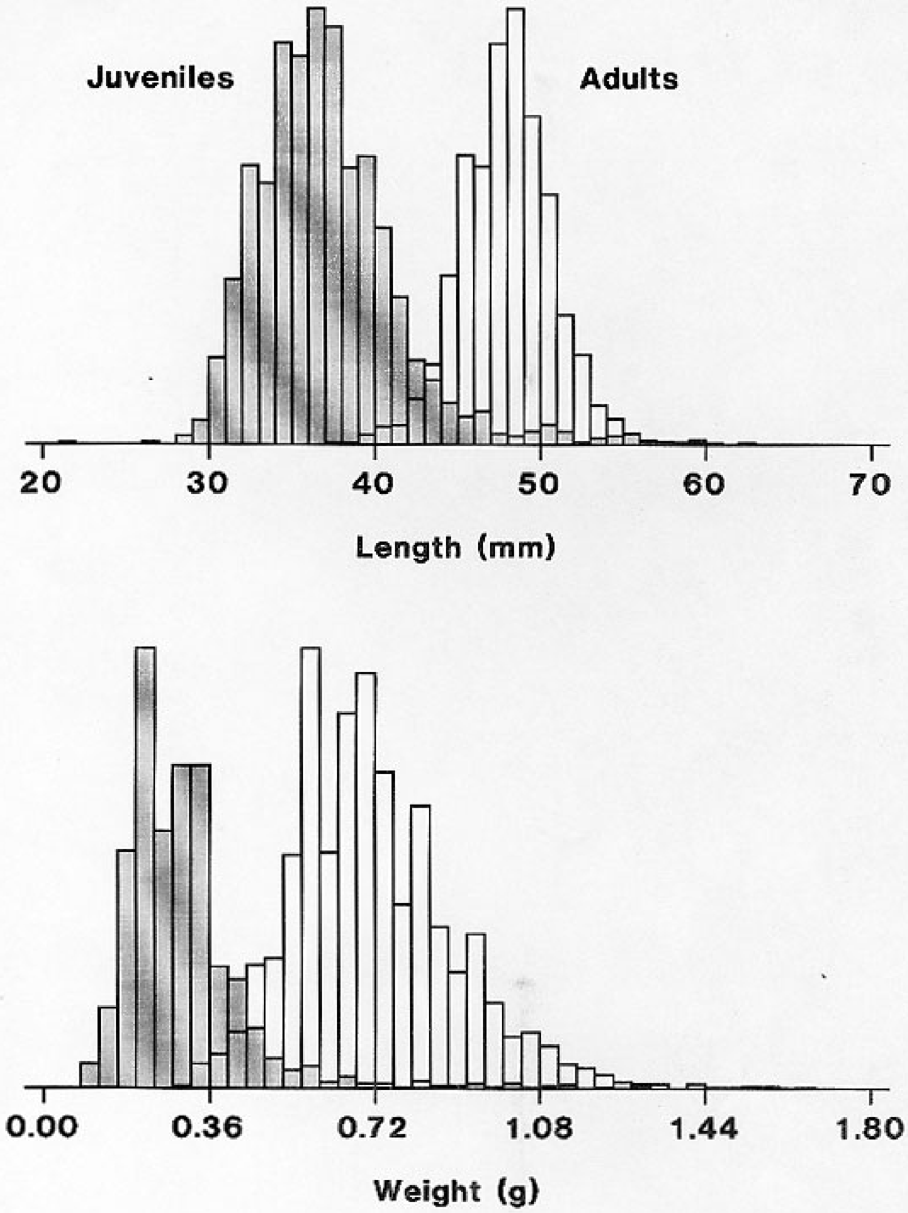


Figure 6: Length and weight frequency comparisons for smelt caught in the Ohau Channel in November 1995 and February 1996 (shaded bars).

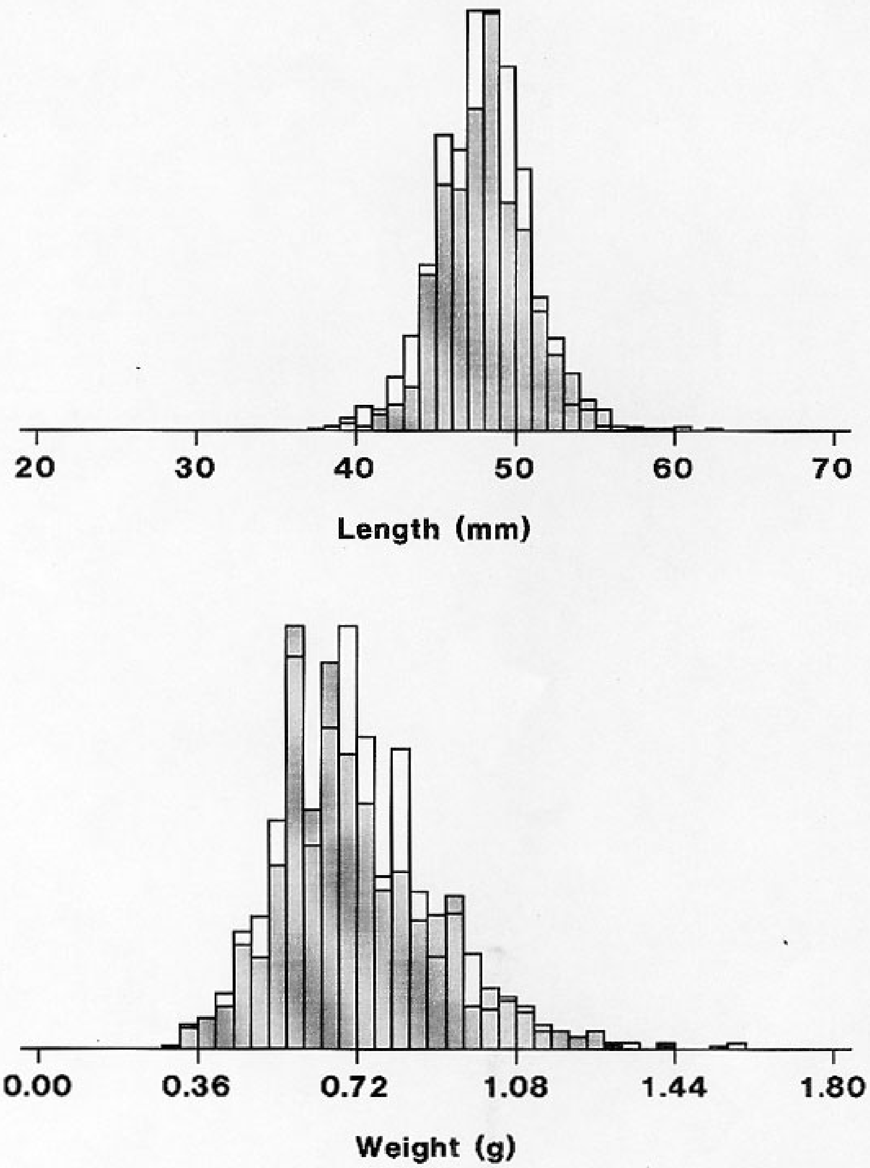


Figure 7: **Length and weight frequency comparisons for smelt caught downstream and top (shaded bars) of the Ohau Channel fish pass in November 1995.**

Note: there is no change in the smelt size structure - all adults are able to ascend the fish pass.

