NIWA
Taihoro Nukurangi

# A trial of infiltration gallery effectiveness for excluding fish at the Selwyn District Council intake, Te Pirita, Canterbury

## Prepared for Irrigation NZ

June 2013

**Authors/Contributors**:
Marty Bonnett

**For any information regarding this report please contact:**
Marty Bonnett

Scientist
Freshwater
+64-3-348 8987
3-348 8987
marty.bonnett@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
10 Kyle Street
Riccarton
Christchurch 8011
PO Box 8602, Riccarton
Christchurch 8440
New Zealand

Phone +64-3-348 8987
Fax +64-3-348 5548

| | |
|---|---|
| NIWA Client Report No: | CHC2013-048 |
| Report date: | June 2013 |
| NIWA Project: | INZ13501 |

# Contents



## Tables

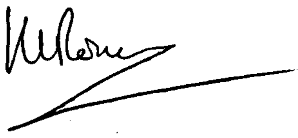
## Figures



Reviewed by

Don Jellyman

Approved for release by



Helen Rouse

# Executive summary

Fish exclusion structures ("fish screens") are present on many irrigation intakes in Canterbury, and have three core fishery functions:

1. To prevent fish from becoming entrained within the irrigation system.
2. To prevent or minimise exposure of fish to physical harm or predation near the intake.
3. To safely divert or "bypass" fish to the river downstream of the intake.

In addition, screens on intakes perform an important operational function by preventing or minimising the intrusion into the irrigation scheme of objects that may otherwise interfere with pumps and other infrastructure.

Although fish exclusion structures have been incorporated into some intakes for many years, there has been uncertainty around their effectiveness. This study was commissioned to measure the effectiveness of an infiltration gallery structure as a fish exclusion device, and was conducted at the Selwyn District Council (SDC) intake on the northern bank of the Rakaia River near Te Pirita, Canterbury. This is a large intake (maximum rate of abstraction 1.4 $m^3$ $sec^{-1}$) which utilises an infiltration gallery screen situated underneath part of the bed of a large pond.

The trial was designed to observe how juvenile fish were screened and diverted from the intake, and comprised releasing 30,000 hatchery-reared juvenile Chinook salmon upstream of the intake pond, and then monitoring the numbers of fish passing through the gallery compared with the number passing down the bypass channel.

The infiltration gallery was very good at excluding fish: only 1.3% of the trial fish passed through the infiltration gallery screen, and 98.7% were diverted into the bypass channel back to the Rakaia River. Over the two days and nights of the trial, about 6,500 of the trial fish were recovered, with the remainder (about 23,500) probably remaining in the intake pond for some days – or even weeks - before migrating downstream.

The infiltration gallery structure was effective at screening and diverting hatchery reared fish at the time of the trial, however it may be slightly less effective at screening and diverting (smaller) wild salmon, and/or less effective when operated differently (e.g. when a higher proportion of the flow into the pond is abstracted into the scheme rather than into the bypass). Observations of the bypass channel also show that it is very long (more than 5km), and at times there may be insufficient flow to transport fish safely back to a braid of the Rakaia River. The presence of native fish (including upstream-migrating adult lamprey) in the bypass channel is also of concern. Ways to lessen the risks to all fish are discussed at the conclusion of the report.

# 1 Introduction

Irrigation and stock water intakes from New Zealand rivers are required by regulatory agencies (Regional Councils, Fish and Game Councils, and the Department of Conservation) to have fish exclusion devices. These are routinely referred to as “fish screens”, and they have several core functions: to prevent fish from becoming entrained within the irrigation system; to prevent or minimise exposure of fish to increased risk of physical harm or predation near the intake; and to safely divert or “bypass” fish back into the river downstream of the intake. Although there is concern for a range of fish species, the issues in Canterbury have mainly concentrated on the risks to Chinook salmon. This species is notably susceptible, because small juvenile salmon migrate down braided rivers in the region during spring and summer, with the strong possibility of encountering screens on operating irrigation intakes.

In recent years, the requirement for fish exclusion structures at intakes has caused considerable problems for both abstracters of water and the regulatory agencies, as consents for some proposed or existing intakes have been contested on a case-by-case basis, at considerable expense and sometimes to the exasperation of all parties. The problems have mostly arisen over issues around the design and effectiveness of fish exclusion structures.  Jamieson et al (2007) developed guidelines for good practice for designing and operating fish screens at irrigation intakes, and recommended suitable screen apertures, water velocities, and fish diversion measures. However the guidelines are based on theoretical information, mostly derived for overseas situations and overseas fish species, and there has been little or no practical validation of the guidelines in New Zealand. Therefore it has yet to be clearly established if fish exclusion structures do, in fact, effectively exclude fish, irrespective of whether or not the structure has been designed and operated according to the guidelines.

The Canterbury fish exclusion working party (comprising  representatives of the Department of Conservation, Environment Canterbury, Fish and Game NZ, Irrigation NZ, and NIWA), has identified the need to properly validate the guidelines by practical testing, and this  report is the third in a series describing effectiveness trials at fish screens on irrigation intakes in the Canterbury region. Two previous trials have assessed the performance of examples of a rotary drum screening structure (Bonnett 2012a), and an “Andar” type screen structure (Bonnett 2012b).  The main objective of all the trials has been to test the effectiveness of individual screens by monitoring the fate of live fish at an operating screening facility. This gives practical insight as to how well the structures perform, and whether they fulfil their core functions.  A further objective of all the trials was to provide information that assists in the design of future structures at intakes.

