Trial of fish screen effectiveness at Awakino River West Branch irrigation intake, Canterbury

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“SFF Project 4405972: Adoption of Good Practice Fish Screening”

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1 Background

Irrigation New Zealand (INZ) is leading a Ministry for Primary Industries (part funded) national research project to determine good practice guidance and demonstrations of fish screens at water abstraction sites that prevent impingement and entrainment of fish and managing debris/algae while operating as an effective water intake.

The work is being undertaken by consultants and members of the Fish Screen Working Party (FSWP), a group originally set up in 2005 by Environment Canterbury, that includes several key stakeholders with functions, responsibilities or interests in native and sports fisheries.

Previous work of the Fish Screen Working Party resulted in the 2007 NIWA Fish Screen Guidelines (Jamieson et al., 2007). The Guidelines describe seven key criteria that must be met to design, install and maintain an effective fish screen. The criteria apply to all parts of the fish screening operation from the site where water is diverted from its source to where the bypass returns water and fish back to the watercourse.

To date, difficulties remain for abstractors/designers/installers/operators seeking to meet the criteria or relevant local planning legislation requirements. This project aims to fill knowledge gaps and support the adoption of good practice by (*inter alia)* developing guidance and demonstrating case study examples of screens and screen designs that meet the criteria and are thus considered effective.

2 Introduction

The Awakino Trial tests the effectiveness of a “Bossman” fish screen installed in the West Branch of the Awakino River.

Observing fish behaviour, measurement of key design parameters and monitoring fish passage through and past the fish screen will identify how well the fish screen performs. Fish screen effectiveness was assessed against the seven criteria outlined in Jamieson et al (2007):

- Location: is the site located to minimise exposure of fish to the fish screen structure and does it minimise the length of stream channel affected while providing the best possible conditions to meet other criteria?
- Screening material: were fish prevented from penetrating the screen and becoming trapped in the irrigation system, and was the surface smooth enough to prevent any damage to the fish?
- Approach velocity: was the water velocity onto and through the screen (the approach velocity) low enough that fish could escape the screen by swimming away from the screen face?
- Sweep velocity: were fish diverted away from the face of the screen by a flow moving across the screen and toward a bypass?
- Bypass design: did fish locate and use a bypass, and did the bypass return fish safely to the river?
- Bypass connectivity: was there “connectivity” between the fish bypass and somewhere safe? Usually, an actively flowing main stem of the waterway
- Operation and maintenance: was the screen operated and/or maintained in a manner that ensured its effectiveness as a fish screen?

Previous electrofishing and trapping have identified that the Awakino River is a very productive rainbow trout nursery and lesser numbers of juvenile brown trout and Chinook salmon are present. The river also sustains Canterbury galaxias, upland bully and longfin eel. All of these fish species plus a few common bully were used in the Awakino Trial.

The FSWP developed a Fish Screen Guidance Tool to assist screen owners and installers with evaluating critical site conditions and design requirements that contribute to identification of screen options for a range of river types and flow needs. The Guidance Tool was applied to two possible screen sites at the existing West Awakino location: Site 1 – the existing intake channel (Figure 1) and Site 2 – the irrigation head pond containing the existing perforated pipe screen (Figures 2 and 3).

The Guidance Tool identified the existing intake channel as the preferred site for a fish screen. Preferred features of this site were its shorter distance for fish to navigate from the diversion point back to the river; better connectivity of the bypass with the river; and there was better sweep velocity in the existing channel than in the head pond. The Guidance Tool identified the Bossman design as the preferred fish screen option with two preferred features - it does not require a power supply and it can operate in shallow water. The Guidance Tool assessment of the two West Awakino River screen site options is provided as Appendix 1.

The field assessment of effectiveness of the Bossman screen sited in the existing intake channel is based on the proportion of fish from a known number released that are returned to the river of origin, the critical flow conditions within the fish screen and the health of fish exposed to the fish screen compared to the health of fish released.

2.1. Site description

The Awakino Station irrigation intake is located near the Awakino Ski Field Road on the southern bank of the Awakino River West Branch, North Otago at NZTM: 1391255E 5040360N.

Prior to July 2021, the water take from the West Awakino River was approved as a Deemed Mining Permit. The diversion and take consisted of a short intake channel from the river discharging through a control gate and pipe to a head pond of approximately 15m x 15m, by 2m depth (Figure 1). Within the headpond, a perforated pipe on the bed of the pond delivered water to the piped irrigation supply (Figures 2 and 3). The perforated pipe consisted of mesh with approximate 5mm openings through which trout fry and small native fish could enter the irrigation supply. After diversion from the river and through the control gate to the head pond, small fish migrating downstream could not swim back upstream to the river and there was no bypass flow from the pond back to the river. The head pond provided ideal cover and a food supply for large trout preying on trapped small fish.

In July 2021, the Deemed Mining Permit for the irrigation take was replaced with a resource consent authorised under the Resource Management Act 1991. Under this consent (CRC203692), water is diverted from the true right bank at a maximum rate of 53.5l/s for irrigation and stock water. An additional flow, nominally 12l/s, is taken to provide bypass flow from the fish screen back to the Awakino River. The screen bypass is an integral part of the fish screen design and consists of a 3m piped offtake from the fish screen discharging into an open channel back to the river (Figure 4).

Figure 1 View upstream of intake channel from West Awakino River in the background and flow control gate regulating flow to irrigation head pond under Deemed Mining Permit conditions

Figure 2 View upstream from irrigation headpond with intake flow from West Awakino River in the background under Deemed mining Permit conditions

Figure 3 View downstream towards the irrigation take of drained irrigation head pond with perforated pipe fish screen on the bed under Deemed Mining Permit conditions

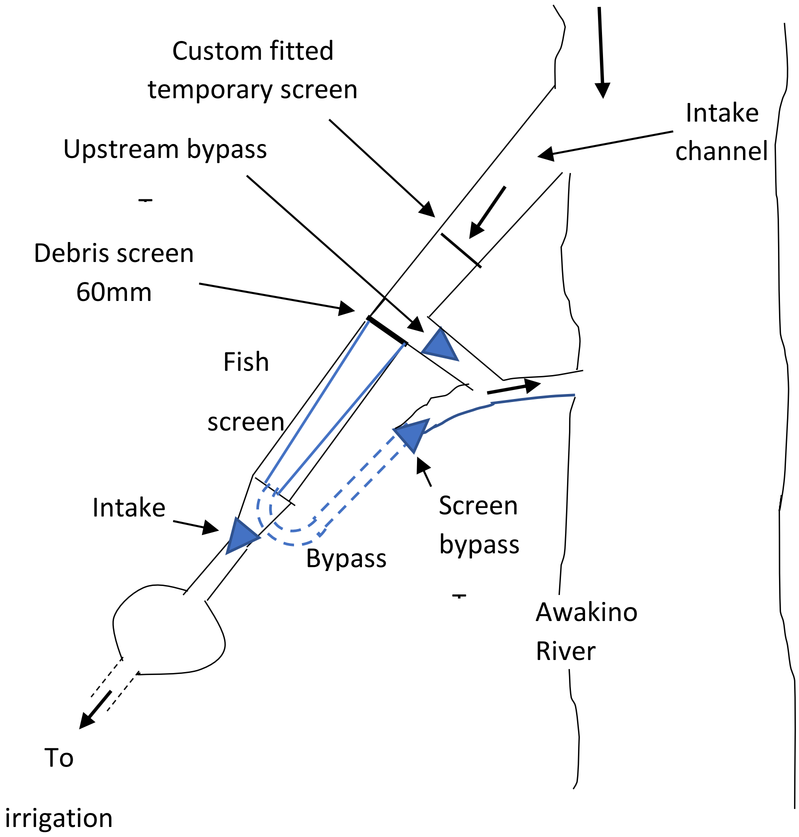

Figure 4 Sketch plan (not to scale) of the Awakino Station West Awakino River irrigation intake and fish screen in June, 2022.

The fish screen is of the "Bossman" design and consists of a 3m conical wedge wire screen with 1.5mm spaces placed lengthwise in the intake channel. The wedge wire provides 40% of screen area as open spaces (Fred Dodson, Bossman Engineering Ltd pers. comm.). Water taken for irrigation diffuses outwards through the wedge wire to a pipe entrance at the downstream end of the fish screen housing. Within the wedge wire cone of the fish screen, water with fish entrained flows to a 3m piped fish screen bypass that turns 180° and discharges into an open channel back to the river. Photographs of the site and fish screen features are provided in Appendix 2.

At the Awakino site, 20-50m downstream from the fish screen, water taken for irrigation water passes through two head ponds of approximately 25m^3 capacity before entering a piped distribution network.

3 Methods

Six field trials with different fish species/life stages were completed across December 2021 (Trials 1-4), February 2022 (Trial 5) and June 2022 (Trial 6) at the Awakino intake site, to test the effectiveness of the fish screen design to prevent impingement and entrainment of fish and assess if fish used the bypass channels. Trial ran for between 15 and 2,445 minutes each. Assessment of the intake against the 7 criteria was also undertaken.