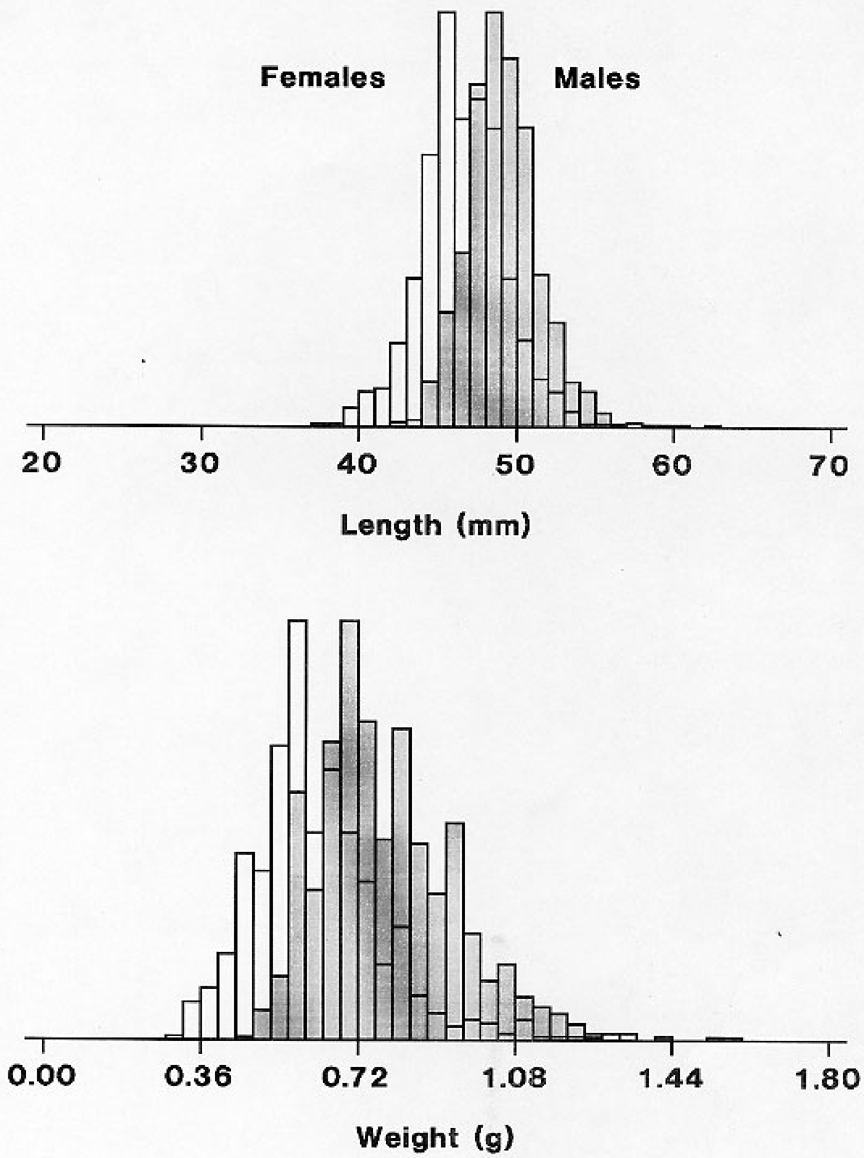


Figure 8: Length and weight frequency comparisons for male (shaded bars) and female smelt caught in the Ohau Channel in November 1995.

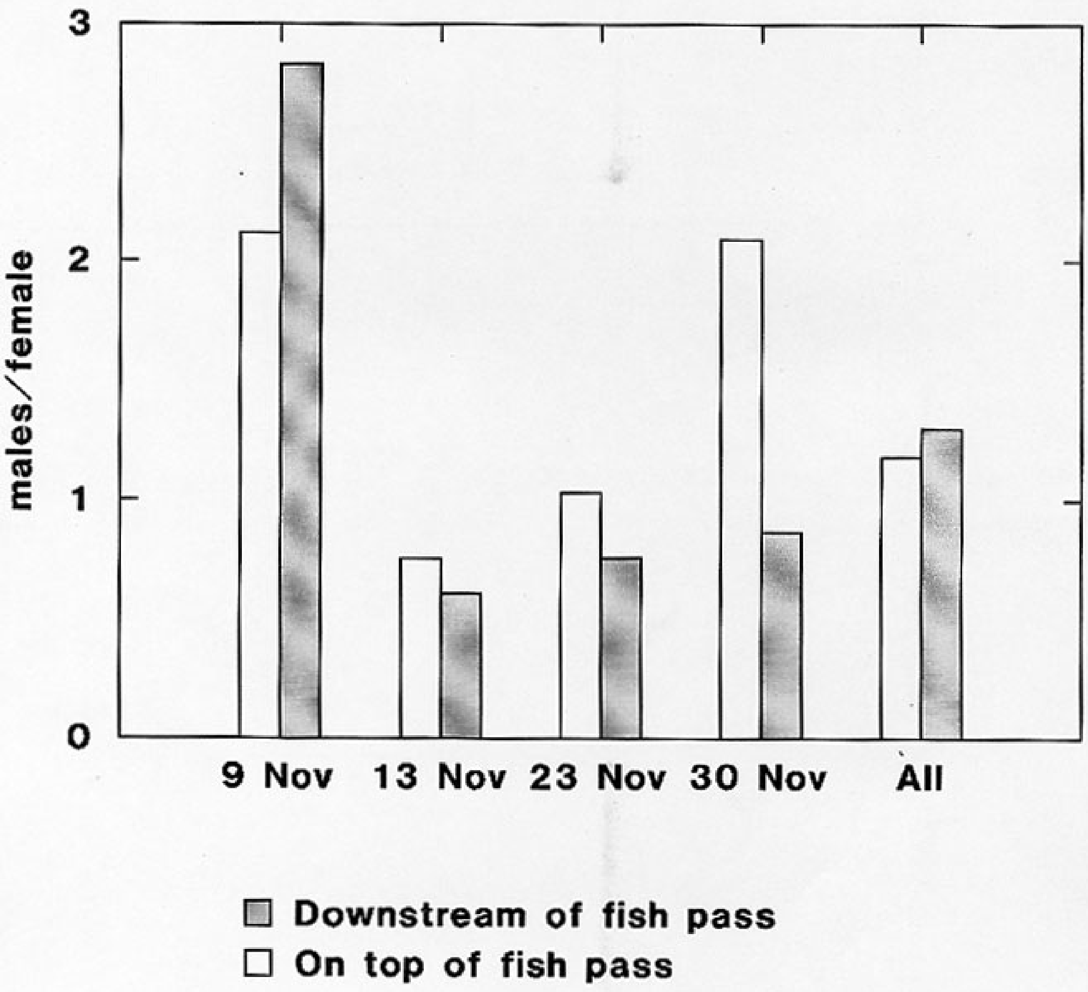


Figure 9: **Comparison of the ratio of male and female smelt using the Ohau Channel fish pass in 1995. "All" represents the combined data.**

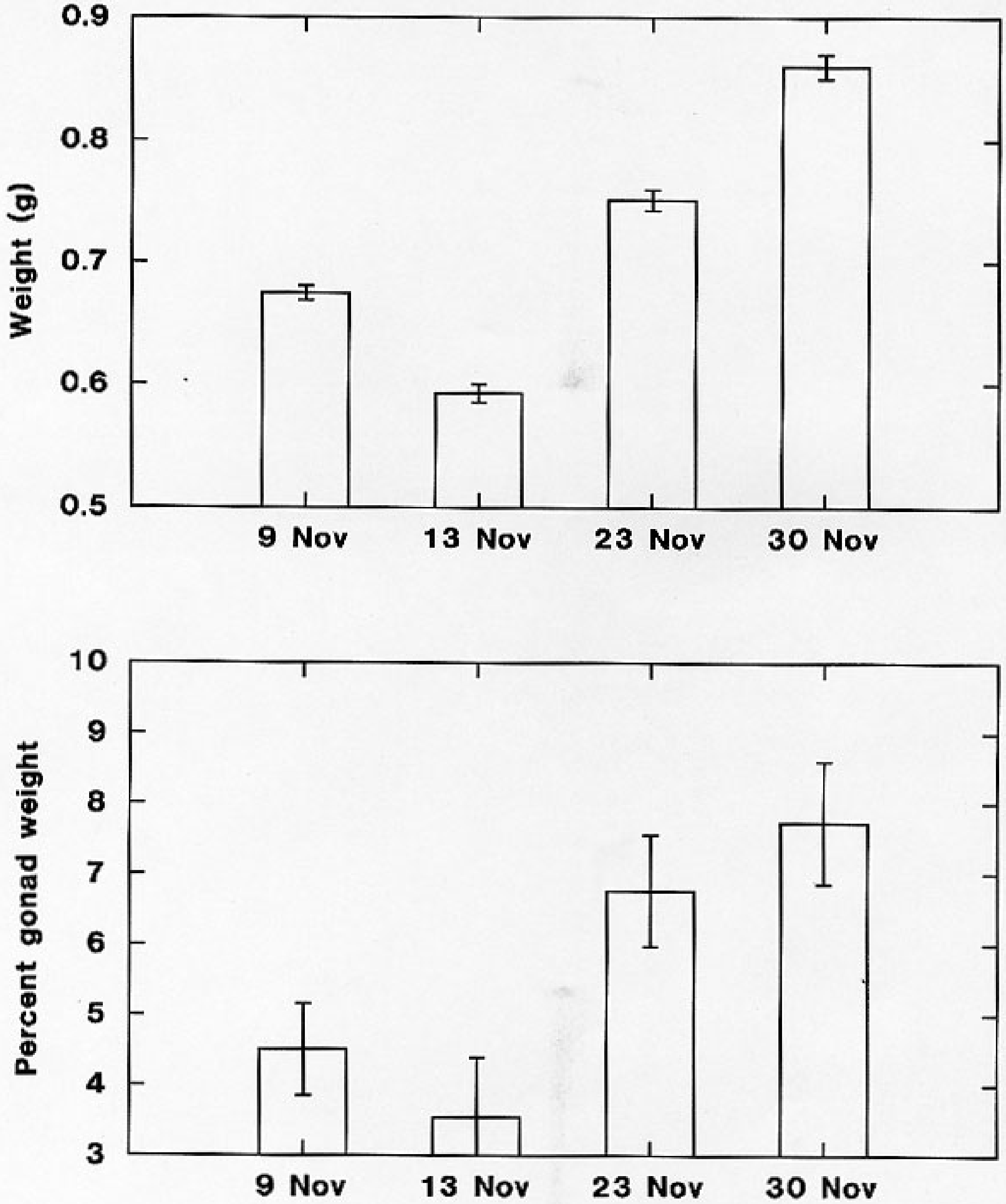


Figure 10: Ohau Channel 1995. Mean weight for all smelt (top) and mean gonad weight as a percentage of body weight for female smelt (bottom). Standard error bars are given.

