Trial of fish screen effectiveness at the Totara Valley intake, Canterbury.

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Executive summary

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 screens have been operating on some intakes for many years, there has been uncertainty around their effectiveness. This study was commissioned to measure the effectiveness of the fish screen at the Totara Valley intake, situated near the southern bank of the Opihi River in Canterbury. The trials were designed to observe how juvenile fish were screened and diverted from the intake, and comprised releasing hatchery-reared Chinook salmon and rainbow trout upstream of the screen structure, and then monitoring their fate (i.e., their location) after they encountered the screen.

Screen effectiveness overall was very poor, as no Chinook salmon and less than 2% of the rainbow trout utilised the bypass back to the Opihi River. 24% of the Chinook salmon and 4% of the rainbow trout penetrated the screen and were entrained into the scheme. A further 14% of the salmon and 27% of the rainbow trout were caught in the trash rack. During a crawl dive at the completion of the trial another 440 salmon – but no trout - were observed in a pool upstream of the screen.

Reasons for the poor effectiveness of the screens, and four suggestions to improve effectiveness, are discussed. It is suggested that:

1. The rubber seal between the screen and its concrete base is refitted and/or repaired to ensure there are no gaps.
2. Modifications are made to the trash sweeping system so that fish are not deposited in the trash rack.
3. The bypass is enlarged and modified so that fish utilise it.
4. The connection between the bypass channel and the Opihi River is better maintained so that bypassed fish can return to the river.

1 Introduction

Irrigation and stock water intakes from New Zealand rivers are required by regulatory agencies (Regional Councils, Fish & Game Councils, and the Department of Conservation) to have fish screens. Screens have three 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 susceptible to effects from irrigation intakes, 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 screens 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 screens. 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 screens do, in fact, effectively screen fish, irrespective of whether or not the screen has been designed and operated according to the guidelines.

This report describes the second of a series of trials at fish screens on irrigation intakes in the Canterbury region. The objective of these trials was to test the effectiveness of screens, using live fish at an operating screening facility. Observing how fish react, and monitoring their fate, will give practical insight as to how well the fish screen performs, and whether it fulfils its core functions. Individual elements of fish screen effectiveness were assessed against the following five guideline criteria outlined in Jamieson et al. (2007).

- **Screen apertures**: were fish prevented from penetrating the screen and becoming entrained (trapped) in the irrigation system?
- **Approach velocity**: was the water velocity onto and through the screen (the approach velocity) low enough so that fish could escape the screen by swimming upstream against the flow?
- **Sweep velocity**: were fish diverted away from the upstream side of the screen by a flow moving across the screen and toward a diversion?
- **Bypass**: did fish locate and use a bypass, and did the bypass return fish safely to the river?
- **Operation and maintenance**: was the screen operated and/or maintained in a manner that ensured its effectiveness as a screen?

An overall assessment of effectiveness of the screen facility is based simply 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 will includes discussion of methods to improve screen effectiveness where appropriate.

2 Methods

2.1 Site description

The Totara Valley irrigation intake is located near the southern bank of the Opihi River, Canterbury, at NZTM: 1439548E 5106288N. Water is diverted from the southern edge of the Opihi River, and flows down a tree-lined intake channel (c. 150 m long) and into a pool. The screen (commonly referred to as the Andar screen because it has been manufactured by Andar Holdings in Timaru) is situated on the southern bank of the pool, and utilises two layers of stainless steel screen set on an inclined angle in the water; the screens are kept clean by constantly moving brushes and rubber squeegees. Leaves and debris cleaned off the screen are transported to the top of the screen and deposited on a “trash rack” above the screen (Figures 2-1 to 2-5).