In order to compare the structures performance against criteria suggested in Jamieson et al. (2007), individual elements of effectiveness are measured or assessed as follows:

- **Screen apertures**: were the apertures in the screen small enough to prevent fish from penetrating the screen and becoming entrained (trapped) in the irrigation system?

- **Approach velocity**:  was the water velocity onto and through the structure (the approach velocity) low enough so that fish could escape the structure by swimming away against the flow?
- **Sweep velocity**:  were fish diverted away from the structure by a flow moving across the structure and toward a diversion?
- **Bypass and connectivity**:  did fish locate and use a bypass, and was the bypass connected to the river for fish to return safely?
- **Operation and maintenance**: was the facility operated and/or maintained in a manner that ensured its effectiveness at excluding fish.

An additional element listed in Jamieson et al. 2007 was "site location", which refers to the selection of a suitable location when designing an intake. Because this was a performance trial conducted at an existing site, this report has not specifically included any assessment of the site's suitability. The location of the site with respect to the presence of native fish is discussed. An overall assessment of effectiveness of the fish exclusion structure is based mainly on the proportion of fish which encounter the intake and are successfully (i.e. safely) transferred back into the river of origin. The conclusion of this report includes discussion of methods to improve effectiveness where appropriate.

# 2 Methods

## 2.1 Site description

The Selwyn District Council (SDC) intake is located near the northern bank of the Rakaia River, Canterbury, at NZTM: 1439548E 5106288N (Figures 2.1 – 2.4). Water is diverted from the northern side of the Rakaia River, and flows down an inlet channel that is c.1800 m long into a headpond c. 1 ha in size. Three control structures can be used to regulate flows into and from the pool:

- A manually-operated gate between the inlet channel and the headpond, which can be used to regulate water flow into the headpond.
- A weir (adjustable using wooden “washboards”) between the headpond and the bypass channel, which can be used to maintain the water level in the headpond and regulate water flow down the bypass channel. Water flowing down the bypass channel returns to a braid of the Rakaia River more than 5 km downstream.
- A remote-controlled gate structure is used to regulate the flow of water from the headpond through the infiltration gallery into the scheme intake.

The infiltration gallery comprises a layer of gravel and small boulders (about 0.5 to 1 m deep) on top of buried galleries (“open pipes”). There are three gallery pipes, each 25 m long and made of steel mesh; the mesh has openings of 25 mm apertures. Water filters down through the gravel and boulders into the galleries, and – when the remote-controlled gate is opened – flows into the scheme intake channel.

During the irrigation season (September to April), up to 1.9 $m^3$ $sec^{-1}$ of water is diverted from the Rakaia River into the headpond. A maximum of 1.4 $m^3$ $sec^{-1}$ flows down the SDC intake, and a maximum of 0.5 $m^3$ $sec^{-1}$ is pumped from the headpond into a separate scheme (Grasslands). The amount of water taken into system varies according to demand, and to restrictions aligned with flow in the Rakaia River.

## 2.2 Operating trial

The main objective of this trial was to assess the effectiveness of the infiltration gallery as a fish exclusion structure, and assess the overall effectiveness of the intake system in diverting fish back to the Rakaia River.

Two traps were installed for this trial: The “intake” trap was installed c. 70 m downstream of the infiltration gallery, and the “bypass” trap immediately downstream of the bypass outlet control (Figures 2-5 and 2-6). These traps were installed before any trial fish were released, and monitored for 24 hours to determine the number of wild (i.e. non-hatchery) salmon and native fish species passing through the screen or bypass.

Before the release of the trial fish, electrofishing was conducted in the reaches of the intake channel and bypass channel isolated by the installed traps. The electrofishing was done while flows down the scheme intake and bypass were temporarily stopped, i.e. when these parts of the channel consisted of standing water only. All fish caught were identified, counted and removed. For the trial, 30,000 hatchery-reared juvenile Chinook salmon were released into the headpond near the intake channel control structure. A sample of wild salmon