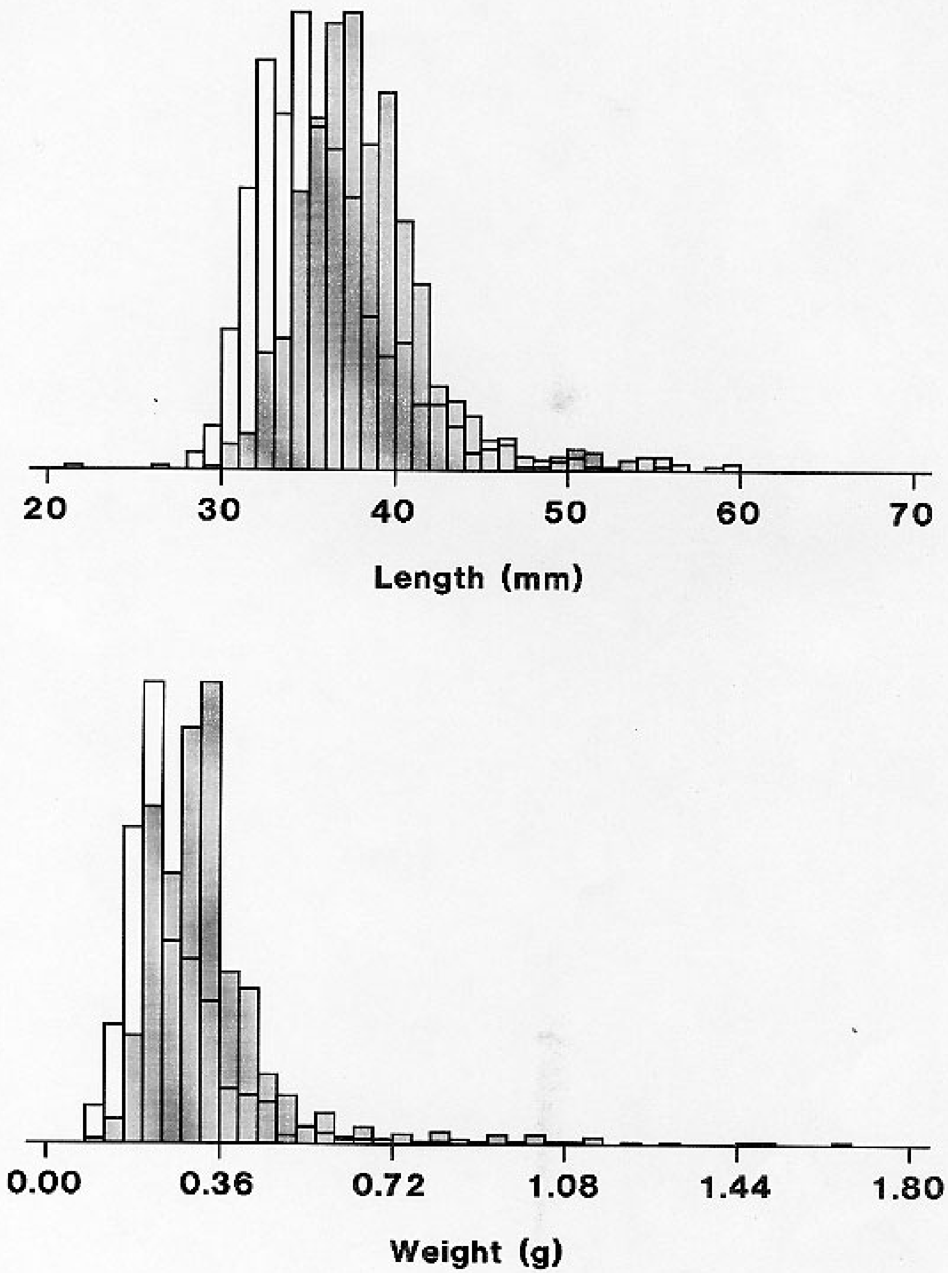


Figure 11: Length and weight frequency comparisons for smelt caught downstream and on top (shaded bars) of the Ohau Channel fish pass in February 1996.

Note: the shift in size frequency - the fish pass is working best for the larger juveniles.

Appendices

Appendix I

No.2180

BAY OF PLENTY CATCHMENT BOARD

AND REGIONAL WATER BOARD

RIGHT IN RESPECT OF NATURAL WATER

Pursuant to Section 21(3) of the Water and Soil Conservation Act 1967, the Bay of Plenty Catchment Board, in its capacity as REGIONAL WATER BOARD for the Bay of Plenty Catchment Area, by a decision dated 2 February 1989 HEREBY GRANTS to:

REGIONAL COUNCIL
BAY OF PLENTY ~~CATCHMENT BOARD~~

PO Box 364
WHAKATANE

a right to DAM THE OHAU CHANNEL AT THE OUTLET FROM LAKE ROTORUA FOR THE PURPOSE OF CONTROLLING THE LEVEL OF LAKE ROTORUA subject to the following conditions:

1. PURPOSE
For the purpose of controlling the level of Lake Rotorua.

2. LOCATION
At outlet from Lake Rotorua as shown on BOPCB Plan No.K4546 submitted with the application.

3. MAP REFERENCE
U15:018 454

4. WORKS

CHANGE:

4.1 The control structure shall be built and sited generally as shown on BOPCB Plan No.K4562 Sheets 1, ~~and~~ 2 and ~~2.~~

4.2 The Grantee shall take every care during the construction works and throughout the term of this right to the satisfaction of the General Manager of the Regional Water Board or his delegate to minimise the discharge of sediment into the Ohau Channel.

4.3 Any erosion control measures which become necessary as a result of exercise of this right shall be undertaken by the Grantee as directed by the General Manager of the Regional Water Board or his delegate.

CHANGE:

CHANGE:

4.4 Construction of the artificial riffles, as shown on BOPRC Plan number K4562 sheet 9, shall be completed before ~~15 June~~ 30 December 1993.

No.2180

5. CONTROL STRUCTURE

5.1 The control structure shall be a two stage broad crested weir installed in accordance with BOPCB Plan No.K4562 Sheet 2 and 9.

SEE CHANGE:

5.2 The central lower portion of the control structure shall be not less than 6m wide.

5.3 The control structure shall be designed and undertaken so that elevations of the central lower crest and the top crest are 278.2m and 279.35m above Moturiki datum respectively.

5.4 The control structure shall be designed, undertaken and operated so that as far as practicable, the level of Lake Rotorua is maintained between the statutorily fixed maximum and minimum levels.

5.5 The control structure shall be designed and undertaken to permit the free passage of fish in general accordance with the recommendations contained within the "Environmental Assessment of the Proposed Lake Rotorua Control Structure, C P Mitchell, MAF Fish, Rotorua, November 1988."

5.6 During construction of the control structure there shall be no excavation of the existing trout spawning beds immediately downstream of the structure or machinery movement within the bed of the Ohau Channel.

SEE CHANGE:

6. ACCESS

The Grantee shall as far as practicable maintain the existing foot access on the right bank of the Ohau Channel downstream of the control structure during the term of this right.

7. SUPERVISION OF WORKS

All planning, design, construction and operation of works associated with this right shall be supervised by Registered Engineers.

8. SURRENDER OF RIGHT NO.289

Authority to exercise this right is conditional upon the Bay of Plenty Catchment Board surrendering Water Right No.289 within one month after the date of issue of this right.

9. TERM OF RIGHT

This right shall terminate on 28 February 2014.

No.2180

10. THE RIGHT hereby authorised is granted under the Water and Soil Conservation Act 1967 and does not constitute an authority under any other Act, Regulation or By-Law.

11. THIS RIGHT may be cancelled by the giving of not less than twelve months' notice in writing by the Regional Water Board to the Grantee if in the opinion of the Regional Water Board the public interest so requires, but without prejudice to the right of the Grantee to apply for a further right in respect of the same matter.

DATED at Whakatane this 16th day of March, 1989.

For and on behalf of
The Bay of Plenty Catchment Board
and Regional Water Board

P J GAVIN
SECRETARY

CHANGE

The change of this permit was approved under delegated authority of the Bay of Plenty Regional Council, dated 9 June 1993, as follows:

Amend Condition 4.1 by deleting "... sheets 1 and 2" and replace with "... sheets 1, 2 and 9".

Add a new condition number 4.4 "Construction of the artificial riffles, as shown on BOPRC Plan Number K4562 sheet 9, shall be completed before 15 June 1993.

Amend condition number 5.1 by deleting "... sheet 2" and replace with "... sheets 2 and 9".

Amend condition number 5.6 by adding to the end of the sentence "or machinery movement within the bed of the Ohau Channel".