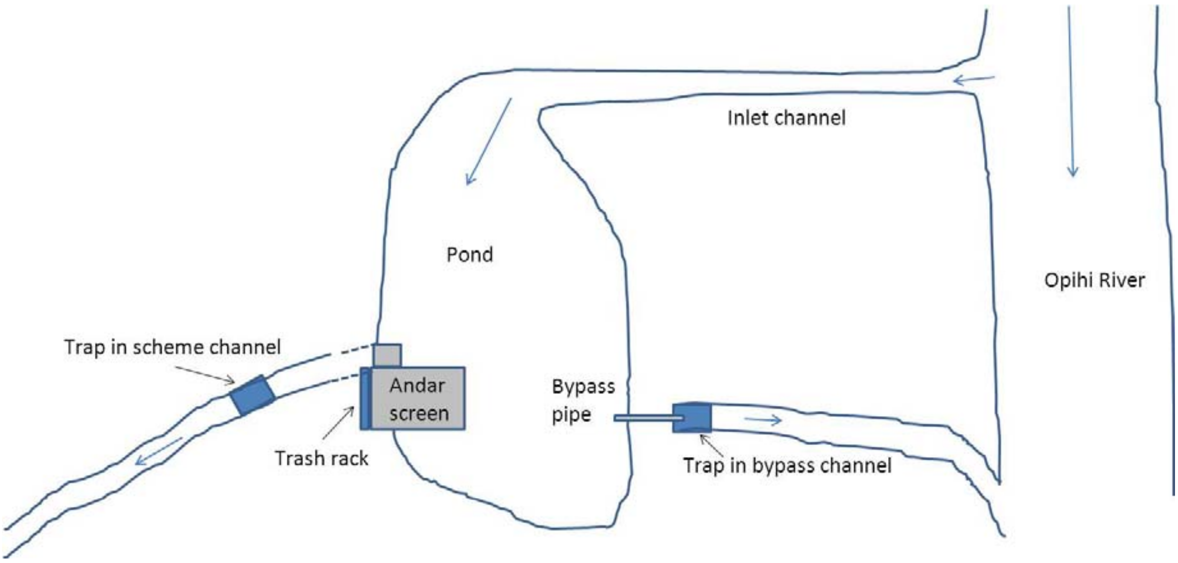

Figure 2-1: **Sketch plan (not to scale) of the Totara Valley Scheme intake.** Water flow is denoted by blue arrows.

On the northern side of the pool, roughly opposite to the screen, is a bypass comprising a pipe (c. 200 mm diameter and > 10 m long) passing through the gravel bank and discharging into the bypass channel. The bypass channel returns a flow of water - and any bypassed fish - back to the Opihi River (Figures 2-6 and 2-7).

Figure 2**-2: Diversion from the Opihi River.** Water is diverted into an intake channel seen on the left of the picture.

Figure 2**-3: The Andar screen and intake pond on the Totara Valley scheme.** Water flows from the pond, through the screen and down into a channel behind the screen (adjacent to the parked vehicle.

