FISH SCREEN CONCEPT
LEVEL PLAINS IRRIGATION SCHEME
OPIHI RIVER

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1.0 Introduction

In 2019 Irrigation New Zealand (on behalf of the Fish Screen Technical Working Group), received a grant from the Sustainable Farming Fund (now Sustainable Food and Fibre) to further research fish screen design criteria. The research ultimately aims to provide clear and simple guidance on fish screen requirements.

For the current stage of this project three locations with screens that are not compliant with current fish screen standards were chosen. The sites were also selected to provide a variety of existing fish screen types and river intake conditions. This report investigates options for achieving a compliant fish screen at the existing Level Plains scheme intake on the Opihi River.

This document includes details of the fish screening design requirements and various options of location and screen type for this intake. This is an initial assessment to enable the MPI project and Opuha Water to consider which of these options for the location and screen type to consider further.

Included in this report is a suggested approach to the selection of the best location for a fish screen at a site and selection of screen types. The following stages in the development of a solution for this site including detailed design could lead to changes to meet all the requirements for a fish screen. The tables in Appendix A are drafts that have been developed with the Fish Screen Working Group which include the issues to consider in selection of the location for a fish screen and some general parameters for different fish screen types.

2.0 Background

The Level Plains Irrigation Scheme supplies water from the Opihi River to farmland as well as the local golf course, covering approximately 3,300 hectares to the east of Pleasant Point on the southern side of the Opihi River. The current maximum consented take from the Opihi River is $3.5m^3/s$ but we understand the maximum at this intake is $2.5m^3/s$. There is an existing fish screen which was constructed in 1987.

The fish screen is located approximately 650m downstream from the river intake. Upstream of the fish screen is a control gate and overflow weir. The fish screen is a flat screen located almost parallel to the flow in the race. The screen is approximately 2m high and 16m in length (refer to Photo 1). The fish bypass comprises approximately 200mm diameter opening in the wall downstream of the screen which leads back to the river via a pipe. The screen has a travelling rotating bush system which moves along the screen to keep it clean.

Figure 1: Level Plains Fish Screen (looking upstream)

3.0 Review of Existing Intake and Fish Screen

An engineer from RILEY visited the site with 2 Fish & Game officers and two of the Opuha staff on 31 January 2020 as part of the selection of suitable fish screens for the study. In general the concept of the screen appears quite sound although there are improvements required. The screen appeared in good condition and the travelling bush appears to be effective in keeping the mesh clean.

In 2010 a detailed assessment of the fish screen was undertaken as part of a study into 6 screens in Canterbury. In 2018 Environment Canterbury (ECan) undertook a compliance monitoring inspection. These inspections of the fish screen considered the seven criteria within the NIWA Guidelines[1] as a basis of the assessment. The findings from the 2010 study and inspection by ECan found the following key issues with the screen:

- The approach velocity at the screen measured are significantly greater than 0.12m/s.
- The sweep velocity in general is greater than 0.12m/s but inconsistent along the length of the screen.
- The mesh of the screen is 3mm mesh except with the most downstream panel of the screen which is 5mm.
- The bypass is not considered effective as is a small pipe and has a very low flow in comparison to the take. The entrance to the bypass is not considered suitable for a number of fish species as it is a culvert.

[1] Jamieson, D., Bonnett, M., Jellyman, D., & Unwin, M. (2005). Fish Screening: good practice guidelines for Canterbury. NIWA, Auckland, 70pp.

ECan have also commented in recent assessment on the location of the fish screen. This has previously been raised in in the fish trials undertaken. Ecan have indicated that they agree that the location of the screen is not ideal for overall screen effectiveness particularly considering the weirs involved and the habitat created which favours large trout increasing the subsequent risk of this intake to all other fish species. ECan have also stated that they do not consider that location is an issue which falls within the scope of the current consent conditions but that this issue will need to be resolved when the current consents expire. The current consents expire in 2030.