R B GARDNER
Manager Environmental Regulation and Monitoring

for J A JONES
General Manager

No.2180

CHANGE

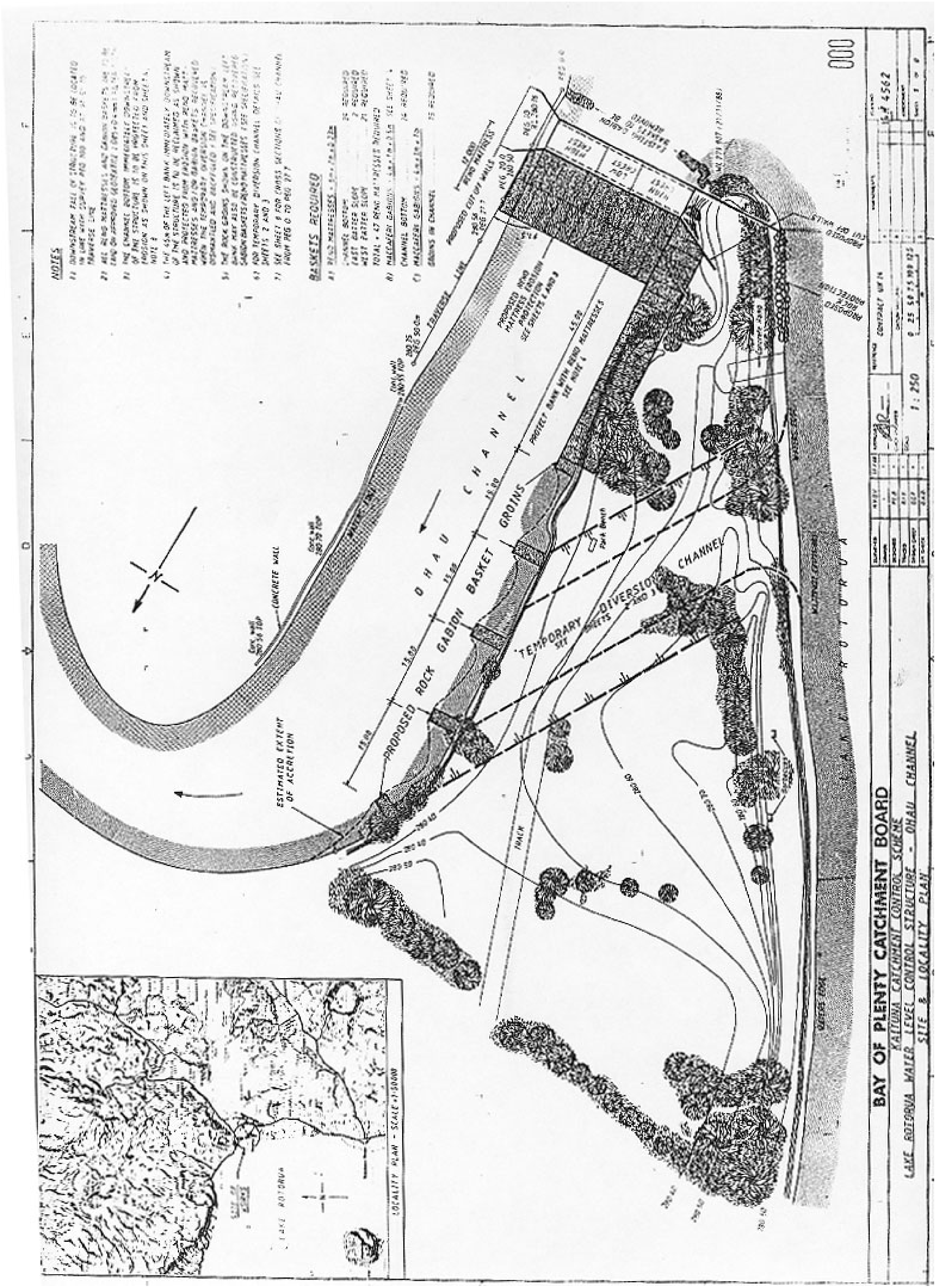
The change of this permit was approved under delegated authority of Environment B.O.P, dated 26 October 1993, as follows:

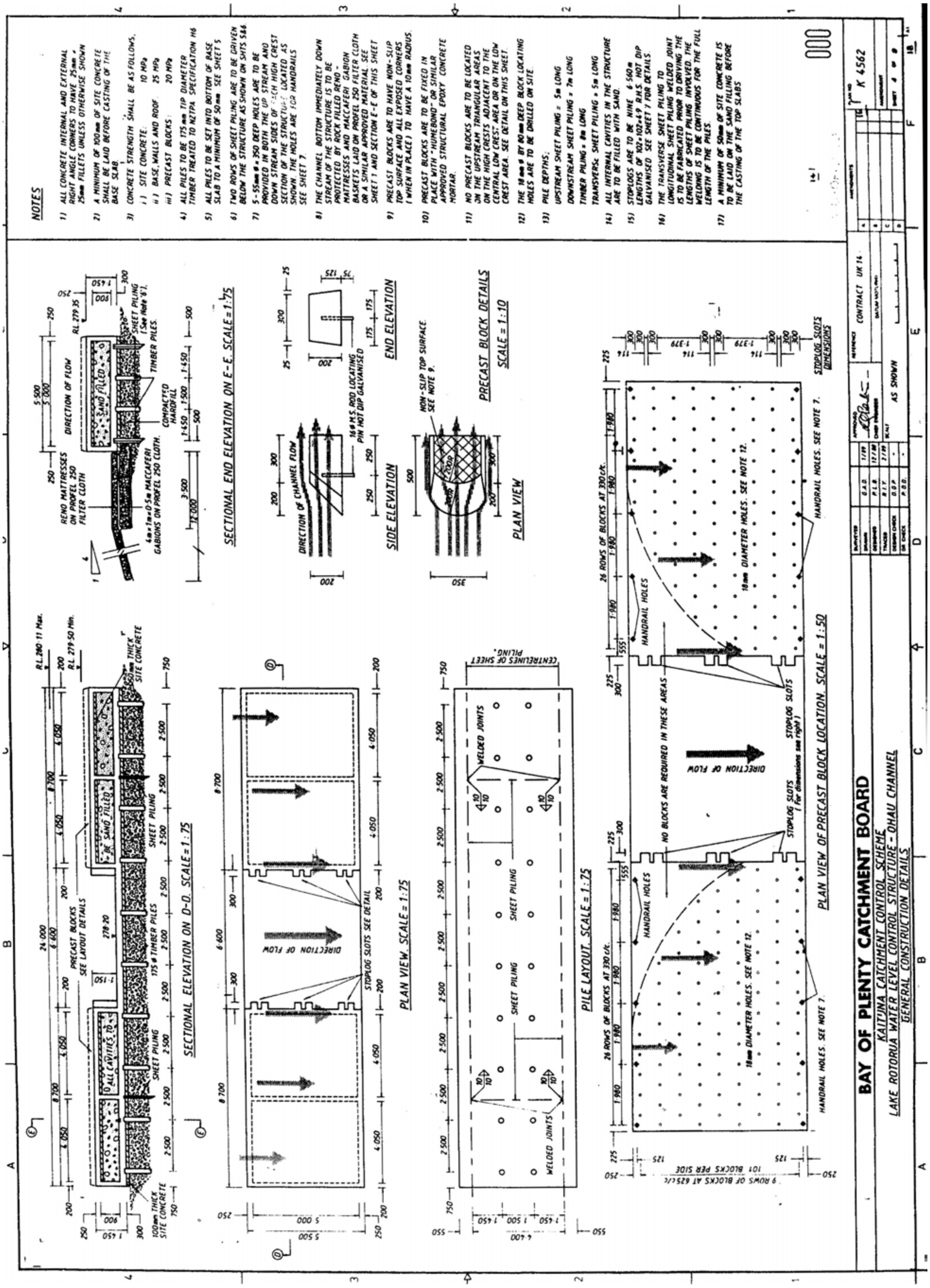
Amend condition 4.4 by deleting "... 15 June ..." and replacing it with "... 30 December ...".