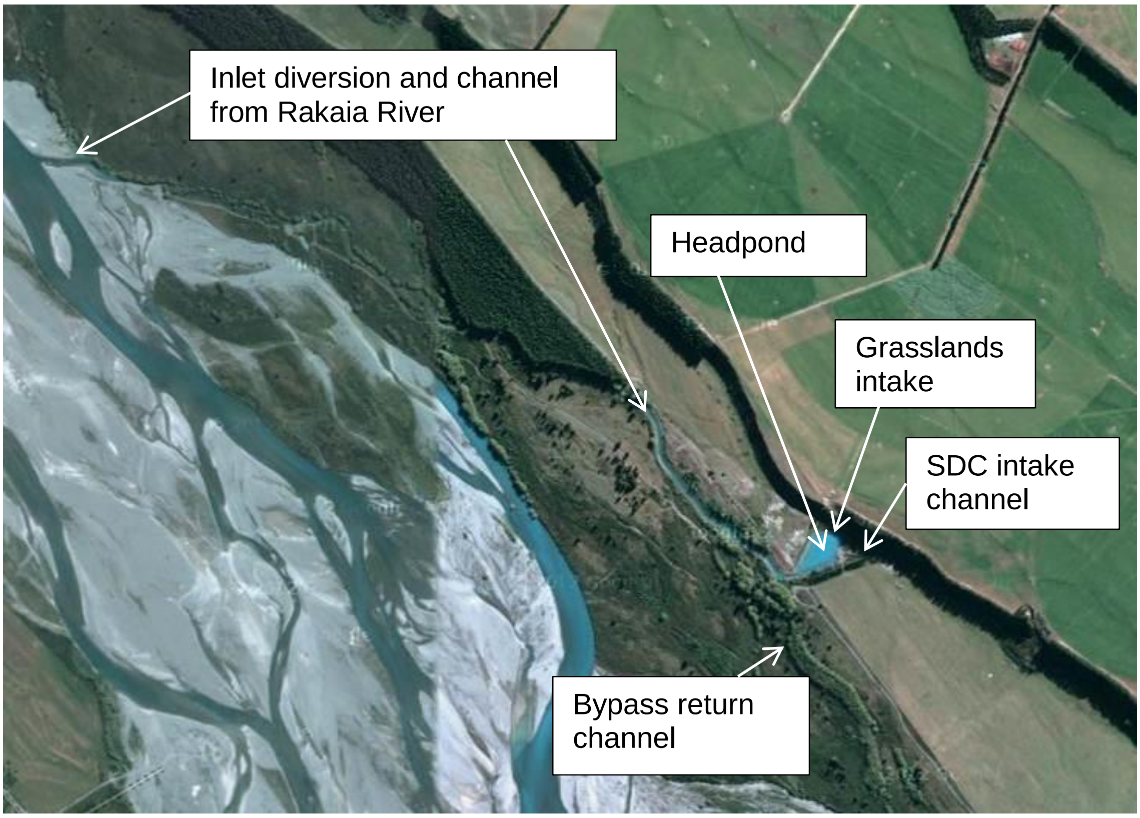



**Figure 2-1: Photograph of the SDC intake near Te Pirita (Google Earth).**


**Figure 2-2: The headpond.** The infiltration galleries (IG) and SDC intake are situated near the vehicle seen on the left, and the bypass weir (BW) is just visible on the edge of the pond to the right of the vehicle. In the foreground are the pumps for the Grasslands intake (not operating during this trial), and on the far right of the headpond is the control gate (CG) for water entering from the Rakaia River via the inlet channel.

**Figure 2-3: The infiltration gallery pipes, Winter 2012.** Screen material and silt had been removed during maintenance and new material was replaced before the headpond was refilled.

**Figure 2-4: The headpond as seen from near the bypass weir.** In the foreground the SDC intake control (brown cylinder) and headworks for the infiltration galleries (bunded structure). The galleries are underwater and under a layer of gravel and boulders in the centre foreground of the picture.

**Figure 2-5: The intake trap.** Water passing through the infiltration gallery flowed into the scheme intake channel and then through the trap.

**Figure 2-6: The bypass trap.** This trap was installed directly in the bypass channel immediately downstream of the outlet weir.

obtained from the Rakaia River, and a sample of the hatchery-reared trial fish, were measured before the release of trial fish to determine if there was a size difference which would allow differentiation between hatchery-reared fish and wild fish during the trial.

After the release of trial fish, the scheme trap and bypass trap were monitored for the succeeding two days, and the numbers of fish caught in the traps was recorded at regular intervals. The length of each fish caught in the traps was also measured and recorded, although only a subsample was measured when high numbers of fish were caught. During the trial, flows in the intake and bypass channel were gauged.

At the conclusion of the trial, water flow through the traps was again stopped and electrofishing conducted in the vicinity of the traps; i.e. between bypass outlet control and the bypass trap site, and in the channel between the infiltration gallery control structure and the scheme trap. The traps were then removed.

# 3 Results

## 3.1 Size of hatchery and wild salmon

Records of the length of juvenile salmon were collected as follows:

- A sample of 19 wild salmon was collected from the Rakaia River on 19 September 2012 and measured.
- A sample of 56 hatchery-reared trial salmon was retained and measured before the release of the 30,000 trial salmon into the headpond.
- Fish recovered from the intake and bypass traps were retained and measured; when catches were large only a subsample was measured, and the remainder counted.

Length frequency plots (Figure 3-1) clearly show that the hatchery-reared trial salmon were substantially larger (52 to 74 mm in length) than the wild salmon (which with one exception were 32 to 44 mm in length). Thus during the trial, wild salmon were distinct from hatchery salmon by their smaller size. For determining the overall effectiveness of the screen, total catch of salmon (wild and hatchery combined) in the bypass and intake traps is used. Examination of the catch of wild salmon in the traps provides some indication of the effectiveness of the screens for smaller salmon only.

## 3.2 Timeline of trap operation and catches of salmon

The timing of trap installation, electrofishing, trap operation, release and recapture of salmon (hatchery and wild combined) is summarised in Table 3.1. Overall, the trial showed that of the salmon moving downstream out of the headpond, 98.7% went via the bypass; in other words the infiltration gallery was 98.7% effective as a fish exclusion structure. Over the course of the trial more than 6,000 of the hatchery-reared salmon had moved downstream via either the infiltration gallery or the bypass, which meant that the fate of almost 24,000 hatchery salmon was unknown: some were seen in the headpond at the conclusion of the trial, and although some may have been eaten by predators (birds, trout, eels), or died in the headpond, it is assumed that most would eventually move downstream.

## 3.3 Effectiveness for wild salmon

Wild salmon caught in the scheme intake trap were counted and measured, whereas on some occasions (when the catch was large) the catch in the bypass trap was sub-sampled - thus the number of wild salmon in the bypass trap could only be estimated from proportions in the subsample. It was estimated that 451 wild salmon were caught in the bypass, compared to 34 in the scheme intake trap. This indicates that the facility was slightly less effective (93%) for (smaller) wild salmon, compared to 98.7% effective for all the trial fish (hatchery and wild salmon combined).

Figure 3-2 compares the length frequency (n= 112) of wild salmon caught and measured in the intake and bypass traps, and suggests that it is the smallest of the wild salmon (30 – 35 mm in length) which are most vulnerable to passing through the infiltration gallery screen.