During the site visit on 31 January 2020 the depth of water at the screen and length of the screen was measured to undertake a simple calculation of the approach velocity. The water depth at the screen was just under half of the depth of the screen and from debris lines and discussions with Opuha staff this is the typical operating level at the screen. The approach velocity was estimated to be in the order of 0.25m/s based on an inflow of $2.5m^3/s$. Given that only one half of the screen is below the water level this suggests that increasing the water depth will be a potential option to reduce the approach velocity.

The control gate structure just upstream of the fish screen has a drop in the water level of approximately 0.8m based on measurement during the site visit.

4.0 Basis for Design of Fish Screen

In Canterbury the recommended approach in the design of a fish screen is the NIWA Guidelines reference in Section 3.0 and Canterbury Land and Water Regional Plan (CLWRP)[2] Schedule 2.In most recent consents this is often used as the basis for consent conditions related to fish screening.

4.1 NIWA Design Guidelines

The NIWA guidelines outline seven design criteria for fish screens as follows:

1. Location.
2. Approach (through screen) velocity.
3. Sweep velocity.
4. Fish bypass at screen.
5. Fish bypass connectivity to river.
6. Screen materials and mesh size.
7. Operations and maintenance.

These design criteria need to be demonstrated in determining the fish screen location and fish screen type. The other considerations in the selection relate to operational actions (i.e. automated screen cleaning) and ease of operation/maintenance, construction costs, operating costs, and ongoing compliance monitoring risks and costs. Under 5. Fish bypass connectuivity to the screen, consideration of whether to allow upstream fish passage also needs to be considered which influences the overall placement and design of the bypass.

[2] Canterbury Land and Water Regional Plan. Schedule 2 Fish Screen Standards and Guidelines. (December 2016).

ECan is involved within the "Fish Screen Working Party (FSWP)" which is considering recommendations for fish screen requirements in Canterbury. The approach in general being discussed is as follows:

- If a fish screen meets the seven design criteria outlined in the NIWA guidelines/Schedule 2, then the design would be considered compliant and would only require verification that it meets the design criteria. Generally no ongoing monitoring of the screen effectiveness would be required.
- If a fish screen does not meet all of the seven criteria, then the criteria not being compliant would need to be described and mitigations to address such none compliance described. Such a screen may be required to prove its effectiveness for all fish species and ongoing effectiveness monitoring may be required.

Attempts to perove the effectiveness of fish screens has been attempted through live fish trials, but this process is problematic and proves difficult to achieve definitive results for river intakes. The uncertainty in these trials appears to be very high and introduces a significant risk to the consent holder where plan objectives and consent conditions require monitoring to demonstrate screen effectiveness to an absolute standard (i.e. LWRP Schedule 2). Therefore an approach based on absolute design criteria is more easily measured/audited and is the recommended approach.

4.2 Design Philosophy for Velocity

The NIWA Guidelines as discussed above have seven key criteria and two relate to the velocity of flow into/through the screen (approach) and across the screen (sweep). A common discussion is whether these criteria need to be met on average or in all parts of the screen. It is recommended that any new screen should aim to not only meet the average velocity requirements but that it shows design considerations to aim for equal distribution of velocity across the screen surface.

The main two means of achieving the approach/through screen velocity is by:

1.0 Increasing the total screen area and screen open area ratio to achieve the design velocity criteria

2.0 Reducing the average velocity by providing a baffle behind the screen to control the distribution of flow. A baffle is often a plate with a variety of openings. The size and density of the openings enables the distribution of flow to be more uniform. The design of a baffle is very complex and requires some research and development depending on the shape of the screen, the flows and velocities being designed. A number of the screens available on the market have baffles within their design.

5.0 Fish Screen Location

5.1 General Process in the Selection of the Fish Screen Location

The selection of the most suitable location for the fish screen needs to take account of a variety of factors. Appendix A includes a table that details the different factors in this selection process and the questions that need to be considered in the assessment. The following is a list of the key elements that need to be considered in assessing the best location for a fish screen for a site.

- River intake conditions.

- Potential to combine river intakes and fish screens.
- Flood water levels and protection of infrastructure.
- Fish bypass location, length and connection back to river.
- Upstream fish passage in the fish bypass.
- Control of flows for the any diversion channel, fish screen and bypass.
- Management of debris and didymo.
- River user and operator safety.
- Operation and maintenance.
- Monitoring of the intake and fish screen.