R B GARDNER
Manager Environmental Regulation and Monitoring

for J A JONES
General Manager

Appendix II


BAY OF PLENTY CATCHMENT BOARD
KAITUNA CATCHMENT CONTROL SCHEME
LAKE ROTORUA WATER LEVEL CONTROL STRUCTURE - OHAU CHANNEL
SITE & LOCALITY PLAN
1 : 250
NOTES
BASKETS REQUIRED
OHAU CHANNEL
PROPOSED ROCK GABION BASKET GROINS
TEMPORARY DIVERSION CHANNEL
CONCRETE WALL
ESTIMATED EXTENT OF ACCRETION
LAKE ROTORUA
LOCALITY PLAN - SCALE 1:50000


SECTIONAL ELEVATION ON D-D. SCALE = 1:75
PLAN VIEW. SCALE = 1:75
PILE LAYOUT. SCALE = 1:75
PLAN VIEW OF PRECAST BLOCK LOCATION. SCALE = 1:50
SECTIONAL END ELEVATION ON E-E. SCALE = 1:75
SIDE ELEVATION
END ELEVATION
PRECAST BLOCK DETAILS
SCALE = 1:10
PLAN VIEW
STOPLOG SLOTS DIMENSIONS
DIRECTION OF FLOW
NO BLOCKS ARE REQUIRED IN THESE AREAS
HANDRAIL HOLES
STOPLOG SLOTS
NOTES
1) ALL CONCRETE INTERNAL AND EXTERNAL RIGHT ANGLE CORNERS TO HAVE 25mm x 25mm FILLETS UNLESS OTHERWISE SHOWN
2) A MINIMUM OF 100mm OF SITE CONCRETE SHALL BE LAID BEFORE CASTING OF THE BASE SLAB.
3) CONCRETE STRENGTH SHALL BE AS FOLLOWS. i) SITE CONCRETE: 10 MPa ii) BASE, WALLS AND ROOF 25 MPa iii) PRECAST BLOCKS: 20 MPa
4) ALL PILES TO BE 175mm TIP DIAMETER TIMBER TREATED TO NZTPA SPECIFICATION H6
5) ALL PILES TO BE SET INTO BOTTOM OF BASE SLAB TO A MINIMUM OF 50mm. SEE SHEET 5
6) TWO ROWS OF SHEET PILING ARE TO BE DRIVEN BELOW THE STRUCTURE AS SHOWN ON SHTS 5&6
7) 5-55mm ø x 350 DEEP HOLES ARE TO BE PROVIDED IN BOTH THE UP STREAM AND DOWN STREAM SIDES OF EACH HIGH CREST SECTION OF THE STRUCTURE LOCATED AS SHOWN. THE HOLES ARE FOR HANDRAILS SEE SHEET 7.
8) THE CHANNEL BOTTOM IMMEDIATELY DOWN STREAM OF THE STRUCTURE IS TO BE PROTECTED BY ROCK FILLED RENO MATTRESSES AND MACCAFERI GABION BASKETS LAID ON PROFEL 250 FILTER CLOTH OR A SIMILAR APPROVED MATERIAL. SEE SHEET 1 AND SECTION E-E OF THIS SHEET
9) PRECAST BLOCKS ARE TO HAVE NON-SLIP TOP SURFACE AND ALL EXPOSED CORNERS (WHEN IN PLACE) TO HAVE A 10mm RADIUS.
10) PRECAST BLOCKS ARE TO BE FIXED IN PLACE WITH "HUMEBOND" OR SIMILAR APPROVED STRUCTURAL EPOXY CONCRETE MORTAR.
11) NO PRECAST BLOCKS ARE TO BE LOCATED ON THE UPSTREAM TRIANGULAR AREAS ON THE HIGH CRESTS ADJACENT TO THE CENTRAL LOW CREST AREA OR ON THE LOW CREST AREA. SEE DETAIL ON THIS SHEET.
12) THE 18mm ø BY 80mm DEEP BLOCK LOCATING HOLES ARE TO BE DRILLED ON SITE.
13) PILE DEPTHS; UPSTREAM SHEET PILING = 5m LONG DOWNSTREAM SHEET PILING = 7m LONG TIMBER PILING = 8m LONG TRANSVERSE SHEET PILING = 5m LONG
14) ALL INTERNAL CAVITIES IN THE STRUCTURE ARE TO BE FILLED WITH SAND.
15) STOPLOGS ARE TO BE NINE 6.560m LENGTHS OF 102x102x4.9 R.H.S. HOT DIP GALVANISED. SEE SHEET 7 FOR DETAILS.
16) THE TRANSVERSE SHEET PILING TO LONGITUDINAL SHEET PILING WELDED JOINT IS TO BE FABRICATED PRIOR TO DRIVING THE LENGTHS OF SHEET PILING INVOLVED. THE WELDING IS TO BE CONTINUOUS FOR THE FULL LENGTH OF THE PILES.
17) A MINIMUM OF 50mm OF SITE CONCRETE IS TO BE LAID ON THE SAND FILLING BEFORE THE CASTING OF THE TOP SLABS
BAY OF PLENTY CATCHMENT BOARD
KAITUNA CATCHMENT CONTROL SCHEME
LAKE ROTORUA WATER LEVEL CONTROL STRUCTURE - OHAU CHANNEL
GENERAL CONSTRUCTION DETAILS
CONTRACT UK 14
AS SHOWN
K 4562

Appendix III

Memorandum

To:	Ross Titchmarsh **Manager Technical Services**
	Bruce Crabbe **Manager Rivers and Drainage**
From:	Robert Donald **Environmental Scientist**
Date:	11 October 1995 **File reference:** 3080 07, 02 2179
Subject:	**OHAU CHANNEL CONTROL STRUCTURE - WATER VELOCITY OVER THE FISH PASS**

INTRODUCTION

The following relates to velocity measurements taken on the Ohau Channel fish pass before and after the installation of additional blocks on the high crest. It was expected that these would further reduce water velocity to levels which would not restrict the upstream movement of smelt and bullies.

Mitchell (1989) provides guidance on the maximum water velocity which will allow fish passage over structures of a given length (copy attached). The Ohau Channel control structure has a length of 5.5 m (upstream to downstream). In this case the velocity over the high crest should ideally be less than 0.35 m/s to allow the passage of smelt and bullies (see Fig. 3 of Mitchell (1989)).

To negotiate the structure small fish must first use "burst swimming" to move through the rocks and boulders (artificial riffle) located downstream of the high crest. The burst swimming speed is around 0.5 m/s for smelt and 0.6 m/s for common bully. Once on top of the high crest "steady swimming" would be used to proceed into the lake. Steady swimming speeds are around 0.3 m/s for smelt and common bully (Mitchell 1989).

METHODS

Trials were carried out on 8 June 1994 by experimenting with temporary blocks on the high crest. Velocity was measured near the block corners using a Gurley Pygmy meter positioned 2-3 cms above the base of the crest. In some cases readings were also obtained just below the water surface. Based on the results of the trials extra blocks (250 l x 200 h x 90 w) were installed diagonally between the original blocks. Velocity measurements were carried out to assess the effect of the new blocks on 24 May 1995.

RESULTS

The trials conducted in June 1994 suggested that diagonally placed blocks would significantly reduce water velocity over the fish pass (Figs 1 & 3). Most importantly it was possible to reduce the velocity on the high crest and in the artificial riffle to levels below the respective steady and burst swimming speeds.

OHAU CHANNEL CONTROL STRUCTURE - WATER VELOCITY OVER THE FISH PASS
11 October 1995

Measurements taken after the extra blocks were permanently installed indicate that velocities on the high crest are low (mean of 0.25 m/s from 48 measurements) and generally below the steady swimming speeds (Figs 1 & 4). Velocities were higher than for the initial trial possibly because of the greater flow and lake level on 24 May 1995 compared to 8 June 1994 (18.5 m^3/s and 280.003m MOT datum versus 14.7 m^3/s and 279.888m MOT datum)*. Measurements taken just below the water surface (Fig. 4) give some idea of how much the water velocity on the high crest is slowed by the concrete blocks. In the artificial riffle area the velocities have been reduced further than was indicated by the initial trial (Fig. 3).

DISCUSSION

The information presented here suggests that smelt and bullies will have little trouble negotiating the Ohau Channel control structure into Lake Rotorua. There is still concern that weed and sediment build up on top of the high crest will obstruct the movement of smelt and bullies. This is likely to be an ongoing problem and the situation could be alleviated by employing a local person to act as 'caretaker' for the fish pass.

CONCLUSIONS

1 The modifications to the Ohau Channel fish pass have succeeded in lowering the water velocity over the high crest.

2 There is now no reason to suspect that smelt and bully passage through the fish pass is restricted by water velocity.

3 Weed and sediment build-up on the fish pass may be reducing its effectiveness.

Robert Donald
ENVIRONMENTAL SCIENTIST

R:\REPORT\ROBERT\SMELTVEL.MEM

*Errata - these figures were accidently transposed when preparing the original memo. This should read "(14.7 m^3/s and 279.888m MOT datum versus 18.5 m^3/s and 280.003m MOT datum)". As described in the monitoring report velocities in the fish pass actually tend to be highest when the flow in the Ohau Channel is low.