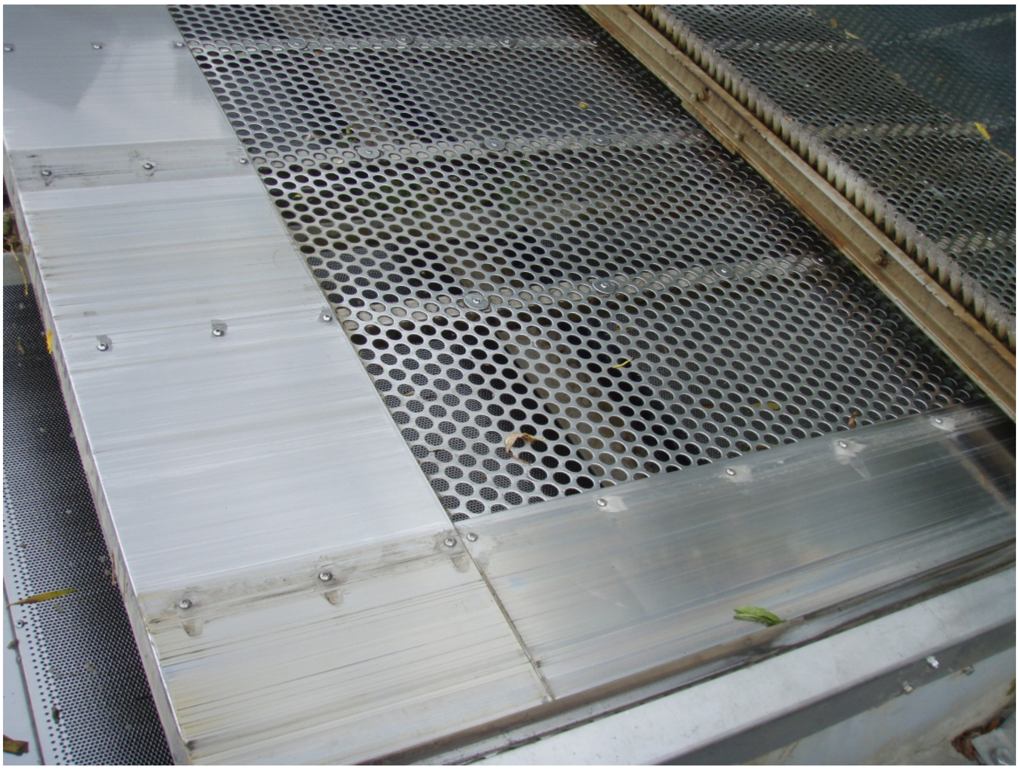

Figure 2-4: The outer coarse screen, and (at left) the inner fine screen. Screens are cleaned by constantly moving brushes as at right of picture, and by rubber squeegees.

Figure 2-5: The trash rack at the top of the screen. Leaves and debris that have been cleaned off the screens by the brushes and squeegees are deposited on a rack above the top of the screen.

Figure 2-6: The bypass pipe. On the northern bank of the pond - opposite the screen - is an outlet pipe leading to the bypass channel.

Figure 2-7: The bypass channel. Water from the outlet pipe flows along the bypass channel and back to the Opihi River.

2.2 Operating trial

Traps were installed downstream of the scheme intake screen and downstream of the bypass pipe (Figures 2-8 and 2-9). These traps were installed several days before any trial fish were released, and monitored to determine if any wild (i.e., non-hatchery) fish were passing through the screen or being bypassed. Electric fishing of a section of the Opihi River was conducted to obtain a sample of wild fish for size comparison with hatchery fish used in the trial. Electric fishing was also conducted in the intake channel and between the screen and scheme trap to remove any wild fish. Approximately 150 wild Chinook salmon fingerlings were observed in the intake channel, but were not able to be removed. At the start of the trial 1,000 hatchery-reared juvenile Chinook salmon and 1,000 juvenile rainbow trout were released into the pool c. 50 m upstream of the screen. Samples of hatchery-reared fish (75 of each species) were separately retained for measurement, and a further 20 Chinook salmon and 20 rainbow trout were retained alive as a control at the Fish and Game office. After the release of trial fish, the scheme trap, bypass trap, and the trash rack were monitored for the succeeding two days.

At the conclusion of the trial, a crawl-dive was conducted from the screen upstream through the intake channel to the Opihi River.

Figure 2-8: The scheme trap. Water passing through the Andar screen (out of picture to right) flowed under the gravel into the scheme channel and then through the trap.

Figure 2-9: The bypass trap. This trap was installed directly downstream of the pipe outlet into the bypass channel.

3 Results

3.1 Dates of trial and water flow in the intake

A sample of 17 wild Chinook salmon was obtained from the Opihi River for length measurement on 24 January, and pre-trial trapping of the scheme was conducted from 24 January to 30 January 2012. During this time the Andar screen was removed for several days for repairs. Trial fish were released at 6pm on 30 January 2012, and trapping continued until the morning of 1 February 2012.

During the trials the flow of water through the screen and into the irrigation scheme was estimated by gauging to be 0.486 m^3 sec^{-1} (486 litres per second), and the flow through the bypass pipe was about 0.001 m^3 sec^{-1} (1 litre per second).

3.2 Numbers, fate (location), and size of fish.

No (wild) fish were caught in the traps before the commencement of the trial. The numbers and size of fish caught in the scheme trap, bypass trap, and trash rack are presented in Table 3-1. For comparison, the table includes the numbers and size of wild (non-hatchery) Chinook salmon, and of hatchery fish separately sampled prior to the trial release.