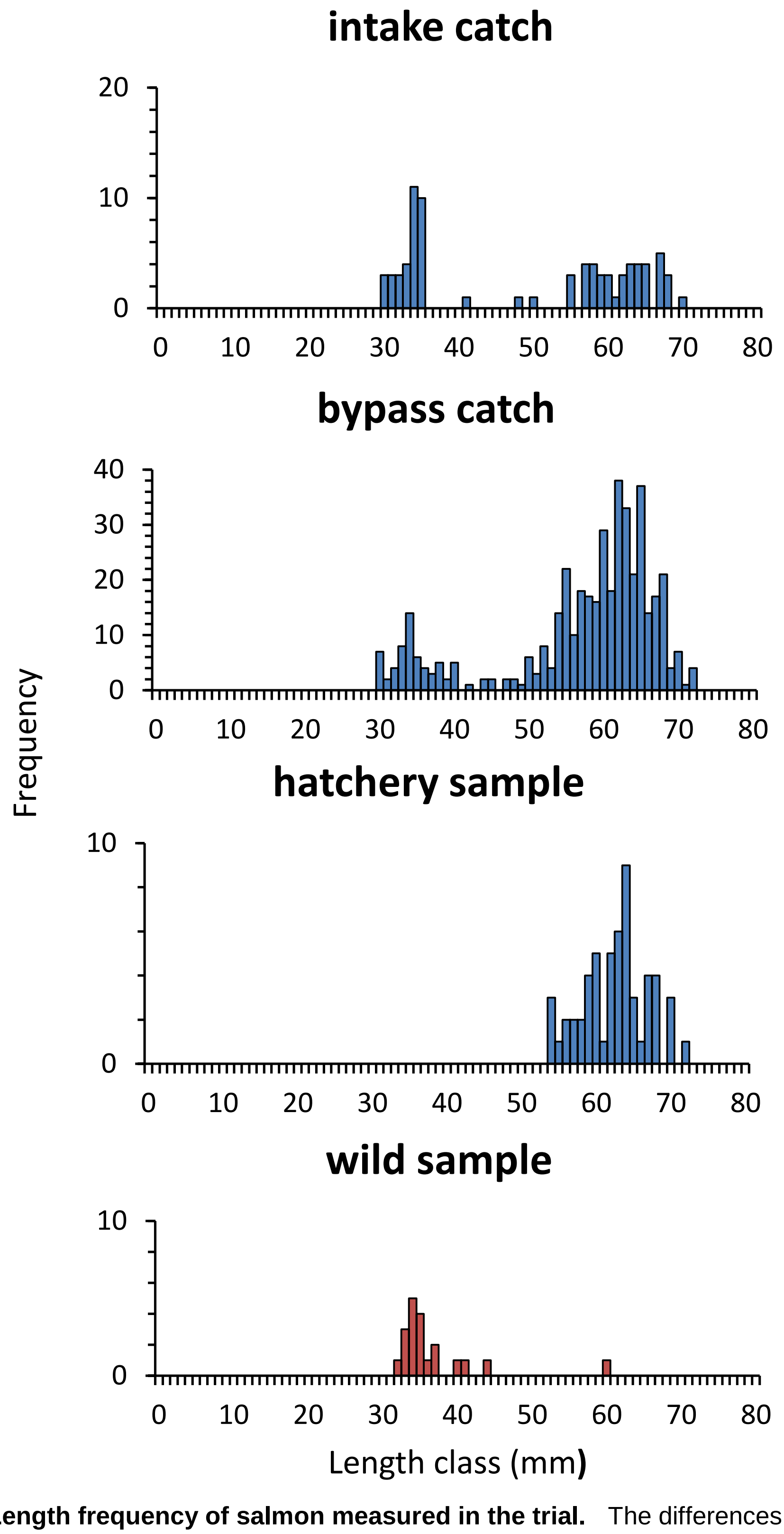



**Figure 3-1: Length frequency of salmon measured in the trial.** The differences between wild and hatchery salmon sizes (i.e. the two lower plots) allowed differentiation of the two populations in the trial, so that it could be determined that a higher proportion of smaller wild fish passed through the infiltration gallery.

**Table 3-1: Dates and times of trap operation in the intake and bypass, and numbers of salmon caught.** Grey shading represents approximate hours of darkness.

| Date and time | No. of salmon recovered: intake trap | No. of salmon recovered: bypass trap | |
|---|---|---|---|
| 17 Sep 2012 13:00 | | | Traps installed; electric fishing conducted while flow lowered; flow reinstated. |
| 15:00 | | | |
| 16:00 | 0 | | |
| 16:15 | | 0 | |
| 18:00 | 0 | | |
| 18:15 | | 0 | |
| 20:30 | 0 | | |
| 20:45 | | 1 | |
| 18 Sep 2012 2:00 | 0 | | |
| 2:20 | | 6 | |
| 7:00 | 0 | | |
| 7:15 | | 3 | |
| 13:00 | 0 | | |
| 13:15 | | 1 | |
| 14:45 | | | ~30,000 hatchery fish released in headpond |
| 16:10 | | 7 | |
| 16:15 | 2 | | |
| 18:45 | 0 | 0 | |
| 19 Sep 2012 0:30 | 10 | 746 | |
| 5:15 | 14 | | |
| 5:30 | | 668 | |
| 9:45 | 5 | 15 | |
| 15:00 | 0 | | |
| 15:10 | | 16 | |
| 18:30 | 1 | | |
| 18:35 | | 7 | |
| 21:20 | | 2972 | |
| 22:30 | 16 | | |
| 20 Sep 2012 7:00 | 30 | | |
| 7:05 | | 1753 | |
| 13:25 | 1 | | |
| 13:30 | | 18 | Flows stopped, channels re-electrofished. |
| 14:25 | | 1 | Traps removed |
| **Total recovered** | **79** | **6214** | |
| **(proportion of catch)** | **(1.3 %)** | **(98.7 %)** | |