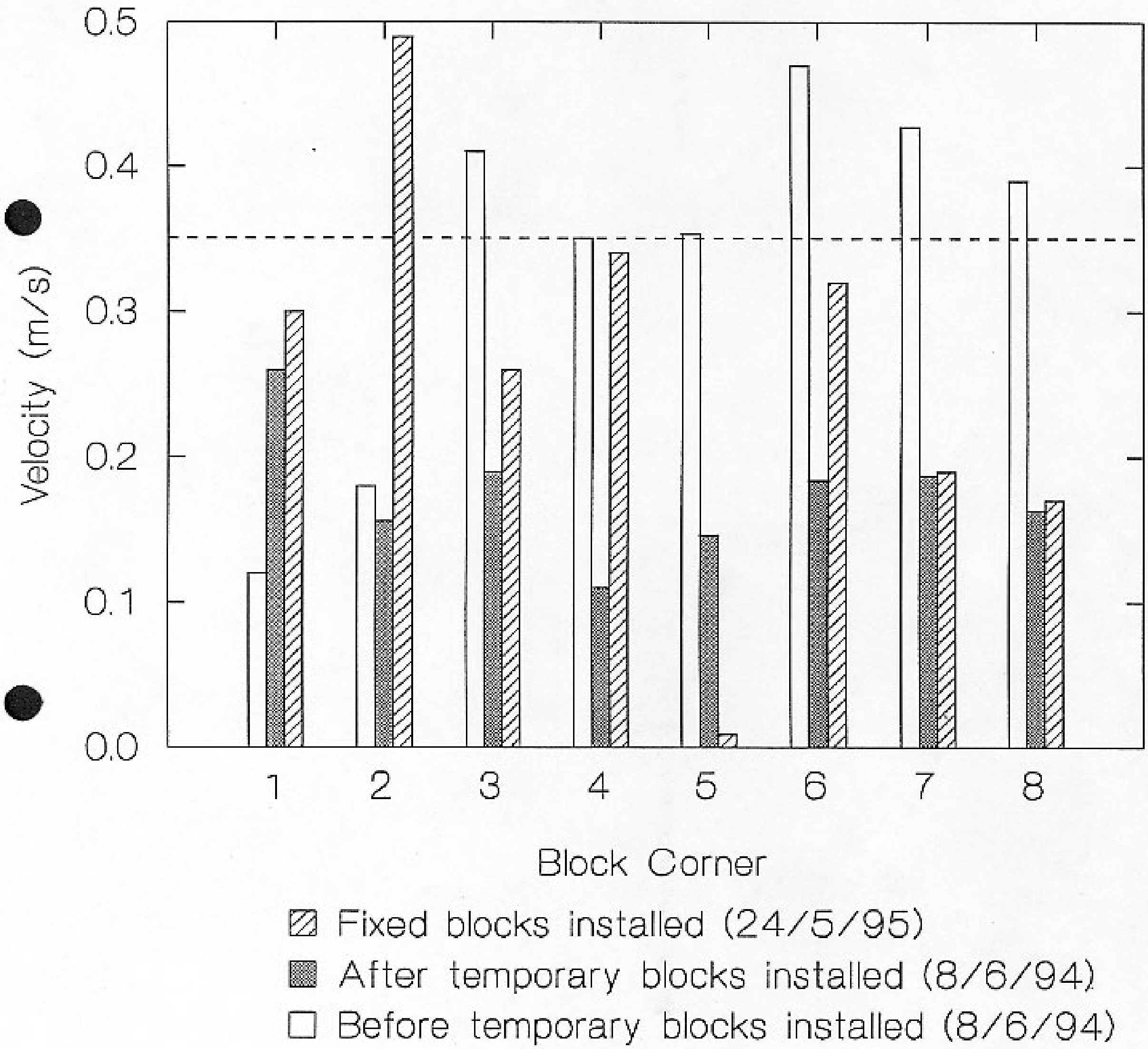
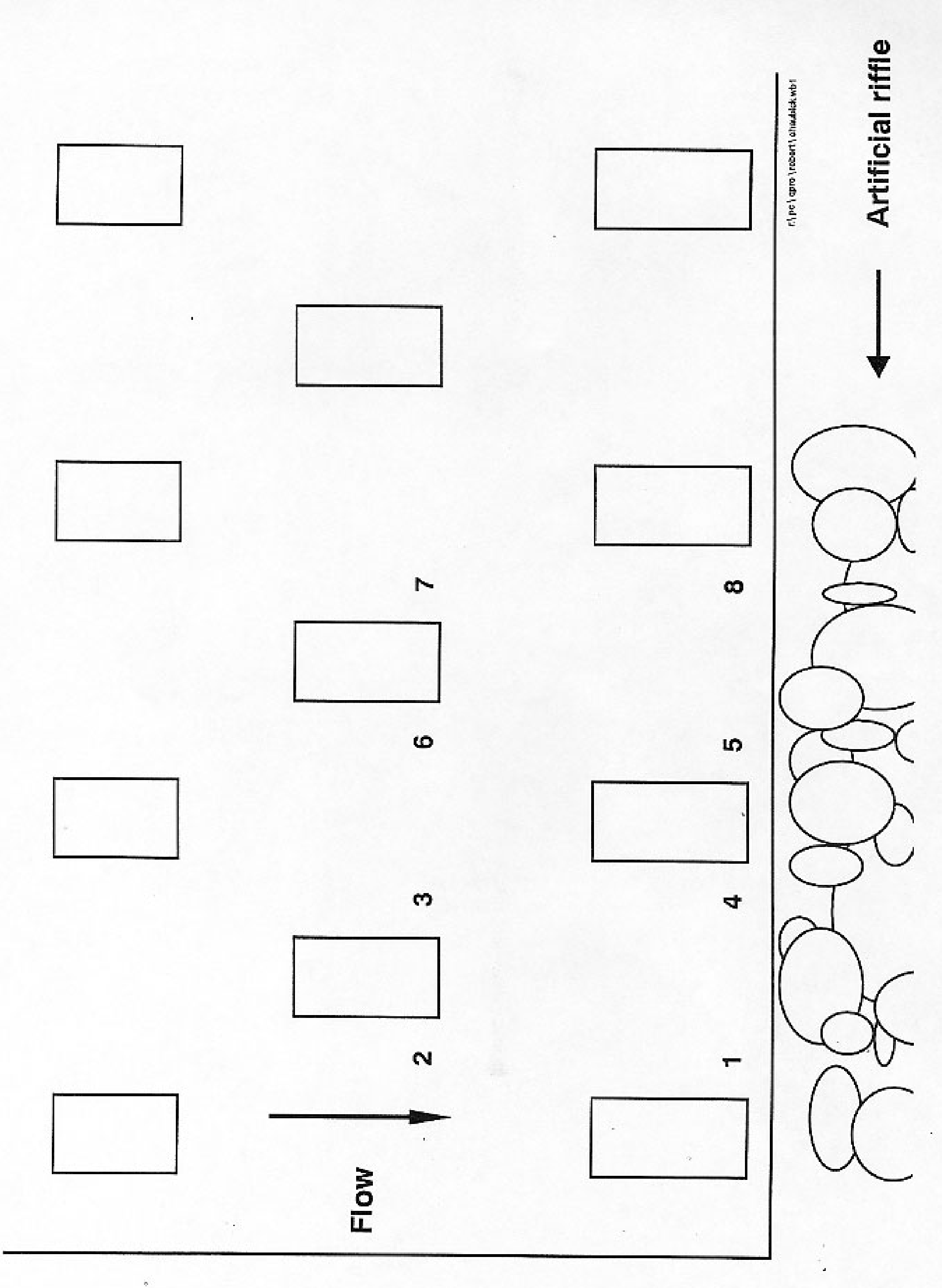


Figure 1: Velocities at the block corners before and after the installation of temporary and fixed blocks. Dashed line indicates the maximum allowable velocities for movement of smelt and bullies over the structure. Positions of block corners are identified in Figure 2.

Figure 2: Positions of block corners given in Figure 1.