Table 3-1: Number caught, number measured, mean length, standard deviation, and length range of wild and hatchery (trial) fish in this investigation.

Species	No. caught	No. measured	Mean length (mm)	Std. dev.	minimum	maximum
Chinook salmon						
wild fish						
opihi river	17	17	89.9	7.76	77	103
scheme trap	10	10	88.3	9.12	74	101
trash rack	2	2	81.0	2.83	79	83
bypass trap	0	0				
trial (hatchery) fish						
pre-trial sample	75	75	87.2	9.86	57	106
scheme trap	244	32	98.3	8.14	75	111
trash rack	144	21	91.4	10.12	65	108
bypass trap	0	0				
rainbow trout						
trial (hatchery) fish						
pre-trial sample	75	75	37.5	5.99	28	52
scheme trap	40	0				
trash rack	276	0				
bypass trap	14	9	34.7	3.97	30	42

3.3 Proportion of fish recovered

One thousand Chinook salmon, and 1,000 rainbow trout were released for this trial; recovery in the traps and trash racks totalled 388 (38.8%) salmon and 330 rainbow trout (33.0%) (Table 3-2).

Table 3-2: Numbers, and in brackets percentage, of hatchery (trial) fish recovered by site.

Site (fate)	Chinook salmon	Rainbow trout
Scheme trap	244 (24.4)	40 (4.0)
Bypass trap	0 (0.0)	14 (1.4)
Trash rack	144 (14.4)	276 (27.6)
All combined	388 (38.8)	330 (33.0)

3.4 Time of day when fish were recovered

The traps and the trash-rack were checked at various times during the two days of the trial; a histogram of catch by time of day (Figure 3-1) shows that most of the Chinook salmon were caught early in the morning (between 0600 and 0900) and most of the rainbow trout in the middle of the night (between midnight and 0200).

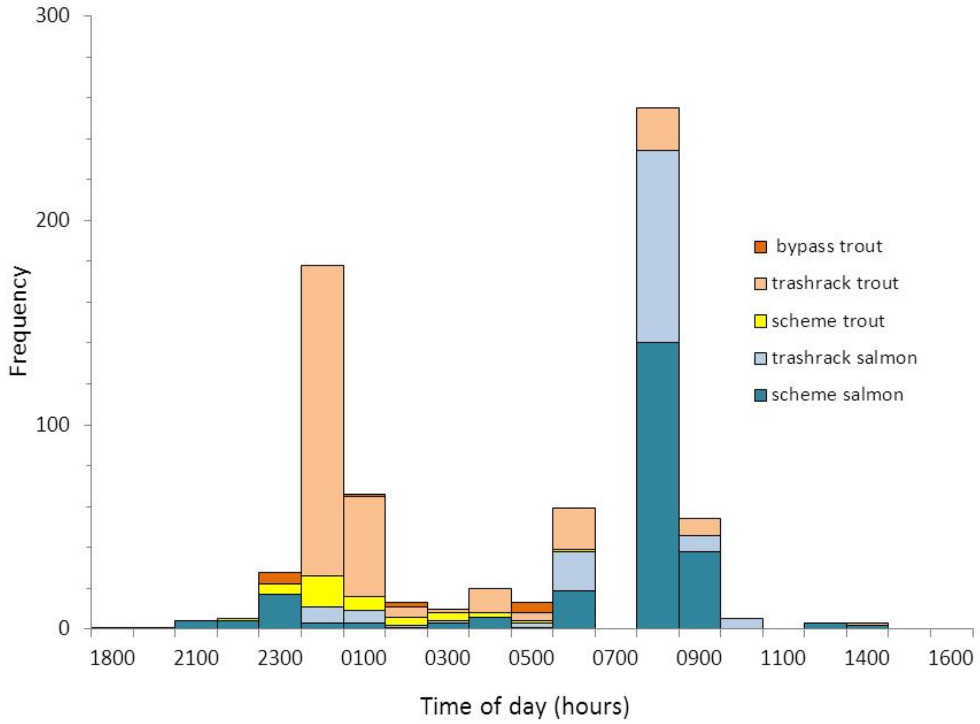

Figure 3-1: Recovery (catch) of trial fish by time of day.