Changes were made to the intake channel, fish screen and trapping procedures between trials to implement lessons learned from previous trials (Figures 5,6 and 7). Changes were made as follows:

- Only juvenile rainbow trout were used in Trials 1-3. Juvenile and adult rainbow trout, juvenile brown trout, upland bully and Canterbury galaxias were used in Trial 4. Up to seven species were used in Trials 5 and 6.
- Trials 1-4 were undertaken during daylight only. Released rainbow trout appeared reluctant to move during daylight after the first 10 minutes from release. Trials 5 and 6 comprised trapping of one release per period with monitoring of fish movement for up to 40 hours that included two night-time cycles.
- Flow and velocity information in and around the fish screen were collected in February 2022.

Figure 5 Intake channel upstream from fish screen and upstream "Maxi" net barrier to reduce migration of wild fish into the test area and released fish out of the test area, December 2021

Figure 6 Screen intake and control gate (foreground), prefabricated steel apron insert, fitted upstream fish proof barrier and upstream fish bypass (lower right). June 2022.

Figure 7 Screen intake on left with prefabricated steel base insert and temporary upstream screen to confine fish. upstream bypass exit at bottom right. February 22.

3.1 Operating trials

The fish screen was subject to four trials on one day in December 2021, and two trials extending over three days each in February 2022 and June 2022. Each trial required the release of a known number of test fish in front of the fish screen and monitoring of recaptures to identify where fish moved and the proportions of fish using the options available.

3.2 Site preparation

For Trials 1-4, fine mesh nets were fitted to the irrigation (Figure 8) and screen bypass outlets (Figure 9) to collect any fish that moved past the fish screen to the bypass outlet or through the screen to the irrigation outlet. The soft mesh irrigation outlet trap had mesh dimensions of 1.88mm stretched knot to knot and the rigid wire mesh screen bypass trap had internal wire to wire dimensions of 1.40mm.

Rigid framed nets used in Trials 1- 4 on the irrigation and screen bypass outlets were replaced with custom-fitted soft mesh nets with internal traps for Trials 5 and 6 (Figure 10 and 11). These soft mesh nets had mesh dimensions of 1.40mm stretched knot to knot.

There was no physical restriction on fish movement upstream away from the fish screen for Trials 1 and 2. For Trials 3 and 4, a “maxi” rigid framed net (internal wire to wire 1.40mm mesh), restricted upstream escape of fish and enabled a sample of “escaping” fish to be trapped in the intake channel about 10m upstream of the fish screen (Figure 5).

Figure 8 Rigid-framed mesh net with irrigation outlet pipe discharging into two internal non-return mesh traps, December 2021.

Figure 9 Rigid-framed wire mesh net on the screen bypass outlet, December 2021.

Figure 10 Custom-fitted soft mesh net with internal trap on the irrigation outlet, February and June 2022.

Figure 11 Custom-fitted soft mesh net with internal trap on the screen bypass outlet, February and June 2022

Prior to Trial 5, a pre-fabricated steel apron approximately 3m in length was added upstream of and joining the fish screen. The apron was an inverted trapezoid in cross-section and included an upstream bypass close to the fish screen intake (Figure 7). For Trial 5, a temporary screen (wire to wire 2.36mm mesh) was added at the upstream end of the apron in an attempt to confine fish to the apron and screen test area. The new upstream bypass had sufficient fall to allow an angled rigid framed wire mesh trap (wire to wire 1.40mm mesh) to be set at its outfall (Figure 12).

Figure 12 Rigid-framed net used on the upstream bypass outlet February and June, 2022.

The temporary screen used at the upstream end of the steel apron in Trial 5 was replaced with a custom fitted screen (wire to wire 2.36mm mesh) for Trial 6 to better contain released fish within the test area (Figure 6).

Prior to Trials 1-4, the intake race was dewatered for 48 hours while the fish screen was fitted. There were no resident “wild” fish present in the upstream intake channel or inside the fish screen before these trials. Before Trials 5 and 6, the area of the intake between the upstream end of the steel apron where the temporary or fitted screen were installed, down to the intake of the fish screen, was electrofished to remove resident “wild” fish.

3.3 Fish collection

Fish were collected from the Awakino River below the test site and from the neighbouring Hakataramea River to make up numbers. Only fish species found in the Awakino River Catchment were used. Fish were captured by electrofishing using a Smith-Root® LR-24 Electrofisher.

Fish collected were transferred to live boxes held in the Awakino River West Branch adjacent to the test site. On each occasion fish were collected in the morning and held for at least six hours prior to release for fish screen testing.

3.4 Hydrological conditions

Flow characteristics into, around and out of the fish screen were measured with a Sontek Flowtracker®2 handheld Acoustic Doppler Velocimeter during Trial 5 on 16 February 2022 over approximately one hour during which no changes were made to intake or bypass flows (Figure 13). Flows were estimated for other trials by eye or, where flows were conducive, the time taken to fill a known volume.

Figure 13 Measurement of irrigation intake flow 0.85m from the entrance to the screen at which point the fish screen diameter is 0.27m.

3.5 Timing of trials

Trials 1-4 were undertaken during daylight to facilitate observations of fish behaviour in proximity to the fish screen. Test fish were released approximately 1 hour before sunset for Trials 5 and 6 to place fish, particularly salmonids, in the test area at a time when they exhibit increased movement and are likely to show natural responses to the fish screen.

Details of the timing of trials, fish numbers, and flow conditions are provided in Table 2-1.

3.6 Fish released

Only rainbow trout fry were released in Trials 1-3. Up to 7 fish species were released in Trials 4-6 (Table 2-2).

In Trials 1 and 2, approximately 50 rainbow trout fry were randomly selected for release from a large pool of potential test fish. Prior to the trial, approximately 20 of the 50 fish to be release were removed and euthanised; these fish were measured for length as an indication of the size range of fish used in each trial and a baselines for later external examination as indicators of the physical condition of fish prior to release. Where possible all fish captured in traps or during post-trapping removal were euthanised for later examination for screen-related external injuries.

No pre-release rainbow trout were measured or kept for examination in Trial 3. All fish recovered in the upstream or screen bypasses during the trial were measured and kept for examination.

In Trials 4- 6, all fish were measured prior to release and all small fish recovered in traps or post-trapping, were euthanised and preserved for later measurement and examination for post-release external injuries. The two adult trout from Trial 4 and the sole longfin eel from Trial 6 were returned alive after brief examination for external injuries.

3.7 Release sites

In all trials, fish were released as gently as possible from a submerged bucket.

In Trials 1 and 2, fish were released approximately 1m upstream of the fish screen intake. During the first two trials, test fish were observed residing within the intake of the screen and not passing into the screen. To increase the opportunity for fish to interact with the screen, the release site for Trials 3 and 4 was moved downstream of the screen's inflow control gate and immediately upstream of the conical screen mouth (Figure 2-10).

Following installation of the temporary screen for Trial 5 and the fitted screen for Trial 6, fish were released within 1m downstream of these screens (Figures 7 and 6).

Figure 14 Location of fish released for Trials 1-4.

3.8 Fish recovery additional to trapping

On completion of Trials 1 and 2, electrofishing was undertaken in the intake channel above the fish screen and around the fish screen to catch remaining released fish and to discourage them from remaining at the site and interfering with subsequent trials. After electrofishing, the fish screen was shut down and drained to remove any remaining fish from within the screen or bypass.

During Trial 3, 15 minutes after fish release, the fish screen intake flow control gate (Figure 6) was closed for 3 minutes then reopened fully to provide a flush through the screen. This was undertaken to identify if the flow manipulation resulted in fish within the screen leaving via the screen bypass as flow receded, or if the flush on re-opening caused more fish to enter the screen and bypass.

On completion of Trials 3 and 4, the upstream “Maxi” net was checked for fish and reset before electrofishing was undertaken in the intake channel between the “Maxi” net and the fish screen and around the fish screen to catch remaining released fish or discourage them from remaining at the site and interfering with subsequent trials. After electrofishing, the fish screen was shut down and drained to remove any remaining fish from within the screen or bypass.

On completion of Trials 5 and 6, a fine mesh screen was placed over the fish screen intake. Electrofishing of the upstream apron was undertaken to catch any fish that remained on the apron between the temporary (Trial 5) or custom fitted (Trial 6) screen at the upstream end of the apron and the fine mesh screen over the fish screen intake. Electrofishing was undertaken in the intake channel upstream of the temporary or custom fitted screens to identify if any released fish avoided passage through the fish screen or upstream bypass by escaping upstream past the temporary or custom fitted screens.

3.9 Fish health

Fish were examined for scale loss as an indication of an adverse effect on fish health from passage through the upstream bypass outlet and through the fish screen to the bypass outlet or irrigation outlet. In all trials, samples of recovered fish were euthanised and kept on ice for later examination.

To provide a baseline for calibrating adverse effects, random samples of fish from each batch of fish to be released were euthanised prior to release and kept on ice for later examination. These fish did not have any contact with the screen.

An additional random sample of live fish from the total pool of fish to be released in the December, February and June trials were kept in a live box in the West Awakino River for the period of each month’s trials. All of these fish were euthanised at the end of each month’s trials and kept on ice for later examination.