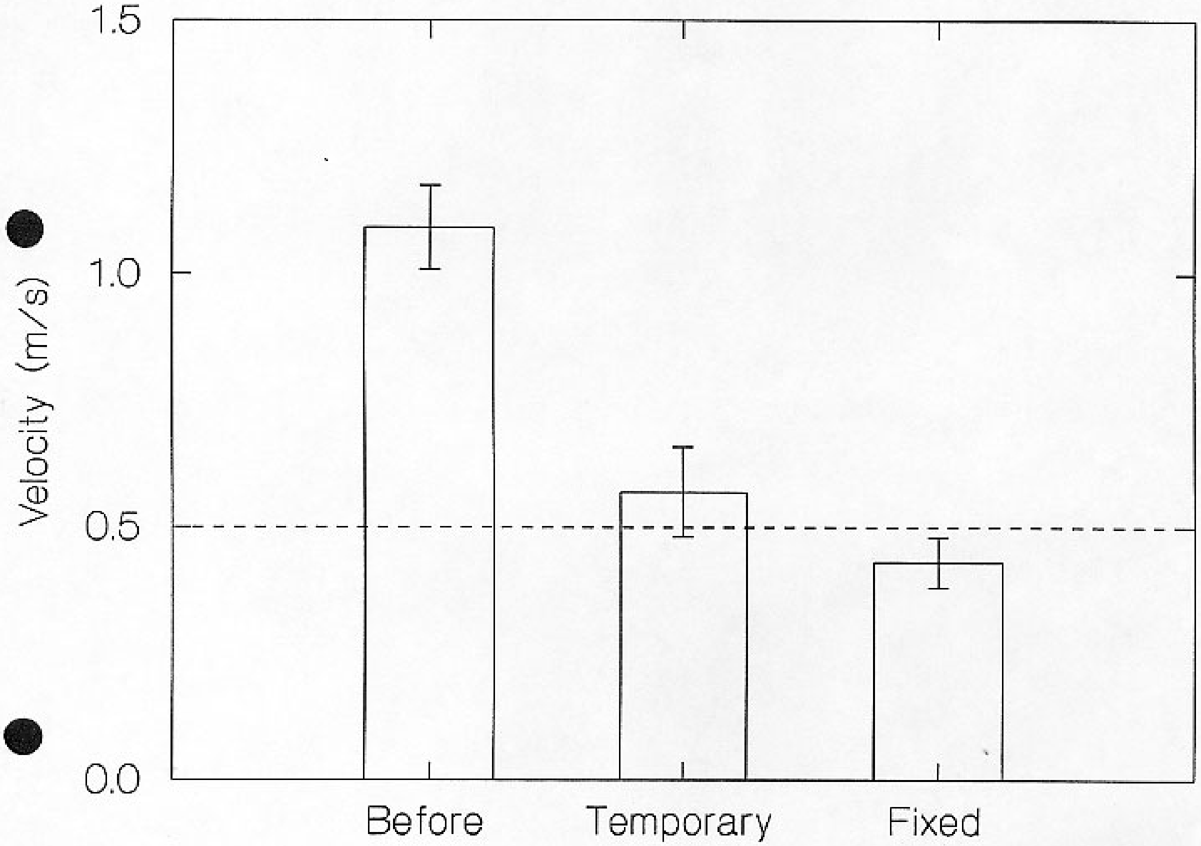
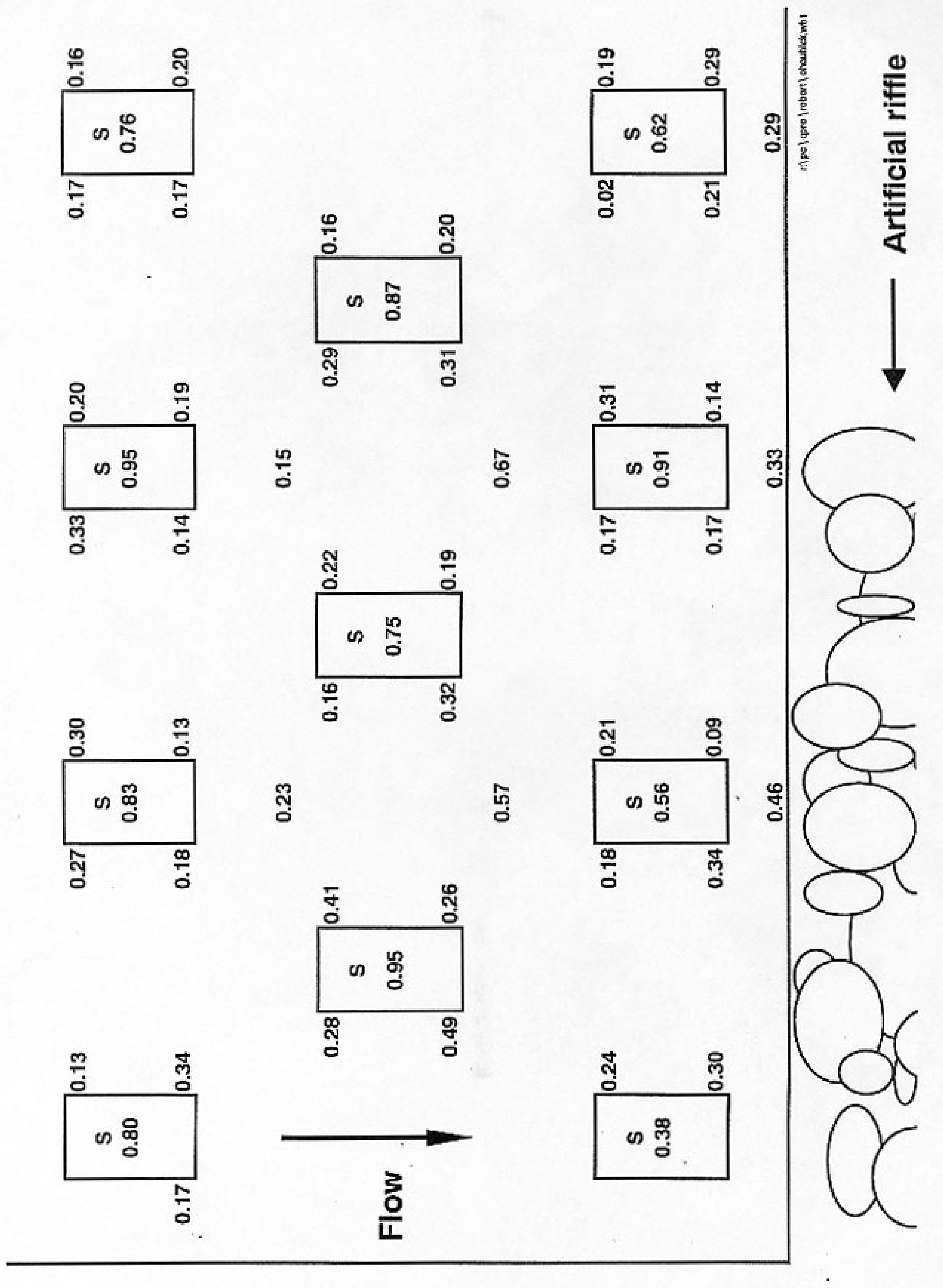


Figure 3: Mean velocities (+/- SE) in the artificial riffle before and after the addition of temporary and fixed blocks. Dashed line indicates the burst swimming speed of smelt.

Figure 4: Velocity measurements taken on 24/5/95 on the right bank of the Ohau Channel.
S - indicates surface readings.



Appendix IV

Appendix 4:

Field notes for smelt monitoring.

Date	Time (NZST)	Cloud cover (%)	Wind	Surface conditions	Weed and debris	Sediment depth on crest (cm)	Water depth on crest (cm)	Downstream drop off crest (cm)	Lake level (m to Moturiki)	Ohau Channel flow (cumecs)
09/11/95	0900-1500	0-10	Nil	Calm	Minor	1-2	Not measured	Not measured	279.9	17.11
13/11/95	0830-1400	10-30	Nil	Calm	Minor	1-2	Not measured	Not measured	279.9	17.16
17/11/95	0800-110	50-60	SW, 1-5 knots	Slight chop	Minor	1-2	36.5	Not measured	279.88	16.58
23/11/95	1000-1200	70	N 1-2 knots	Calm	Minor	1-2	35	5-10	279.85	15.43
30/11/95	0845-1030	5-10	Nil	Calm	Yes	Yes	Not measured	Not measured	279.92	17.96
26/01/96	1000-1300	50	S-SW 10-20 knots	Rough	No	Yes	35	0	279.9	17.35
05/02/96	1000-1300	30-40	W 1-10 knots	Slight swell	Extensive on left bank	2-3	39	5	279.89	16.72
09/02/96	1000-1200	1-10%	SW, light	Slight ripple	Minor	<1	40-42	<2	279.94	18.49
20/02/96	1100-1300	90	NW, 5-10 knots	Moderate swell	Minor	No	40	2	279.92	18

Date	Smelt downstream of high crest	Smelt on high crest	Smelt samples taken	Comments
09/11/95	Yes	Yes	Yes	Smelt massing downstream of right bank but not moving over crest, movement over crest occurring on left bank, stoplogs in place
13/11/95	Yes	Yes	Yes	1 koaro juvenile caught on high crest, smelt massing at right bank but no movement over crest, more smelt were running on 9/11/95
17/11/95	Yes	Occasionally	Yes	Few smelt caught on high crests, 1 koaro juvenile caught downstream, some smelt movement over right bank
23/11/95	Yes	Yes	Yes	Frequent smelt movement over left bank, sporadic on right bank
30/11/95	Yes	Left bank only	Yes	High rainfall 3-4 days earlier, flows high
26/01/96	Yes	No	No	Water discoloured
05/02/96	Yes	Yes	Yes	Water clearer on left bank
09/02/96	Yes	Yes	Yes	Rain over the last 2 days, smelt movement over left bank high crest but few on right bank
20/02/96	Yes	Yes	Yes	Water dirty. Large numbers massing downstream, moving over crest on left bank continuously but few over right bank

file c:\pc\qpro\robert\ohaublck.wb2 (field notes)

Appendix V

Appendix 5:

Mean length, weight and sample size for smelt caught on top of the high crests and downstream of the artificial riffles.