3.5 Observations

Schools of Chinook salmon were seen at various times of the day in the pool, and were observed close to the screen (Figure 3-2). During daylight hours salmon schools appeared drawn to the screen, and were probably following the water current; they were seen “playing” around the screen under the brushes. During daylight hours very few salmon were trapped in front of the brushes, however at night the numbers caught in the trash rack suggests that avoidance of brushes was less successful. Overall, Chinook salmon were mostly caught in the scheme trap during daylight hours, whereas rainbow trout were mostly caught in the trash rack during the night.

Rainbow trout were not observed in the pond (they were much smaller fish) and it is not known if these fish formed schools at any time. No rainbow trout were seen during the crawl dive after the trial; many would probably have been eaten by the large brown trout in the intake channel, some of which were observed feeding in the area where juvenile rainbow trout were released.

Over the two day trial, eels and bullies were occasionally caught in the scheme trap, and bullies were also sometimes caught in the trash rack.

One other pertinent observation made during the trial was that the rubber flange around the Andar screen appeared to fit poorly in places (Figure 3-3); it is likely that a substantial flow of water was passing around the screen at any spot where the flange was not sealing properly. Such a flow of water may have "attracted" fish in the vicinity, and may have been sufficient to draw fish down and into the scheme.

Figure 3-2: School of Chinook salmon near the screen.

Figure 3-3: The rubber flange on the Andar screen. The black rubber flange appeared to be fitting poorly to the concrete base; in the foreground a gap between the concrete and flange can be seen. This gap is mostly out of the water and consequently has little effect on fish - however any such gaps in deeper water might allow a strong flow of water that bypasses the screen, and draw fish through directly into the scheme channel.

4 Discussion

4.1 Screen performance against guideline criteria

Below, the performance of the Totara Valley screen is compared to the guideline criteria as outlined in Jamieson et al. (2007).

4.1.1 Aperture (mesh) size

An inherent property of an effective fish screen is that the screen mesh is of sufficiently small aperture to prevent fish penetrating the screen. The inner Andar screen is comprised of stainless steel plate material with uniform round apertures 3 mm in diameter, which is small enough to prevent the penetration of small salmonids.

4.1.2 Approach velocity

Approach velocity is the term used to describe the speed of water immediately upstream of a screen. 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 them 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” 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 rainbow trout used in these trials (which were about 30 mm long), the approach velocity should be no greater than 120 mm per second (or 0.12 $msec^{-1}$). Similarly for the Chinook salmon used (about 80 mm long) the approach velocity should be no greater than 0.32 $msec^{-1}$.

Approach velocity was not measured during the trial, however the observation of Chinook salmon “cruising and playing” very close to the screen indicate that approach velocity was not high.

An approach velocity of 0.15 $msec^{-1}$. was roughly estimated (using an estimated wetted screen size of 8 m^2, the open area of perforated plate being 40%, and the gauged flow of water in the scheme channel being 0.486 m^3 sec^{-1}). Such a velocity is very close to what is recommended.

4.1.3 Sweep velocity

The term “sweep velocity” refers to the velocity of water sweeping across the screen (i.e., at right angles to the flow of water through the screen). Sweep velocities should be greater than approach velocities, in order to sweep fish from upstream of the screen into a bypass system. There was no apparent “sweeping” flow across the Totara Valley intake screen, and it is highly unlikely that a sweeping flow exists; more than 450 litres of water per second were passing through the screen during the trial, and the almost insignificant flow of water down the bypass outlet (estimated at around 1 litre per second) would be insufficient to cause a sweeping flow across the screen on the other side of the pond.