All examinations of fish samples for scale loss or other external damage were completed using a 40 power magnification binocular microscope within 24 hours of the end of each trial period.

4 Results

4.1 Hydrological performance

Flow characteristics into, around and out of the fish screen were measured on 16 February 2022 during Trial 5. It was assumed all water entering the screen and bypasses was accounted for and there was no leakage into or out of the screen.

At the irrigation outlet –

Diameter of outlet = 0.3m
Flow to irrigation = 0.0332 m^3/s (33.2l/s)

At the screen bypass –

Diameter of pipe = 0.165m
Area of pipe cross section = $0.0214m^2$
Average flow velocity = 0.97m/s
Flow = $0.02076m^3/s$ (20.76l/s)

At the screen mouth –

Flow into screen mouth = flow to irrigation (0.0332m3/s) + flow to screen bypass ($0.02076m^3/s$)
Flow = $0.05396m^3/s$ (53.96l/s)
Diameter of screen mouth = 0.3m
Area of screen mouth = $0.0707m^2$
Average velocity at screen mouth = 0.763m/s

At the upstream bypass –

Velocity at 0.4 of the depth on 3 verticals across the 0.28m wide rectangular channel and averaged
Average flow velocity = 8.8m/s
Intake channel cross sectional area = $0.0226m^2$ ($226cm^2$)
Flow = $0.018m^3/s$ (18l/s)

4.1.1 Sweep velocity in the screen at point of entry

At the point of entry of flow into the fish screen, total flow was 0.05396 m^3/s being the sum of the measured irrigation take and the screen bypass flow and all of this flow was contained within the screen. At the point of entry, the screen had a circular area of $0.0707m^2$. The average velocity of water inside the screen at the point of take was 0.763m/s. This was the sweep velocity parallel to the screen at the point of entry.

4.1.2 Sweep velocity inside the screen at point of exit

Three meters downstream, at the end of the fish screen, flow to the screen bypass was $0.02076m^3/s$ as measured at the piped exit. Within the fish screen, the bypass exit had a diameter of 0.15m. At the bypass exit within the screen, the screen exit had an area of $0.01767m^2$ and to pass a flow of $0.02076m^3/s$ it was estimated that an average velocity of 1.175m/s would be required. This was the sweep velocity inside the screen and parallel to the screen at the point of exit.

4.1.3 Average sweep velocity inside the screen

If the sweep velocity in the entrance to the screen was 0.763m/s and the sweep velocity in the exit of the screen was 1.175m/s, the average sweep velocity across the screen was calculated as the average of these two flows = 0.969m/s. The screen was designed with an internal cone to maintain even water pressure along the length of the screen and it is assumed water velocity changes linearly along the screen.

4.1.4 Sweep velocity at a point within the screen

The Bossman fish screen can be described as a tube within a box. Flow is confined within the box and tube such that at any cross section the total flow through the cross section is the same as the flow that enters the screen intake. At any point down the screen's length, If either of the flow inside the screen or the flow outside the screen but still within the box is known, then the flow of the unknown component can be calculated.

On 16 February 2022, flow measurements were taken 0.85m from the front of the screen. Only the flow on the outside of the screen – the irrigation take, could be measured. Flow was measured at standard 0.2, 0.6, and 0.8 of total depth of 0.385m for estimating average velocity in a water column. The velocities at these points were measured on both sides of the screen – six points. The measured diameter of the screen at 0.85m from the front of the screen was 0.27m.

Calculation of sweep velocity inside the fish screen and parallel to the fish screen at 0.85m from the front of the screen -
Total cross section area of irrigation + screen water at 0.85m = total wetted depth x total wetted width

= 0.385m x 0.635m

=0.2444m^2

Cross sectional area of screen at 0.85m = π x (screen radius)^2

= π x (0.135m)^2

= 0.0573m^2

Cross sectional area of irrigation flow at 0.85m = total cross section area – screen cross section area

= 0.2444 – 0.0573

= 0.1872m^2

Average measured velocity of irrigation flow at 0.85m = 0.056m/s
Flow to irrigation at 0.85m = cross section area for irrigation x average velocity for irrigation

= 0.1872m^2 x 0.056m/s

= 0.01048m^3/s (10.48l/s)

It followed that if the flow to irrigation at the 0.85m cross section was 0.01048m^3/s and the total flow of irrigation plus screen flow at any cross section down the screen must equal 0.05396m^3/s, then the total flow within the screen at the 0.85m cross section is 0.05396m^3/s minus 0.01048m^3/s which equalled 0.04348m^3/s.

At the 0.85m cross section, the area of the screen is 0.0572m^2 and the flow through this area is 0.04348m^3/s. To pass this flow through this area an average velocity of 0.7601m/s is required.

0.7601m/s is the average sweep velocity parallel to the screen at the screen surface at the 0.85m cross section.

4.1.5 Average approach velocity at a point within the screen

Calculation of average approach velocity inside the fish screen between the front of the fish screen and a point 0.85m downstream –
Area of fish screen between front of screen and 0.85m cross section = average diameter of screen x length

= (circumference at 0m + circumference at 0.85m)/2 x 0.85
= ((π x 0.3m) + (π x 0.285m)/2) x 0.85
= 0.78108m^2

However, the wedge-wire screen is 40% hole and 60% frame (F Dodson pers. Comm.) so the area of screen able to pass water is 40% of the total area of screen –

= 0.4 x 0.78108m^2
= 0.3124m^2

If the flow from the inside of the screen to the outside of the screen (the irrigation component) between the screen entry to a point 0.85m downstream was 0.01048m^3 and the area of screen through which this water must pass was 0.3124m^2 then the average velocity of water through the screen between the start of the fish screen and a point 0.85m downstream –

= 0.01048m^3 / 0.3124m^2
= 0.034m/s (3.4cm/s)

4.1.6 Sweep and approach velocity summary

Sweep velocity:

At screen entrance - 0.763m/s
At bypass exit 3m downstream from screen entrance– 1.175m/s
At 0.85m from front of screen - 0.7601m/s

Approach velocity:

Average across first 0.85m of screen length from front of screen - 0.034m/s

4.2 Number of fish recovered

The number of fish that were released and subsequently recovered during and after each trial are summarised in Table 3-1.

In total 419 fish were used in the trial with 42% being upland bully, 32% rainbow trout, 10% other salmonids and 16% other native fish. Two hundred and eighty fish (66.8%) were recovered.

4.3 Location (fate) of released fish

For all trials, the number and proportion of fish recovered in the upstream bypass, screen bypass and irrigation outlet during trapping and recovered post-trapping are summarised in Table 3-2.

No fish were captured in the irrigation outfall in any of the six trials.

The screen bypass was the bypass route from the test area used by most fish with 183 of 230 (79.6%) of all fish captured being in the screen bypass. Capture of salmonids in the screen bypass at 94.1% of all salmonids using one or other of the bypasses was higher than for native fish at 73% of native fish using the screen bypass.

4.4 Timing of fish recovery

Trials 1-4 were of between 15 to 25 minutes duration with the expectation that fish would not delay in front of the screen and instead move quickly through the upstream bypass or screen. The short duration trials failed to catch more than about half of the fish released.

Trials 5 and 6 ran for up to 40 hours each with release times being close to sunset and two full nights trapped. Across both these trials, and for all species, the majority (85 to 100%) of recaptures were taken in the first 24 hours after release and only an additional 0 to 15% of recaptures were taken over the second night (Table 3-3). Between 60 and 100% of recaptures for each species were taken in the first night's trapping (0 to 12 hours)

4.5 Size of fish released and recovered

Where practical, the size of all fish to be released was measured or a random sample from the fish to be released was measured. Every attempt was made to measure all fish recovered.

In Trials 1-4, rainbow trout fry were newly hatched, and most were <30mm, Brown trout fry being approximately 2 months older were around 50mm. Upland bully and Canterbury galaxias were around 50 -60mm with some individuals up to 80 -90mm (Table 3-4).

By Trial 5, rainbow and brown trout juveniles had grown to around 60 and 100mm respectively. Upland bully and Canterbury galaxias were on average smaller than those used in Trials 1-4 while a few larger individuals remained. This indicated a new cohort from spring breeding was dominating the sampled populations (Table 3-5).

In Trial 6, rainbow and brown trout juveniles had continued to grow with most exceeding 100mm. Upland and common bully, and Canterbury galaxias averaged 55 to 75mm (Table 3-5).

For all species and sites of recovery, there were no indications that the size range of fish recovered at any site differed markedly from the size range of fish released. There was no size bias apparent that would suggest fish of a certain size used one bypass more than the other.

The three sampling periods ensured a wide range of fish sizes were assessed for their interaction with the fish screen and incidence of injury.

4.6 Condition of released and recovered fish

Negligible or no external injuries were noted on all fish and species before and after going through the bypasses or in other traps (Tables 3.6 – 3.9).