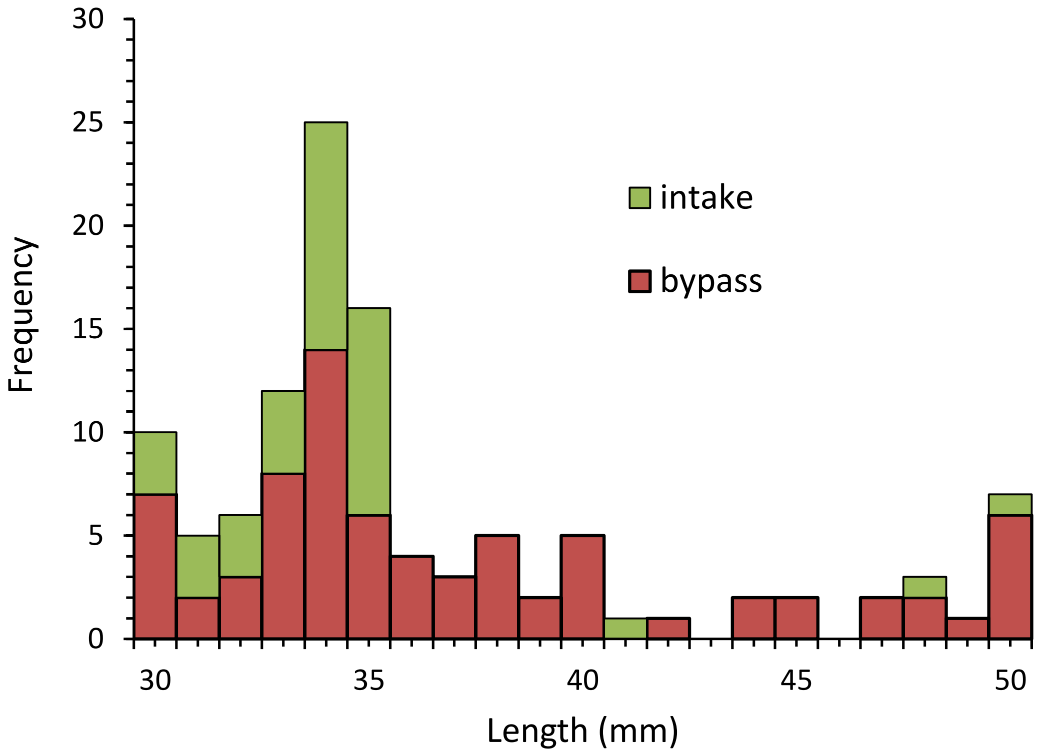



**Figure 3-2: Length frequency of wild salmon caught in the intake and bypass traps.**

## 3.4 Proportion of salmon caught at night

As expected, catches of salmon were much greater during the hours of darkness, as summarised in Table 3-2.

**Table 3-2: Numbers (and percentage) of salmon caught in the bypass and intake traps during the day and at night.** Catches are of wild and hatchery-reared salmon combined.

| | Day | Night | Total |
|---|---|---|---|
| bypass trap | 68 (1.1 %) | 6146 (98.9%) | 6214 |
| intake trap | 9 (11.4%) | 70 (88.6) | 79 |
| both traps combined | 77 (1.2%) | 6216 (98.7%) | 6293 |

## 3.5 Flow gauging during the trials

Flow was measured in the intake and bypass channels several times during the trial (Table 3-3). In the intake, flow was between 1.166 and 1.426 $m^3 sec^{-1}$, and in the bypass between 0.299 and 0.343 $m^3 sec^{-1}$. The flows experienced during the trial were within the normal operating range.

**Table 3-3: Gauged flow downstream of the intake and bypass channels during the trial.**

| Date | Time | Flow ($m^3$ $sec^{-1}$) |
|---|---|---|
| | Intake channel | |
| 17/09/12 | 1445hs | 1.166 |
| 18/09/12 | 0945hs | 1.426 |
| 19/09/12 | 1640hs | 1.168 |
| 20/09/12 | 1015hs | 1.232 |
| | Bypass channel | |
| 18/09/12 | 1020hs | 0.299 |
| 19/09/12 | 1700hs | 0.317 |
| 20/09/12 | 1035hs | 0.343 |

## 3.6 Capture and observations of other fish species

Electrofishing catches (all fish species) from the scheme intake channel and bypass channel areas before and after the trial are summarised in Table 3-4. The main purpose of electrofishing before the trial was to clear the two areas of fish, which gave confidence that fish subsequently caught in the traps had actually moved downstream from the headpond via the infiltration gallery or bypass.

**Table 3-4: Lengths (mm) of fish caught by electrofishing in the intake and bypass channels before (17/09/12) and after (20/09/12) the trial.**

| Site | Scheme intake channel | | Bypass channel | |
|---|---|---|---|---|
| Date | 17/09/12 | 20/09/12 | 17/09/12 | 20/09/12 |
| Area fished ($m^2$) | 100 | 100 | 30 | 3 |
| **Species** | | | | |
| Longfin eel | 610,670 | | | 270 |
| Brown trout | 115,107 | 132,110 | 125 | |
| Common bully | | 32,55 | | |
| Upland bully | 75,65 | | | 70,60,57,67,62,60 |
| Torrentfish | | | | 105,76,115,85 |
| Chinook salmon | | | | 46,35 |

Catches of fish other than Chinook salmon in the scheme intake trap and bypass trap are summarised in Tables 3-5 and 3-6 respectively.