4.1.4 Bypass provision and connection

No Chinook salmon, and only 14 rainbow trout, utilised the bypass during the trial. The possible reasons for this are:

- The bypass outlet is at a considerable distance from the screen, on the opposite side of the pool, and has very little flow. Thus the bypass does not create a “sweeping” flow across the screen to draw fish into a bypass system.
- As very little water passes through the bypass, it probably makes it hard for fish to detect/find.
- The entrance to the bypass consists of a circular pipe passing through a gravel bank to the bypass return channel. This is not ideal for salmonid fish, which avoid entering a closed pipe. Bypass channels are preferably open-topped, at least until fish are drawn into the bypass and cannot return.

Of further concern is that the flow of water down the bypass channel is insufficient to ensure that the bypass is well connected to the Opihi River; near the river the bypass channel disperses amongst the bankside willows and becomes very shallow, making it difficult even for small fish to regain the river. It also exposes any fish in the bypass channel to predation by birds and eels (Figure 4-1).

Figure 4-1: The bypass channel near the Opihi River. Near the river the bypass channel becomes wide and shallow as it disperses amongst willows and scrub.

4.1.5 Screen operation and maintenance

Although the screen facility appeared to be well operated and maintained (except for apparent gaps in the seal) 284 of the trial fish passed into the scheme channel, probably via gaps between the rubber flange and the concrete base.

Furthermore, 420 of the trial fish were trapped amongst the leaves and debris of the trash-rack. This presumably occurred because the fish moved close to the screen at times (possibly they were attracted to the flow of water though the screen) and became caught amongst the debris and leaves by the moving brushes and squeegees.

4.2 Overall performance/effectiveness

The overall measure of screen effectiveness is simply the proportion of fish encountering the screen which are returned to the river of origin. The trials demonstrated that the Totara Valley screen is almost totally ineffective, with no Chinook salmon, and only 1.4% of the rainbow trout, moving down the bypass channel. Even this tiny proportion of fish would not necessarily be safely returned to the Opihi River, as the bypass return channel may not provide a good connection to the river.

4.3 How might the screen effectiveness be improved?

There are at least four ways that the performance and effectiveness of the Totara Valley screen might be improved:

1. Improvement of the seal between the screen and its concrete base would eliminate any gaps that presumably allow a flow of water (and fish) directly into the scheme channel (i.e., not via the screen). Further inspection of the rubber flange and seal is required, as it was not possible to investigate whether gaps were present at depth

during the trial, and nor was it possible to measure the flow through any gaps. However, the presence of significant numbers of trial fish in the trap downstream (i.e., the scheme trap) demonstrates that fish are able to get through somehow, and the flange seal is the only apparent “chink in the armour”.

2. Modifying the system of trash sweeping. Substantial numbers of fish ended up in the trash rack, having been caught by the brooms and squeegees that constantly clean debris and leaves from the screen. Two possible remedies exist:

    a. Modify the brooms and squeegees to allow fish to escape more readily, either by offsetting or angling them (so that fish are able to move to the lower side of the moving barrier) and/or provide gaps in the brooms, e.g. reduce to 50% coverage with individual broom sections of 100 mm in length – these could alternate between brooms so that the screen would still be entirely cleaned

    b. Ensure that fish swept to the top of the screen are returned to the pond or bypass channel, by “filtering” the leaves with a coarse and inclined mesh, so that heavier fish will drop vertically down into a small channel (e.g., plastic spouting) with a flow of water to the pond/bypass channel/collecting container.

3. Modifying the bypass intake. The present location, size, and design of the bypass intake is not appropriate. The bypass intake is likely to better utilised if it is closer to the screen, and passing a much greater flow of water. Salmon and trout will generally avoid entering an enclosed pipe intake, and open-topped channels are much more effective. An open-topped channel intake could feed into a smaller pipe at higher gradient, so that fish would enter the bypass channel and then be drawn by higher velocity flow through a pipe.

4. Ensuring the bypass channel is well connected to the Opihi River. A greater flow of water down the bypass would probably go a long way to ensuring better connection with the Opihi River, however some occasional maintenance may also be required to make sure the channel is reasonably channelized, rather than dispersed

5 Acknowledgements

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