Trials 1 to 3 involved release of rainbow trout fry only. All fry recovered in these trials were examined for external damage. In Trials 1 and 2, condition of recovered fish was compared with that of control fish that were not released above the screen and were from the same batch of fish selected for release. In Trial 3 rainbow fry only exited the screen through the screen bypass and these were examined for damage. There were no control fish for Trial 3. Across Trials 1 to 3, 41 rainbow fry that were not exposed to the screen were examined and 35 fry that passed through the fish screen and were trapped in the screen bypass were examined. One rainbow fry recovered by electrofishing after completion of trapping in Trial 3 was also examined (Table 3-6). Less than 1% scale loss for salmonids was considered to be negligible.

Four fish species were used in Trial 4. One adult rainbow trout and four upland bully were caught in the screen bypass and all of the upland bully were later examined for external damage. No external damage could be found in any of the upland bully that had passed along the fish screen to the screen bypass during Trials 1-4.

The same four fish species used in Trial 4 were used in Trial 5. Rainbow and brown trout juveniles in Trial 5 replaced rainbow trout fry in Trials 1-4 and juvenile cohorts of upland bully and Canterbury galaxias were present in Trial 5. No external damage could be found in Trial 5 in any of the fish that had been diverted through the bypass upstream of the fish screen or had passed along the fish screen to the screen bypass or had been kept as control fish and not subject to release above the fish screen (Table 3-7).

Assessment of scale loss in Trials 1-5 identified that salmonids were the species most prone to scale loss and this was further quantified in Trial 6. Scales in bully spp. examined were far less visible and appeared to have a higher degree of adhesion to the body and a thicker protective mucous layer on top of the scales than salmonids. Canterbury galaxias and longfin eel do not have scales.

Trial 6 implemented an arbitrary and semi-quantitative assessment of scale loss for salmonids. This was based on focusing the binocular microscope view on the lateral line of each fish and counting lost scales within the image as the view was moved to cover a band down the lateral line from the operculum to the caudal peduncle. The standard count for a fully scaled salmonid was based on the total number of scales along the lateral line centred view on both sides of a 114mm brown trout – estimated to be 1,125 scales per side or 2,500 scales in total for both sides (Table 3-8).

Brown trout released into the screen exhibited 0 to 0.96% scale loss. No scale loss was observed in three brown trout caught in the first five minutes after their release. Two of seven brown trout captured 225 minutes after release had no scale loss and two fish captured after 585 and 945 minutes had no scale loss. The one brown trout recovered after 2,445 minutes had 0.96% scale loss and this was the highest scale loss for any brown trout in Trial 6. Two brown trout were recovered after passing through the upstream bypass and neither of these had any scale loss. Five of fourteen brown trout passing through the fish screen and being recovered in the screen bypass trap did not have any scale loss and scale loss in the remaining 9 ranged from 0.12 to 0.96% scale loss.

Rainbow trout scale loss for fish exposed to the screen ranged from 0 to 0.76%. One control fish that was not released into the screen and instead kept in a live box was examined at the end of the trial after 2,445 minutes and had no scale loss. Like brown trout, the first rainbow trout caught in the screen trap after passing along the screen, had no scale loss 5 minutes after release. Only one rainbow trout was examined after capture in the upstream bypass 225 minutes after release and had 0.04% scale loss. Four rainbow trout were examined after using the screen bypass ranging from 5 to 1,425 minutes after release, with scale loss of 0 to 0.76%.

Chinook salmon released into the screen exhibited 0 to 2.44% scale loss. Two fish caught 5 minutes after release using the screen bypass had the lowest and the highest individual salmon scale losses. Only one salmon using the upstream bypass was examined and had 0.24% scale loss. Five salmon using the screen bypass 225 to 2,445 minutes after release had scale loss ranging from 0.16 to 1.28%.

Assessment of external damage for native fish in Trial 6 was completed as for previous trials (Table 3-9).

4.7 Observations of fish behaviour

Fish were released during daylight hours in Trials 1-4 enabling observation of fish behaviour in the vicinity of the fish screen entrance. In these trials, many test fish – rainbow fry, brown trout juveniles, upland bully and Canterbury galaxias, appeared reluctant to enter the fish screen. Rainbow fry were particularly adept at finding and holding station at the screen entrance in eddies associated with the flow control gate or any square corner or other screen protrusion. Many upland bully and Canterbury galaxias held station on the flat steel bottom of the screen between the debris screen and the throat of the screen.

In Trials 3 and 4, to minimise the opportunity for release fish to take up station around and upstream from the screen flow control gate and other components at the front of the screen, fish were released downstream of the screen flow control gate and immediately in front of the throat of the screen. The recovery rate for rainbow fry was improved in Trials 3 and 4 from that of Trials 1 and 2, but none of the brown trout juveniles or Canterbury galaxias released in Trial 4 were recovered and less than half of the upland bully were recovered.

In Trial 3, rainbow trout fry released into the screen throat downstream of the screen flow control gate were able to swim upstream away from the screen and into the intake channel. More than half of the rainbow fry released in this trial were recovered at the end of the trial in an upstream net in the intake channel and only 17% were recovered having passed through the screen bypass.

Avoidance of the screen by many fish released in Trials 1-4, identified a reluctance of fish to enter the screen, at least during daylight, and their ability to hold station and/or swim upstream to find refuge.

Twilight release of fish in Trials 5 and 6 precluded observation of fish response to the fish screen immediately after release. Recovery rates were significantly better for Trials 5 and 6 then earlier trials and likely to be from a combination of time of release and extended length of trial. The timing of recoveries in Trials 5 and 6 suggests that while released fish may have initially, up to 1 hour after release, avoided passage into the fish screen, most fish used the screen bypasses 1 to 12 hours after release where this period was overnight.

Trial 5 provided clear evidence that the confined area in front of the screen into which test fish were released, was not fish-proof. Four rainbow trout were released onto the apron at the start of the test but nine were captured in fish traps during the trial and a further two were captured during electrofishing of the test area after trapping was completed. If Awakino resident rainbow trout migrated downstream past the temporary screen and into the test area it is likely other fish species released into the test area could have migrated in the opposite direction out of the test area. This may have particularly applied to Canterbury galaxias that were observed actively seeking upstream passage from the release site.

Electrofishing upstream of the temporary barrier at the conclusion of trapping for Trial 5, undertaken with the assistance of a saline infusion to improve water conductivity, identified an abundant resident juvenile trout population estimated at 3 fish per m^2 in the intake channel. The high catch confirmed that the saline improved the efficiency of electrofishing however no Canterbury galaxias or any other fish species associated with the trial were observed or captured.

5 Discussion

5.1 Overall performance/effectiveness

The overall measure of screen effectiveness is the proportion of fish encountering the screen that are returned to the river of origin unharmed. The fish screen testing programme evolved in response to issues identified in each trial and subsequent changes made to the fish screen and the testing area. In the last trial using 7 fish species, between 69% and 100% of fish released used the upstream bypass or the screen bypass that would have returned them to the Awakino River. Five of the seven species used in the trial, including all the salmonids, made 100% use of the bypasses. No fish were recovered from the irrigation scheme side of the fish screen in any trials.

Minor scale loss (<2.4%) was observed in 27 salmonids passing through the bypasses compared to scale loss of up to 0.84% in control fish not released. This level of scale loss is considered minor and not life threatening

All trials were confounded by an inability to account for the fate of all test fish released. The trapping methods employed on the irrigation outlet, upstream bypass and screen bypass would have been 100% effective at retaining fish. Fish may have been unaccounted for in Trials 1-4 when movement upstream was unrestricted.

In Trials 5 and 6, loss of fish from the test area could have resulted from imperfect sealing of the upstream apron. This may have provided subsurface escape routes accessible to the more benthic orientated fish, particularly upland bully and Canterbury galaxias.

5.2 Screen performance against guideline criteria

The Fish screening: good practice guidelines (Jamieson et.al. 2007) identify six “whole of intake design” characteristics that should be implemented to provide for efficient and effective screening of fish from intakes. Each of these characteristics is considered below in relation to the West Awakino Bossman fish screen and the results of this trial.

None of the trials were able to be undertaken when flow conditions through the screen to the screen bypass or irrigation intake, were at their consented values. During the hydrological investigation on 16 February the flow to irrigation was measured at 33l/s and was the nearest the irrigation flow came to the consented flow of 53.5 l/s for any of the trials.

5.2.1 Location

Guideline recommendation: The site is located to minimise exposure of fish to the fish screen structure and minimises the length of stream channel affected while providing the best possible conditions for factors 2-6 below.

Field test recommendation: Compliance

The length of intake channel from the Awakino River to the front of the fish screen was approximately 25m and the bypass channel back to the river was approximately 6m. The bypass channel returned to the river in a generally upstream direction as it descended the bank and effectively shortened the length of river between the intake and bypass return points. This distance was approximately 20m and is considered a minimal length of stream channel to be affected.

The fish screen could not have been placed closer to the river without increasing its exposure to any flood flows. The historical siting of the fish screen behind the bedrock peninsular was a significant feature of the longevity of the previous fish screen and intake.

The intake channel from the river to the fish screen currently contains deeper slower water that provides habitat suitable for large predatory fish. Reducing the depth of water in the intake channel and increasing the speed of flow would reduce large fish holding habitat. Natural substrate could be retained as cover for juvenile fish.