Date	Weight (g)		Length (mm)		Sample size		Notes
	Downstream	High crest	Downstream	High crest	Downstream	High crest	
09/11/95	0.68	0.66	47.6	47.3	453	134	11 bullies
13/11/95	0.57	0.61	45.8	46.4	143	149	15 bullies
17/11/95	0.6	0.6	48.1	47.7	188	3	4 bullies, 1 koaro juvenile, 1 trout juvenile
23/11/95	0.71	0.8	47.3	48.7	238	189	1 koaro juvenile
30/11/95	0.85	0.96	48.4	50.3	266	34	
05/02/96	0.25	0.33	35.1	37.8	168	471	3 bullies
09/02/96	0.28	0.37	36.2	39	392	303	1 bully
20/02/96	0.23	0.31	33.6	36.7	200	152	

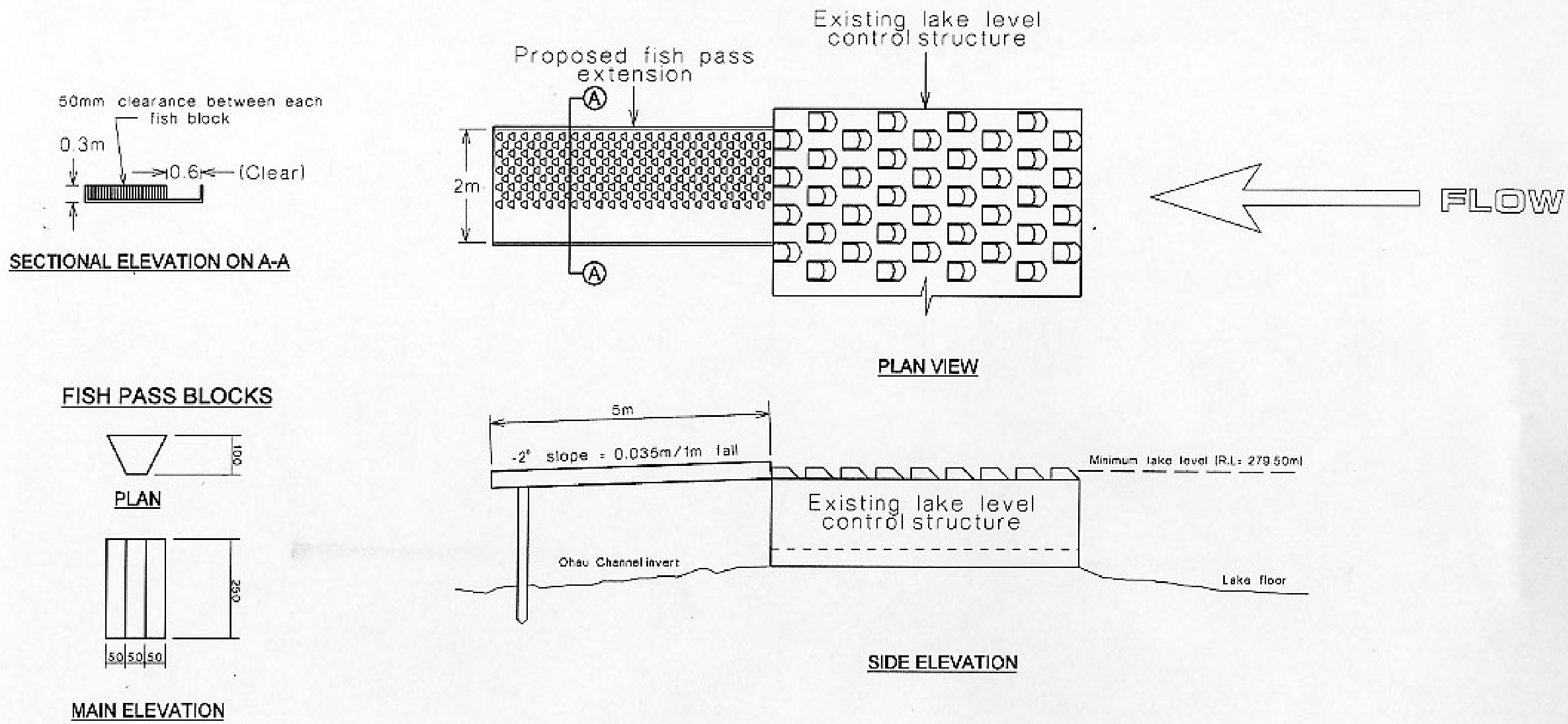
file r:\pc\qpro\robert\ohaublck.wb2 (stats)

Appendix VI

Notes on the design concept for the proposed modifications to the Ohau Channel fish pass.

The following notes relate to the concept drawing for the artificial riffle given on the opposite page.

- The recommended 2° slope is critical to the successful operation of the artificial riffle.
- A 600 mm area has been left clear of velocity blocks on the channel side of the ramp. This is intended to provide an attraction flow for migrating fish.
- The actual size, shape and arrangement of the velocity (fish pass) blocks is likely to be finalised following testing in the channel.
- The method of installing the structure to the high crest is yet to be finalised. The structure may either be fixed to the bed of the channel or hinged from the high crest.



Appendix 6: Design concept for the proposed modifications to the Ohau Channel fish pass.

Appendix VII

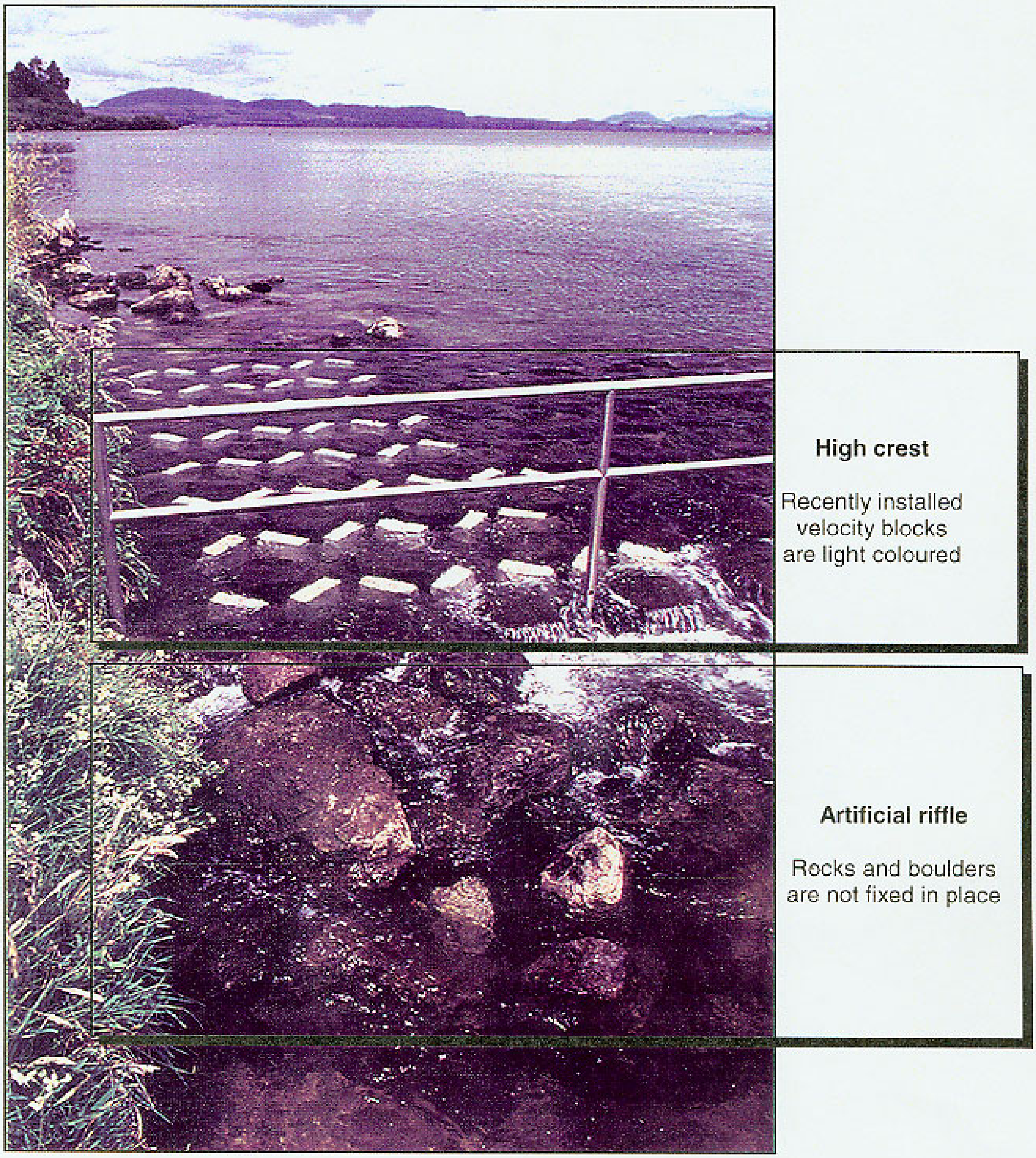


Photo 1: Right bank of the Ohau Channel illustrating the layout of the fish pass (May 1995).