**Table 3-5: Lengths (mm) of fish other than Chinook salmon caught in the scheme intake trap during the trial period.**

| Date | 17/09/12 | 17/09/12 | 18/09/12 | 18/09/12 | 19/09/12 | 19/09/12 |
|---|---|---|---|---|---|---|
| Time | 1800 | 2030 | 0200 | 0700 | 0515 | 2230 |
| Species | | | | | | |
| Longfin eel | | | 445 | | 100 | |
| Brown trout | | | | 147 | 28,29,85 | 68,49 |
| Common bully | | | | | | |
| Upland bully | | 55,75 | | | | 70 |
| Torrentfish | 105 | | | 108 | | |
| Unidentified galaxiid | | | 70 | | | |

**Table 3-6: Lengths (mm) of fish other than Chinook salmon caught in the bypass Intake trap during the trial period.**

| Date | 17/09/12 | 18/09/12 | 18/09/12 | 19/09/12 | 19/09/12 | 19/09/12 |
|---|---|---|---|---|---|---|
| Time | 2045 | 0220 | 0715 | 0030 | 0530 | 2120 |
| Species | | | | | | |
| Longfin eel | | 620 | | | | |
| Brown trout | 95,160 | 162 | 29 | 170 | 115,75,28,29 | 140 |
| Common bully | | 77,87,80,63 | 63 | | | 70 |
| Torrentfish | 110 | | | 111 | | |
| Unidentified galaxiid | | 72 | | | | |

In addition, two adult lamprey were observed near the bypass channel trap at the conclusion of the trial (when the bypass trap was being removed), and were seen to attempt to migrate upstream over the bypass weir. These fish had almost certainly arrived at the weir by moving up the bypass channel from where it joins the Rakaia River. Other species of fish observed in the traps, or by electrofishing, are just as likely to have arrived at the facility by being diverted downstream into the inlet channel.

Overall, the species composition of fish other than salmon is typical of what is found in the nearby reaches of the Rakaia River (Davis et al. 1983).

# 4 Discussion

## 4.1 Performance against guideline criteria

Below, the performance of the SDC fish exclusion structure is compared to five guideline criteria as outlined in Jamieson et al. (2007). These guidelines were developed for traditional mesh–based fish screens, and are harder to reconcile for an infiltration gallery. In this trial the measurement of aperture size, approach velocity and sweep velocity were not practical, and for this report a combination of estimates and assessments are used.

### 4.1.1 Aperture size

An inherent property of an effective fish exclusion structure is that any mesh screen is of sufficiently small aperture to prevent fish penetrating the screen. Although the “open pipes” of the gallery are constructed with mesh of c. 25 mm apertures, the operative part of the screen is not mesh; it is comprised of a layer of gravel and boulders above the pipes, and the size of the apertures between the gravel and boulders will be highly variable – conceivably anything from less than 1 mm up to more than 100 mm in diameter. However, the infiltration gallery does not comprise a single layer of gravel and boulders with apertures between – there are multiple layers of bed material and thus a succession of apertures of varying sizes.

### 4.1.2 Approach velocity

Approach velocity is the term used to describe the speed of water immediately upstream of a fish exclusion structure. It is important that the approach velocity is low enough to allow fish to swim upstream against the flow, and escape from the screen. If a fish cannot sustain a swimming speed greater than the approach velocity it will become exhausted while trying to escape, and for mesh screens the fish will then either penetrate or become (fatally) impinged on the screen. A fish’s sustained swimming speed is proportional to its length, i.e. larger fish can maintain a higher speed. The “rule of thumb” for fish screens is that water approach velocities at a screen should be no greater than four times the body length of the fish each second (Clay 1995) – so for the smallest salmon in this trial (which were about 30 mm long), the approach velocity should be no greater than 120 mm per second (or 0.12 m $sec^{-1}$).

Approach velocity in the water directly above the infiltration gallery can be estimated using the known flow of water down the intake and the area of the bed material on top of the galleries. There are three galleries, each 25 m long and 0.6 m in diameter, so that the bed material on top of the galleries occupies an area of bed that is 3 x 25 x 0.6 = 45 $m^2$. At maximum flow through the galleries (1.4 $m^3$ $sec^{-1}$) approach velocity toward the bed averages 1.4 / 45 = 0.031 m $sec^{-1}$. This is much less than the 0.12 m $sec^{-1}$ approach velocity recommended for conventional fish screens. However this is only a very rough approximation for two contrasting reasons: (1) much of the surface area of substrate directly over the gallery is comprised of gravel and boulders, so the total “open area” of apertures will be much less than the total surface area. (2) Water will be flowing down to the galleries through apertures that are not directly above the buried gallery pipes, so that effectively there is a much larger surface area being utilised.

### 4.1.3 Sweep velocity

The term “sweep velocity” refers to the velocity of water sweeping across a screen (ie at right angles to the approach velocity). Sweep velocities should be greater than approach velocities, in order to sweep fish away from the screen and into a bypass system. No perceptible sweep flow was observed in the water near the infiltration galleries during the trial, and in a body of water the size of the headpond it is unlikely that there would be a flow of water above the galleries substantial enough to sweep fish away.

### 4.1.4 Observations regarding aperture size, approach velocity and sweep velocity.

For the infiltration gallery tested in this trial, it was not practical or relevant to measure aperture size or sweep velocity, and approach velocity could only be estimated. As there is no appreciable sweep velocity to take fish away, then approach velocity through the galleries needs to be very low in order to prevent fish moving down through the galleries.