5.2.2 Screening material

Guideline recommendation: Screening material on the screen needs to have openings small enough to exclude fish and a surface smooth enough to prevent any damage to the fish.

Field test recommendation: Compliance

The “Bossman” wedge wire screen had 1.5mm spacings and the wedge wire on the inside surface faces towards the fish and runs parallel with the sweep velocity.

None of the released fish, and no other fish, were caught in the trap on the outlet to the irrigation system during the trials. There was no evidence that fish could pass through the fish screen and be lost from the river.

Assessment of scale loss in Trials 1- 5 identified that salmonids were the species most sensitive to external damage manifested as scale loss and this was further quantified in Trial 6. Scales in bully spp. examined were far less visible and appeared to have a higher degree of adhesion to the body and a thicker protective mucous layer on top of the scales than salmonids. Canterbury galaxias and longfin eel do not have scales.

Trial 6 implemented a quantitative assessment of scale loss for salmonids. Half of the salmonids that were taken from the pool of released fish and were kept separate and not exposed to the fish screen, had their full complement of scales. The other half had scale loss ranging from 0.12 to 0.84%. This confirmed that some scale loss could be expected in fish prior to exposure to the screen.

Scale loss for salmonids that passed through the upstream bypass ranged from 0 to 0.24% and for those that passed along the screen and exited through the screen bypass scale loss ranged from 0 to 2.44%. Generally, scale loss was less for brown and rainbow trout than for Chinook salmon.

Specific criteria for “excessive descaling” have evolved for more than a decade in North America. As a guide, a fish can be considered “descaled” and an “assumed mortality” if visual observations find that scale loss on each side of the body is >20% (Ryder, 2022). Maximum lateral line scale loss of 2.44% estimated for salmonids in Trial 6 of the Bossman screen is about one-tenth of the level of the North America “assumed mortality” criteria. It is acknowledged that some additional damage in the form of scale loss may be sustained by salmonids that have passed through the Bossman fish screen bypasses but the level of scale loss appears to be minor and not life threatening.

Across the 6 trials, 124 upland bully, 20 Canterbury galaxias and 6 common bully that had passed through the upstream or screen bypasses were examined for external injuries; no injuries were found.

5.2.3 Approach velocity

Guideline recommendation: Water velocity through the screen (approach velocity) is slow enough to allow fish to escape entrainment or impingement.

Field test recommendation: Theoretical compliance. Note: Consenting authority must approve methodology for assessing field compliance.

Approach velocity is the speed of water immediately upstream of the screen face and perpendicular towards the screen face. If a fish cannot maintain a swimming speed greater than the approach velocity it may become impinged on the screen. In the absence of information on swimming capabilities for small native fish, the Fish Screening: good practice guidelines identify an approach velocity of 0.12m/s based on the sustained swimming speed for a 30mm salmon fry.

Many rainbow trout fry used in Trials 1-4 were smaller than 30mm and indicative of the size of wild rainbow trout fry that are abundant in the Awakino River catchment. Rainbow trout fry down to 23mm will be common and accordingly an approach velocity of no more than 0.092m/s should safeguard these fish.

The approach velocity at one cross section inside the fish screen 0.85m from the front of the screen was estimated to be 0.034m/s., This was well below the Guidelines recommended 0.12m/s, and about one-third of the sustained swimming speed for the smallest rainbow trout fry.

5.2.4 Sweep velocity

Guideline recommendation: Water velocity across the screen (sweep velocity) is sufficient to sweep fish past the intake promptly.

Field test recommendation: Theoretical compliance. Note: Consenting authority must approve methodology for assessing field compliance.

Sweep velocity is the speed of water across the face of the screen and acts at right angles to the approach velocity. The sweep flow directs fish from the fish screen intake to a bypass that returns them to the river. Sweep velocity should be greater than the approach velocity.

The West Awakino screen had calculated sweep velocities of between 0.76m/s and 1.175m/s at sites at the screen intake, inside the screen 0.85m from the intake, and at the screen bypass intake 3m from the screen intake. The sweep velocity inside the screen at a cross section 0.85m from the screen intake was estimated to be 0.7601m/s and the approach velocity on the same cross section was estimated to be 0.034m/s. At the 0.85m cross section the sweep velocity was approximately 26 times greater than the approach velocity.

5.2.5 Bypass design

Guideline recommendation: A suitable fish bypass is provided so that fish are taken away from the intake and back to the source channel.

Field test recommendation: Compliance

For Trials 1-4, the Bossman screen provided a single screen bypass returning fish to the river. For Trials 5 and 6 an upstream bypass was added. The upstream bypass was above the screen and provided a path for fish to return to the river without passing through the fish screen. Both bypass channels joined and returned fish to the river in a single channel.

Approximately three-quarters of fish using a bypass in Trials 5 and 6 used the screen bypass with the remainder using the upstream bypass. Entry to the upstream bypass was raised from the floor of the screen apron and was 90° to the direction of flow in the intake channel.

The upstream bypass design would be improved by extending the intake to the base of the fish screen to enhance its use by benthic fishes e.g., common and upland bully and Canterbury galaxias and aligning the entry to the intake bypass with the direction of flow in the intake channel i.e., the direction of flow into the bypass is the same as the direction of flow in the intake channel.

5.2.6 Bypass connectivity

Guideline recommendation: There is connectivity between the fish bypass and somewhere safe, usually an actively flowing main stem of the waterway.

Field test recommendation: Compliance

The upstream and screen bypass flows merged in an open channel that discharged directly to the mainstem of the West Awakino River approximately 6m from the fish screen. At the point of bypass discharge, the river was in a confined single channel gorge and would always maintain connectivity with the bypass channel.

5.2.7 Screen operation and maintenance

Guideline recommendation: The intake needs to be kept operating to a consistent standard with appropriate operation and maintenance.

Field test recommendation: Unable to be assessed.

This is a requirement on the operator of the screen and was not part of the fish screen trial. During the trials it was observed that the control valve for the irrigation scheme was less than 200m from the fish screen. Regular monitoring of fish screen condition and performance could be an easily achieved function of scheme operation. It was also noted that the fish screen was sited behind a natural rock promontory where it was protected from floods but the intake channel would be exposed and would require reinstatement. The operation and maintenance of the screen is defined in a Operations and Maintenance Plan associated with the screen.

5.3. How might effectiveness be improved?

There are four ways that the performance of the West Awakino Bossman screen might be improved:

1. The intake channel from the river to the fish screen currently contains deeper slower water that is attractive to larger predatory fish. Reducing the depth of water in the intake channel and increasing the speed of flow would reduce large fish holding habitat. Natural substrate habitat could be retained as cover for juvenile fish.
2. A permanent custom fitted concrete forebay with upstream bypass included to replace the steel apron. This would ensure all flow in the intake channel passes through the upstream bypass or screen bypass and there are no subsurface flows that could trap fish under the fish screen.

3. The upstream bypass should extend from bed level to the water surface and flow into the bypass should be a continuation of the intake channel flow i.e. there should be no change of angle of the intake channel flow to the bypass channel. This would facilitate fish entering the bypass without being required to turn from their original direction of travel.
4. Minimise internal obstructions and square corners in the fish screen intake to promote laminar flow and smooth fish passage.

6 Acknowledgements

We wish to thank landowners Dan and Jaz Devine for unfettered access and willingness to run their irrigation scheme at odd and extended hours. Thanks also to the Manager and staff of Bossman Engineering for listening to our suggestions and applying these to the screen design.

7 Literature cited

Jamieson D., Bonnett M., Jellyman D., and Unwin M. 2007. Fish screening: good practice guidelines. NIWA Client report: CHC2007-092. 75p.

Ryder, G., 2022. Rangitata Diversion Race Fish Screen Facility: Fish screen verification management plan. Prepared on behalf of Rangitata Diversion Race Management Limited. Ryder Environmental Limited.

8 Tables

Table 2-1. Date and time of trials, fish numbers released to the fish screen or retained alive as controls, and flow distribution at the time and comparison to consented flow.

Trial #	Date	Time of release	Fish numbers		Flow conditions (l/s)		
			Released	Retained	Upstream bypass	Screen bypass	Irrigation intake
Consented flow							53.5
1	03/12/21	1240 h	33	21	0	10	20
2	03/12/21	1400 h	30	20	0	10	20
3	03/12/21	1530 h	59	0	0	10	20
4	03/12/21	1630 h	47	0	0	10	20
5	15/02/22	1835 h	70	5	18	20.76	33.2
6	08/06/22	1645 h	180	22	20	10	20

Table 2- 1

Table 2-2. Fish species released for each trial.

Trial#	Rainbow trout	Brown trout	Chinook salmon	Common bully	Upland bully	Canterbury galaxias	Longfin eel
1	Y						
2	Y						
3	Y						
4	Y	Y			Y	Y	
5	Y	Y			Y	Y	
6	Y	Y	Y	Y	Y	Y	Y

Table 2- 2

Table 3-1. Numbers of fish (by species) released in each trial and numbers and percentage recovered in fish traps on screen outlets during each trial and recovered elsewhere post-trapping.

Trial	Species	No. released	Trial duration (minutes)	Fish recovered		
				Trap No. (and %)	Post-trapping recovery no.	Total No. and (%)
1	Rainbow fry	33	20	17 (52)	1	18 (55)
2	Rainbow fry	30	25	8 (27)	1	9 (30)
3	Rainbow fry	59	25	10 (17)	33	43 (73)
4	Rainbow juvenile	4	15	0	3	3 (75)
4	Rainbow adult	2	15	1 (50)	1	2 (100)
4	Brown trout juvenile	3	15	0	0	0
4	Canterbury galaxias	11	15	0	0	0
4	Upland bully	27	15	4 (15)	7	11 (41)
5	Rainbow juvenile	4	2,350	9 (225)*	2	11 (275)*
5	Brown trout juvenile	15	2,350	13 (87)	0	13 (87)
5	Canterbury galaxias	22	2,350	7 (32)	1	8 (36)
5	Upland bully	29	2,350	17 ((59)	1	18 (62)
6	Rainbow juvenile	5	2,445	5 (100)	0	5 (100)
6	Brown trout juvenile	14	2,445	14 (100)	0	14 (100)
6	Chinook salmon juv.	8	2,445	8 (100)	0	8 (100)
6	Canterbury galaxias	29	2,445	20 (69)	0	20 (69)
6	Upland bully	120	2,445	93 (78)	0	93 (78)
6	Common bully	3	2,445	3 (100)	0	3 (100)
6	Longfin eel	1	2,445	1 (100)	0	1 (100)

Table 3 - 1

* More fish were caught than were released indicating that rainbow trout of 33 to 67mm were able to move into and probably out of the test area.

Table 3-2. Number of fish (by species) recovered in each trial, and recovery by location, number and proportion (%) recovered.

Trial	Location recovered	Number (and %) of fish recovered						
		Rainbow trout	Brown trout	Chinook salmon	Canterbury galaxias	Upland bully	Common bully	Longfin eel
1	Upstream bypass	0						
	Screen bypass	17 (52)						
	Irrigation outlet	0						
	Post-trapping	1 (3)						
2	Upstream bypass	0						
	Screen bypass	8 (27)						
	Irrigation outlet	0						
	Post-trapping	1 (3)						
3	Upstream bypass	0						
	Screen bypass	10 (17)						
	Irrigation outlet	0						
	Post-trapping	33 (56)						
4	Upstream bypass	0	0		0	0		
	Screen bypass	1 (17)	0		0	4 (15)		
	Irrigation outlet	0	0		0	0		
	Post-trapping	4(67)	0		0	7 (26)		
5	Upstream bypass	3 (75)*	1 (7)		3 (14)	6 (21)		
	Screen bypass	6 (150)*	12 (80)		4 (18)	11 (38)		
	Irrigation outlet	0	0		0	0		
	Post-trapping	2 (50)*	0		1 (5)	1 (3)		
6	Upstream bypass	1 (20)	2 (14)	1 (13)	5 (17)	25 (21)	0	0
	Screen bypass	4 (80)	12 (86)	7 (87)	15 (52)	68 (57)	3 (100)	1 (100)
	Irrigation outlet	0	0	0	0	0	0	0
	Post-trapping	0	0	0	0	0	0	0

Table 3 - 2

* More rainbow trout were captured in Trial 5 than were released indicating that rainbow trout of 33 to 67mm were able to move into and probably out of the test area.

Table 3-3. Time after release for recovery (catch) of fish from traps for Trials 5 and 6.

Species	Trial#	Number of fish recovered					
		0-1 hr	1-6 hrs	6-12 hrs	12-24 hrs	24-40 hrs	Total
Brown trout	5	5	5	1	0	2	13
	6	4	7	2	0	1	14
Rainbow trout	6	1	1	1	2	0	5
Chinook salmon	6	2	3	0	2	1	8
Canterbury galaxias	5	4	1	2	0	0	7
	6	14	3	3	0	0	20
Upland bully	5	7	8	1	1	0	17
	6	6	47	28	8	4	93
Common bully	6	1	1	0	1	0	3
Longfin eel	6	1					1

Table 3 - 3

Table 3-4 Size of fish released (by species) in each trial and size and source of recaptures. “Pre-release” fish were a random sample taken from the sample to be released and were measured prior to release.

Trial	Species	Origin	No. measured	Mean length (mm)	Std. dev.	Minimum	Maximum
1	Rainbow fry	Pre-release	21	28.4	3.77	23	38
		Screen bypass	17	26.3	2.14	23	30
2	Rainbow fry	Pre-release	20	28.9	3.48	25	34
		Screen bypass	8	25.0	1.77	23	27
		Post-trapping	1	26.0			
3	Rainbow fry	Screen bypass	10	28.5	3.57	24	36
4	Rainbow juvenile	Pre-release	4	66.8	12.42	49	78
	Rainbow adult	Pre-release	2	467	51.6	430	503
	Brown trout juvenile	Pre-release	3	49.7	4.50	45	54
	Upland bully	Pre-release	27	64.4	9.5	52	82
		Screen bypass	4	67.0	6.97	58	73
	Canterbury galaxias	Pre-release	11	75.7	11.41	52	90

Table 3 - 4

Table 3-5 Size of fish released (by species) in each trial and size and source of recaptures. “All release” fish were measured prior to release, “pre-release” fish were euthanised from the sample prior to release and “Live controls” were kept alive for the duration of the trial and not subject to release.

Trial	Species	Origin	No. measured	Mean length (mm)	Std. dev.	Minimum	Maximum
5	Rainbow juvenile	All release	4	61.5	2.65	59	65
		Upstm bypass	3	38.3	1.53	37	40
		Screen bypass	6	54.0	12.1	33	67
		Post-trapping	1	40.0			
	Brown trout juvenile	All release	15	100.5	12.74	74	121
		Upstm bypass	1	89			
		Screen bypass	12	96.1	11.17	78	120
	Upland bully	All release	29	41.4	13.38	22	72
		Upstm bypass	6	42.2	12.35	29	58
		Screen bypass	11	48.6	15.46	22	76
		Post trapping	1	33			
	Canterbury galaxias	All release	22	46.4	11.64	36	90
		Upstm bypass	3	42.0	7.0	37	50
		Screen bypass	4	52.5	23.73	39	88
		Post-trapping	1	38			
		Live controls	5	55.4	21.19	41	89
6	Rainbow juvenile	All release	5	112.8	14.55	102	132
		Upstm bypass	1	97.0			
		Screen bypass	4	106.0	13.0	96	124
		Live controls	1	85.0			
	Brown trout juvenile	Pre-release	2	140	16.97	128	152
		All release	14	148.0	18.88	113	180
		Upstm bypass	2	143.0	41.01	114	172
		Screen bypass	12	142.4	15.35	107	159
	Chinook salmon	Pre-release	1	105			

		All release	8	111.6	4.96	103	120
		Upstm bypass	1	109.0			
		Screen bypass	7	109.1	8.25	100	126
		Live controls	1	100.0			
	Canterbury galaxias	Pre-release	1	62.0			
		All release	29	58.5	6.29	42	80
		Upstm bypass	5	58.6	4.51	54	65
		Screen bypass	15	60.1	7.57	50	80
		Live controls	3	57.7	6.03	52	64
	Upland bully	Pre-release	12	54.7	12.56	31	70
		All release	120	52.6	13.53	25	90
		Upstm bypass	25	52.2	12.97	36	80
		Screen bypass	68	50.8	12.12	34	87
		Live controls	14	60.2	12.38	47	65
	Common bully	Pre-release	1	42.0			
		All release	3	72.3	28.04	40	90
		Screen bypass	3	70.7	26.58	40	87
		Live controls	3	76.3	31.2	42	103
	Longfin eel	All release	1	400			
		Screen bypass	1	400			

Table 3 - 5

Table 3-6. External examination of fish under binocular microscope for injuries associated with diversion upstream or along the fish screen and "Pre-release" fish removed from the release batch prior to release for Trials 1-4, December 2021.

			External examination	
Trial	Species	Fish source	No. of fish	Injury
1	Rainbow fry	Pre-release	21	Negligible scale loss, no fin damage
		Screen bypass	17	Negligible scale loss, no fin damage
2	Rainbow fry	Pre-release	20	Negligible scale loss, no fin damage
		Screen bypass	8	Negligible scale loss, no fin damage
		Post-trapping	1	Negligible scale loss, no fin damage
3	Rainbow fry	Screen bypass	10	Negligible scale loss, no fin damage
4	Upland bully	Screen bypass	4	No external injuries

Table 3 - 6

Table 3-7 External examination of fish under binocular microscope for injuries associated with diversion upstream or along the fish screen and "live control" fish removed from the release batch prior to release and kept alive for the duration of the Trial 5, February 2022.