Observation of the performance of the screen for hatchery-reared salmon used in the trial (with 98.7 % effectiveness) gives some feedback on these three features. Such a high efficiency suggests that the combination of aperture size and water velocities is probably close to the recommended guidelines. However it appears that the facility is slightly less effective for smaller wild salmon; this is consistent with the expectation that smaller fish are more vulnerable to being drawn through a gallery than larger fish, as they can more easily penetrate small apertures and are less powerful swimmers.

The apparent lesser effectiveness of the screen for smaller fish is of concern, as most of the wild salmon migrating downstream in the Rakaia River during August, September, and October will be < 50mm in length (Hopkins and Unwin 1987; Unwin 1986). In other words, for the first two months of the irrigation season, the infiltration gallery may be slightly less effective at screening Rakaia River salmon than in later months. From about November onwards, the salmon moving downstream will have been hatched for some time, and will mostly have grown to 50 mm or more in length and therefore be less vulnerable to being drawn through the intake. Furthermore, although the guidelines are based on standards for Chinook salmon as the “benchmark” species, they are also intended to protect many other fish species in our rivers. Thus if the gallery is not completely effective for small salmon it may not be effective for other small fish, including some native species that are regarded as threatened.

## 4.2 Bypass provision and connection

The bypass is located adjacent to the infiltration gallery, and there was a substantial flow of water down the bypass during the trial (c. 0.3 $m^3sec^{-1}$, or about 17% to 22% of the total flow leaving the headpond). These two factors may account for much of the satisfactory effectiveness of the bypass. It is not possible to estimate how effective the bypass might be at different flows through the bypass and through the infiltration gallery screen intake, however its logical to assume that the greater the bypass flow, the greater will be its effectiveness.

A survey of the bypass channel, to its return into a side-braid of the Rakaia River, was conducted by Hamish Stevens of Central South Island Fish and Game on 3 October 2012. His survey showed the return channel was more than 5 km in length (Figure 4-1), and contained many reaches with shallow water and little cover, which would expose fish to increased risk of predation (Figures 4-2 and 4-3). There is also probably a risk of losing connection with the Rakaia River if flows in the bypass channel were lower than during the trials.

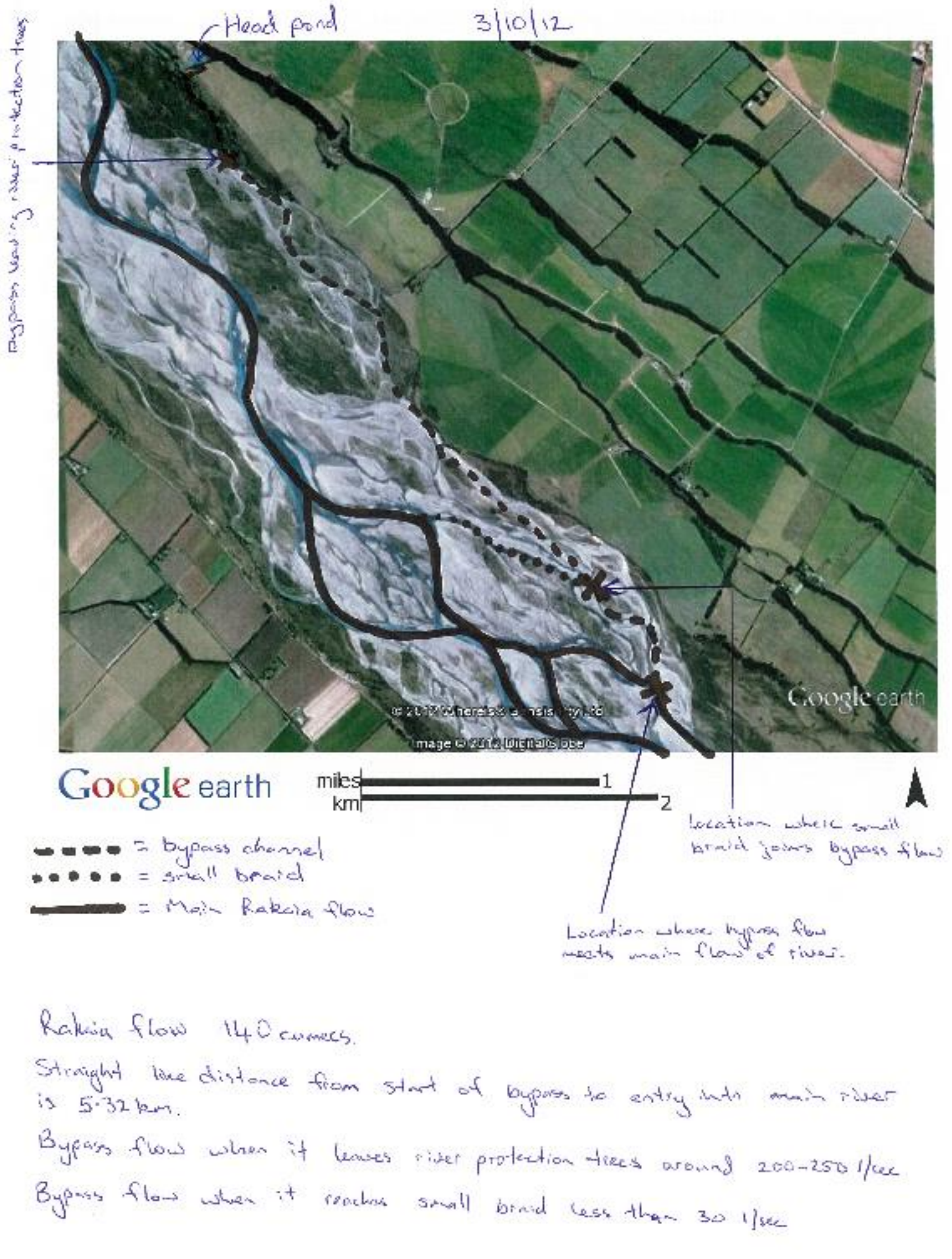



**Figure 4-1: Annotated Google Earth figure of the bypass return channel near the Rakaia River.**

**Figure 4-2: The bypass return channel about 1 km downsteam of the headpond.** Here the channel is wide, shallow and lacking cover for fish.