Trial	Species	Fish source	External examination	
			No. of fish	Injury
5	Rainbow juvenile	Upstm bypass	3	Negligible scale loss, no fin damage
		Screen bypass	6	Negligible scale loss, no fin damage
		Post-trapping	1	Negligible scale loss, no fin damage
	Brown trout juvenile	Upstm bypass	1	Negligible scale loss, no fin damage
		Screen bypass	12	Negligible scale loss, no fin damage
	Upland bully	Upstm bypass	6	No scale loss or fin damage
		Screen bypass	11	No scale loss or fin damage
		Post-trapping	1	No scale loss or fin damage
	Canterbury galaxias	Live controls	5	No scale loss or fin damage
		Upstm bypass	3	No external injury
		Screen bypass	4	No external injury
		Post-trapping	1	No external injury

Table 3 - 7

Table 3-8. Trial 6 binocular microscope assessment of lateral line centred scale loss in salmonids as an indication of injury associated with diversion through the upstream bypass or the screen bypass and comparison with samples of fish removed from the release batch prior to release, one sample of which (pre-release) was euthanised immediately and the second sample (control fish) kept alive until the end of the trial, June 2022.

Species	Time from release (min)	Capture Site	Fish size (mm)	Lateral line scale loss		
				Left side	Right side	Proportion (%)
Brown trout	0	Pre release	128	18	3	0.84
	0	Pre release	152	3	0	0.12
	5	Screen bypass	107	0	0	0
	5	Screen bypass	155	0	0	0
	5	Screen bypass	121	0	0	0
	15	Screen bypass	152	1	3	0.16
	225	Screen bypass	135	0	0	0
	225	Screen bypass	159	6	0	0.24
	225	Screen bypass	150	6	4	0.4
	225	Screen bypass	136	0	7	0.28
	225	Screen bypass	148	3	0	0.12
	225	Screen bypass	150	5	0	0.2
	225	Upstm bypass	114	0	0	0
	585	Upstm bypass	172	0	0	0
	945	Screen bypass	143	0	0	0
	2,445	Screen bypass	153	11	13	0.96

Rainbow trout	5	Screen bypass	107	0	0	0
	225	Upstm bypass	97	1	0	0.04
	945	Screen bypass	124	16	3	0.76
	1,425	Screen bypass	97	4	0	0.16
	1,425	Screen bypass	96	11	0	0.44
	2,445	Live control	85	0	0	0
Chinook salmon	0	Pre release	105	8	0	0.32
	5	Screen bypass	105	0	0	0
	5	Screen bypass	107	53	8	2.44
	225	Upstm bypass	109	0	6	0.24
	225	Screen bypass	112	5	0	0.2
	225	Screen bypass	108	3	29	1.28
	1,425	Screen bypass	126	2	2	0.16
	1,425	Screen bypass	100	4	13	0.68
	2,445	Screen bypass	106	10	16	1.04
	2,445	Live control	100	0	0	0

Table 3 - 8

Table 3-9. External examination of native fish under binocular microscope for injuries associated with diversion upstream from or along the fish screen and for comparison with samples of fish removed from the release batch prior to release one sample of which was euthanised immediately and the second sample kept alive until the end of Trial 6, June 2022.

Trial	Species	Fish source	External examination	
			No. of fish	Injury
6	Canterbury galaxias	Pre release	1	No external injury
		Upstm bypass	5	No external injury
		Screen bypass	15	No external injury
		Control fish	3	No external injury
	Upland bully	Pre release	12	No scale loss or fin damage
		Upstm bypass	25	No scale loss or fin damage
		Screen bypass	78	No scale loss or fin damage
		Control fish	14	No scale loss or fin damage
	Common bully	Pre release	1	No scale loss or fin damage
		Screen bypass	3	No scale loss or fin damage
		Control fish	3	No scale loss or fin damage
	Longfin eel	Screen bypass	1	No body or fin damage

Table 3 - 9

9 Appendix 1

Fish Screen Working Party Guidance Tool assessment of two screen sites on the Awakino Station irrigation intake on the West Awakino River

Fish Screen Guidance Tool

IRRIGATION NEW ZEALAND
WATER | FOOD | FIBRE | LIFE

Ministry for Primary Industries
Manatū Ahu Matua

PURPOSE

The purpose of the Guidance Tool is to provide a process to assist landowners in the identification and selection of a preferred site and fish screen type when looking to install, replace or upgrade a fish screen.

Note, it is important to have conducted a site visit to be able to adequately use the Guidance Tool.

HOW TO USE THE GUIDANCE TOOL

1 There are four spreadsheets. You need to make selections on the first three spreadsheets (Step 1, Step 2, Step 3) and this will enable you to populate Step 4 – the outcome spreadsheet. Answers to these seven design criteria may be required in consent applications.

2 In the Step 1 spreadsheet, work your way through the questions and make your selection by clicking on the box where a dropdown list will appear in the top right-hand corner of the cell. Make your selection from the options available and refer to the 'Notes' column to understand the subjective categories that the numbers relate to. NB The user can examine as many or as few locations as they choose by deleting/adding columns. It is recommended that at least two sites are assessed.

3 In the Step 2 spreadsheet, click on the dropdown list and then untick any boxes that do not apply. Note there are scenarios where ticked boxes 'double up' on the information, but this is the way the sorting process works within the tables and is intentional.

4 When comparing sites, the lowest score is the preferred option. The Guidance Tool enables applicants to consider changing the factors that contribute to high scores (less preferred) to deliver a preferred option. For example, providing power to a preferred site or altering conditions at a particular site to make it more suitable for a particular screen type.

5 In the Step 3 spreadsheet, the recommended location and type of fish screen will pull through from the previous steps and appear in the associated boxes at the top of the sheet.

6 The Step 4 Outcomes address the seven key criteria of fish screen design. You may then attach this assessment to your consent application or use in further discussions when making decisions around your fish screen.

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Ciaran Campbell – Otago Regional Council

HELPFUL RESOURCES

1 To determine what fish species are present at your particular location you can:
-a Refer to the NZ Freshwater Fish Database https://niwa.co.nz/information-services/nz-freshwater-fish-database
-b Contact your nearest Fish and Game or Department of Conservation Office
-c Refer to R M McDowall "The Reed Field Guide to New Zealand Freshwater Fishes"
-d Refer to the Fish Spawning Indicator tool and other useful spawning information https://www.mpi.govt.nz/forestry/national-environmental-standards-plantation-forestry/fish-spawning

- NIWA also has a tool that predicts fish distributions at https://shiny.niwa.co.nz/nzrivermaps/. This is a model and can be used
e in the absence of any other data.

2 Regional Councils can have information in their Regional Plans, including schedules of important locations for fish species, for example, you can add ‘layers’ relating to fish on Environment Canterbury’s GIS “Canterbury Maps” at https://mapviewer.canterburymaps.govt.nz/

LIMITATIONS

Please note that any fish screen or fish screen location derived from the Guidance Tool is to be used as a guide only and is not automatically deemed to comply with any relevant national or regional regulations. It is strongly recommended that landowners seek expert advice to ensure they select and install a fish screen that is fully compliant with the regulations and their resource consent conditions.

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V6 Aug 2022

Fish Screen Guidance Tool – Step 1

Step 1 - Assessment to determine best location of fish screen				
Design Element	**Questions to consider and statements of what assessment is required**	**For each possible location consider these questions** *Note: Columns can compare different locations for one intake*		**Selection critera**
		Location 1 in existing intake	Location 2 in existing pond	
Location	River type	alpine stream	alpine stream	Braided, Single braid, Spring fed, Alpine stream, Pond, Gorge, River mouth/tidal reach, Lake, Drain
Site	Stability of diversion area at waterway	3	3	**1**-Stable **2**-Medium **3**-Unstable
	Stability of fish screen location (level of risk relative to other locations)	1	1	**1**-Stable **2**-Medium **3**-Unstable **10**-Unviable
	Flow variability – ability of site and conditions to take flow range (min (low flow) to max) and management of flood, proportion of flow being taken, and ability to create an effective bypass under different take rates	3	3	**1**-Low **2**-Medium **3**-High
	Gradient of river (this will influence the hydraulic head available to use)	1	1	**1**-Steep **2**-Moderate **3**-Flat
	Comparison of length of intake required across sites. (consider braiding pattern and distance through berm)	1	2	**1**-Least **2**-Moderate **3**-Greatest
	Are priority fish species present? (see Appendix 1)	2	2	**1**-No **2**-Yes
	Is power close by - available?	2	2	**1**-Yes **2**-No
	Are there any physical limitations eg not sufficient space?	2	1	**1**-No **2**-Yes
	Are there any legal limitations eg land ownership?	1	1	**1**-No **2**-Yes
Combination of intakes	Are there other water takes in the vicinity that could be combined with?	2	2	**1**-Yes **2**-No
Flood water levels	Is this area vulnerable to flood damage across locations? Assess flood water levels and vulnerability for the intake, diversion and fish screen location. Use this information to consider what infrastructure is at risk and needs protection and suitability of site.	2	1	**1**-Least **2**-Moderate **5**-Greatest **N/A**
Fish Bypass	Is a Bypass needed because your screen is out of river? Bypass must ensure conveyance of fish back to river	2	2	**1**-No **2**-Yes
	What is length of bypass required? (consider braiding pattern and distance through berm)	1	2	**1**-Least **2**-Moderate **3**-Greatest
	Relative distance fish required to navigate for safe return to waterway from diversion point across locations	1	2	**1**-Least **2**-Moderate **5**-Greatest **N/A**
	Is the intake length longer than the bypass return?	2	2	**1**-No **2**-Yes
	Is there good connectivity between end of bypass and flowing channel - easily maintained?	1	2	**1**-Yes **2**- No
	Does the location provide for effective sweep velocity past the screen to the bypass naturally?	1	2	**1**-Yes **2**-No
	Does any part of the diversion or bypass include a pipe (unless required for upstream fish passage exclusion)	2	2	**1**-No **2**-Yes
	Relative to other locations does this site avoid or provide for upstream fish passage back to the river?	N/A	3	**1**-Greatest **2**-Possible **3**-Least **N/A**
	Is there sufficient extra water available to be taken for bypass flows?			**1**-Yes **2**-No
Coarse Debris management	What level of management of coarse debris is needed at the location to protect the screen? [An undersanding of the type of debris expected and how to manage it at all range of flows and through each season is vital. For existing intakes, the operators will likely have a good knowledge of what the debris issues are]. *Note: A separate debris screen, if not suitably maintained, may compromise the effectiveness/operation of the screen. If it becomes a barrier to flow and then also begins operating as a fish screen, it may raise questions about fish screen compliance.*	1	1	**1**-Low mgmt **2**-Med mgmt **3**-High mgmt
	Considering the previous point, is coarse debris management viable at the location?	1	1	**1**-Yes **10**- No
	Is individual trash rack and fish screen combined into one location as close as possible to the water take. E.g. upstream structures can cater for water control and debris mgmt, can't be done downstream. Or no need for it?			**0**-No trash rack **1**-Combined **2**-Separate
Operation, maintenance and monitoring	Does the design of the intake and fish screen need to take account of river user safety (kayaking, rafting, jet boating, fishing, swimming) and access?	1	1	**1**-No **2**-Yes
	Does the location require a cleaning system?	1	1	**1**-No **2**-Yes
	Does the screen location, including access to the screen, consider operators of the screen/maintenance and provide for a safe means for operation and maintenance, and compliance to be undertaken?	1	1	**1**-Yes **2**-No
	TOTAL SCORE (Lowest score is the chosen/ most suitable)	**35**	**41**	

Fish Screen Guidance Tool – Step 2

Step 2 - Identifying appropriate fish screen types at preferred site	
For more details refer to Appendix 2 - Remember, keep all possibilities ticked	
What is the Intake flow (bypass and take)?	(Multiple Items)
What is the Water depth (maintained at screen)?	(Multiple Items)
What are the Water Gradients (Head loss at Screen)?	(Multiple Items)
Are powered screens an option at the site?	Non-powered
What is the Risk of screen clogging?	(Multiple Items)
What scale footprint is available for the screen?	(Multiple Items)
What is the Proportion of bypass flow required to have an effective intake?	(Multiple Items)
In what parts of the water column will the screen operate?	(Multiple Items)
What type of Maintenance/ cleaning is required?	Self cleaning
Is didymo or other fine filimentous material being considered?	All

Fish Screen Type (Do not change format)

Bossman

Fish Screen Guidance Tool – Step 3

Step 3 - Design Decision Table				
Recommended Location	Location 1 in existing intake channel			**Selection criteria**
Recommended Screen Type	Bossman			
Go through the following additional considerations and check if your design is the most suitable *Note: If you don't gather enough information go back and check for more details*			**Screen Type 1**	
Final design reccomendations:	**Questions**			
Priority species	Changes required to cater for the priority species and lifestages (refer to Appendix 1)		1	1. no (move to next) / 2. yes (alterations required)
Fish Bypass	Is the entrance of bypass suitable to attract fish ?		1	1. yes (move to next) / 2. no (alterations required)
	Is there sufficient flow (minimum of 10%) to assist with the attraction of fish to the bypass?		1	1. yes (move to next) / 2. no (alterations required)
	Does the fish bypass and intake enable upstream passage without entrainment ?		1	1. yes (move to next) / 2. no (alterations required to exclude fish or provide passage)
Control of flows:				
Into intake (Diversion channel if relevant)	Is there any existing structures that are compatible with good screen designs (eg. control gates, weirs, or the geometry at structures)? Where existing controls and structures are not suitable a new design or modification of the existing will be required.		1	1. no (move to next) / 2. yes (alterations required)
	Is there enough water available to provide appropriate sweep and approach velocities, and sufficient continuous and effective bypass flow?		1	1. yes (move to next) / 2. no (alterations required)
River user and operator safety	Does the screen design consider operators of the screen/maintenance and provide for a safe means for operation and maintenance, and compliance to be undertaken?		1	1. yes (move to next) / 2. no (alterations required)
	TOTAL SCORE (Lowest score is the chosen/ most suitable)		**7**	

Fish Screen Guidance Tool – Step 4

Final design criteria *To be completed by the Engineer/ Designer*	**<u>Outcome</u>**
1a. Location & Coordinates	1391255E 5040360N.
1b. Screen types	Bossman
2. Approach velocity	Average across first 0.85m of screen length from front of screen - 0.034m/s
3. Sweep velocity	At screen entrance - 0.763m/s, at bypass exit 3m downstream from screen entrance 1.175m/s, at 0.85m from front of screen 0.7601m/s
4. Fish bypass at screen	Yes
5. Fish bypass connectivity to river (a. Ensuring downstream migrating fish are return to flowing water b. Upstream fish passage is addressed)	Yes
6. Screen materials and mesh size	1.5mm wedgewire and steel
7. Operations and maintenance (a. Maintenance schedule b. Self cleaning mechanism if appropriate? C. Required in river works and frequency)	Yes Can be flushed In river works required for diversion after high flows
INSERT SCHEMATIC AND EXAMPLE PHOTO	**refer other sections**

Fish Screen Guidance Tool Appendix 1 – Priority species

<table>
<tr><td colspan="5">If the following species lifestages are found within the intake area vicinity, then it is likely mesh size alone will not prevent entrainment and impingement and further consideration should be given to locating the intake to avoid the predominant location in the water column and strengthening other criteria like sweep velocity and bypass design to prevent entrainment and impingement. Key locations for these groups and lifestages should be identified within regional planning frameworks, or the NZFFD (https://niwa.co.nz/information-services/nz-freshwater-fish-database) can be used to determine. This table below was developed using species of concern identified in Charteris 2006 and expert opinion of the Fish Screening Working Group (2020) (https://www.doc.govt.nz/globalassets/documents/conservation/native-animals/fish/fish-passage/appendix1-native-fish-requirements-water-intakes-canterbury.pdf). Generally it is concluded it would be best to locate the intake mid column to avoid fish entrainment.</td></tr>
<tr><th>Fish Species groups</th><th>Size</th><th>Migration/movement direction</th><th>Predominant location in water column that should be avoided if possible for intake placement</th><th>Comment</th></tr>
<tr><td>Nationally threatened non-migratory galaxiid larvae within adult habitat or dispersing immediately (1 kilometre) downstream</td><td><20mm</td><td>Downstream</td><td>Surface</td><td>Non-migratory galaxiid larvae become bethic at about 25mm (e.g. Dwarf galaxias and alpine galaxias).</td></tr>
<tr><td>Whitebait and torrentfish larvae migrating to sea after hatching (inanga, koaro, banded kokopu, shortjaw kokopu, giant kokopu and torrentfish), and Paratya shrimp zoae (larval stage).</td><td><10mm</td><td>Downstream</td><td>Surface (night) or Bottom (day)</td><td>Predominately around bottom during night and surface during day.</td></tr>
<tr><td>Lamprey macrophthalmia (young lamprey) during migration downstream</td><td><120mm</td><td>Downstream</td><td>Surface/top</td><td>Macropthalmia migrate downstream in the top part of the water column</td></tr>
</table>

Glass eels (longfin and shortfin eel) migating upstream from the sea	<120mm	Upstream	Bottom	Glass eels are benthic and move along the margins of the river, when eels become elvers (older) they move within mid-column.
Upstream migrating juvenile whitebait/smelt	<50mm	Upstream	Upper region of water column and bottom	
Salmonid juveniles within spawning streams	<40mm	Downstream	Bottom (all junvenile salmoniids) ; mid water column (Salmon)	Juvenile salmonids seek refuge cover on the bottom and around debris when not feeding. Juvenile salmon especially feed in the water column during the day but move downstream at night likely midwater. Juvenile trout generally associated with the bottom.

10 Appendix 2- Photos

West Awakino River site and fish screen photographs

Photo 1. West Awakino River (left) and Irrigation diversion channel (right) towards fish screen out of view, 25m from diversion, December 2021.

Photo 2. Downstream view of fish screen in place. Take to irrigation in right background, December 2021.

Photo 3. Upstream internal view of fish screen with covers off, December 2021.

Photo 4. Outlet to irrigation from downstream end of fish screen, June 2021.

Photo 5. Flow control mechanism for irrigation intake and screen bypass (partially buried in gravel in central foreground), December 2021.


Photo 6. Fish screen placement. Piped screen bypass outlet on left side of fish screen, December 2021.

Photo 7. Screen bypass pipe prior to burial, December 2021.

Photo 8. Fish screen bypass pipe (right) discharging to river return and upstream bypass (left) discharging from steel apron. February 2022.