**Figure 4-3: The bypass return channel (on right) joins a braid of the Rakaia River.**

Improvement of the bypass return channel could be achieved relatively simply by shortening the channel as much as possible and directing it out towards the Rakaia River channels, rather than let it meander downstream for 5 km.

## 4.3 Screen operation and maintenance

The facility appeared to be generally well operated and maintained, and the substrate over the gallery pipes had been removed and replaced during the preceding winter. Replacing the substrate from time-to-time counteracts the build-up of fine silts which otherwise clog up the substrates above the gallery pipes and impede the flow of water through the structure; rather than clean the substrates *in situ*, it is more practical to simply remove all the existing substrates and silt, and replace them with new (silt-free) gravel and boulders. This maintenance not only has the benefit of allowing the full flow of water through the gallery, but may also promote a more uniform distribution of flow above the whole gallery. The potential drawback of such maintenance is that it might be poorly done; for instance, if the layer of substrate is replaced by one of lesser depth and/or larger boulders, it is likely to cause some areas of high approach velocities that fish could not resist.

## 4.4 Overall performance/effectiveness

The overall measure of fish exclusion effectiveness is simply the proportion of fish encountering the facility which are excluded and diverted to the bypass channel for return to the river of origin. This trial demonstrated that the SDC facility is highly effective for salmon of 50 mm or more in length, and only slightly less effective for smaller fish that may encounter it, such as juvenile salmon during the first two months of the irrigation season (September and October).

That so few fish passed though the SDC gallery leads to the conclusion that fish avoided being drawn through the gallery because water approach velocities through the gallery were mostly less than the recommended 0.12 m $sec^{-1}$. This is valuable feedback on the design and operation of infiltration galleries; the SDC facility gallery pipes occupied an area of 45$m^2$ of bed while supporting a flow of 1.4 $m^3$ $sec^{-1}$. This suggests a “rule of thumb”: to achieve reasonable fish exclusion a minimum of 32 $m^2$ of gallery pipe is required per 1 $m^3$ $sec^{-1}$of water being taken. It should be noted, however, that this is based on the trial of the SDC soon after the substrate over the pipes was replaced. A more conservative rule of thumb may be needed to allow for poorer performance of the gallery with the inevitable build-up of silt over the substrates.

The length of the return channel (about 5 km from the bypass back to the Rakaia River) is of concern, as it exposes any bypassed fish to risks of predation and dewatering as it meanders downstream. It is recommended that the bypass is shortened to improve the chances of survival of all bypassed fish.

The traps were operated for 2 days after the commencement of the trial, and over 6,000 salmon were recovered in the traps. There is some uncertainty regarding the fate of the remaining 24,000 trial fish; while it could be presumed that eventually the majority of these fish would find their way downstream via the bypass, it is possible that a substantial number would have been eaten by birds and/or large fish (eels, trout) in the headpond. For any future such trials, it is recommended that trapping should continue for a longer period to give some certainty regarding true effectiveness.

# 5 Acknowledgements

Thanks to Mark Webb and Hamish Stevens for putting in some long hours getting the field work done, and to Fish and Game for providing the fish for this trial. This research was funded by MAF Sustainable Farming Fund, and the trials were made possible by the efforts of the rest of the Canterbury fish exclusion working party:  Paul Reese, Nicolas Dunn, Dave West, Sjaan Bowie, Mary Beech, Patrick Lees, and Adrian Meredith. Many thanks also to the SDC for making the intake and screen facility available for this trial, and to Dave Hyman ("Bunter") for operating the system, as well as for his knowledge and assistance.

# 6 References

Bonnett, M.L. (2012a) Trial of fish screen effectiveness at Mead irrigation intake, Canterbury. *NIWA Client Report* CHC2012-041. 17.

Bonnett, M.L.(2012b) Trial of fish screen effectiveness at Totara Valley intake, Canterbury. *NIWA Client Report* CHC2012-042. 20.

Clay, C.H. (1995). *Design of fishways and other fish facilities*. 2nd Ed. Lewis, Boca Raton. 248 p.

Davis, S.F., Eldon, G.A., Glova, G.J., Sagar, P.M. 1983. Fish populations of the lower Rakaia River. *New Zealand Ministry of Agriculture and Fisheries, Fisheries Environmental Report* 61. 109p.

Hopkins, C.L,; Unwin, M.J. (1987) River residence of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in the Rakaia River, South Island, New Zealand, *New Zealand Journal of Marine and Freshwater Research*, 21: 163-174

Jamieson, D., Bonnett, M., Jellyman, D., Unwin, M. (2007) Fish screening: good practice guidelines for Canterbury. *NIWA Client Report* 2007-092. 70.

Unwin, M.J. 1986 Stream residence time, size characteristics, and migration patterns of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) from a tributary of the Rakaia River, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 20: 231-252