The following sections provide for an assessment of the intake location for the Level Plains fish screen with consideration of the factors listed above.

5.2 Assessment of locations for Level Plains fish screen

We have considered the following potential locations for a fish screen at Level Plains which are shown in Figure 2:

1. At the river intake.
2. Between the river intake and the culvert in the canal.
3. Along the canal between the river intake and control gate.
4. At the existing fish screen location.

Figure 2: Potential Locations of a Fish Screen

The fish bypass is an important component of an effective screen and needs to provide a link back to a river channel. The location and route back to the river is only indicated in the following figures as general concept. Once a preferred option(s) is selected, during a detailed design phase the location and geometry of the bypass will need to be investigated further. The design of the fish bypass will also include a means to control flows in the bypass and consideration of the fish passage downstream in the bypass and should also consider upstream fish passage from the river.

In addition to fish screening there are issues relating to debris/sediment management, flood protection of infrastructure, safety of operators and river users and flow control. It is important to note that these issues should not be considered in isolation and an integrated option may also be more cost effective. The other important consideration is the existing infrastructure and making best use of that to reduce the costs of a compliant solution.

5.3 At the River Intake

At this location, the screens would be exposed to the river and the debris it conveys. A structure in the river may also have issue of changes in the river braids and challenges associated with how the flows to the fish screen would be maintained. The variation in water depths and velocities would mean there is limited control of the sweep velocity for this option. These difficult hydraulic conditions result in challenges to achieve an even distribution of approach velocity at a screen.

The benefits of a fish screen at this location is that it does not require a fish bypass as the fish would remain in the river.

The issues relating to construction, difficulty in any control of sweep or approach velocity distribution and ongoing operation would suggest this is unlikely to be a feasible option for a fish screen at this location.

Figure 3: River Intake

5.4 Between the River Intake and Culvert

Here the fish screen is out of the main flow of the river and has greater protection from flood flows. It also has the advantage of only a relatively short distance from the river intake and fish bypass channel back to the river.

There are two challenges related to the screen located close to the river and only a short distance downstream to outlet of the bypass. The first issue is the water levels at the screen will follow the river water levels and will result in sweep velocities reducing at higher river levels. The second issue is that with only a short distance between the intake and outlet of the bypass there will only be a very small difference in water level and combined with head losses along the canal and bypass can lead to very limited capacity to provide suitable velocities at the screen and in the bypass back to the river.

Figure 4: Before Debris Screen

5.5 Along the Canal Between the Intake and Control Gate

There is no obvious location in this section of the canal that is the best location. The canal runs parallel to the river and therefore the length of a bypass would be similar. Whether there are any suitable active flows to return the fish to the main river channel would also need to be considered in more detail. The benefit of this location in comparison to the option close to the river is that due to the distance between the intake and outlet of the bypass there is a greater water level difference between the intake and bypass outlet. This will enable better control of the sweep velocity and velocity of flow in the bypass. The fluctuations in water level due to changes in river water level at this location will also be reduced.

Figure 5: Along Canal

5.6 At the Existing Fish Screen

A new fish screen could be constructed at the existing fish screen location or it may be possible to modify the existing screen and other infrastructure to be compliant with the guidelines. The advantages of this location are that it is close to existing infrastructure and there are already infrastructure for the management of flows and debris. Unlike the majority of existing screens that have been observed in other locations in Canterbury this screen in concept meets or could be modified to meet all of the design criteria of the guidelines. Most other screens that have been observed require a complete rebuild to enable the criteria to be met. To use the existing fish screen it would be expected that a new fish bypass canal would need to be constructed. The main disadvantage to this location is the distance from the river intake to the outlet of the bypass and how that relates to the issues raised by ECan about the potential problems associated with weirs upstream of the fish screen. The nature of the bypass flow back to the river would also need to be investigated further.

Figure 6: Current Fish Screen Location

6.0 Modifications to Existing Fish Screen

As discussed earlier the existing screen has a number of positive features in regard to overall concept. The following are potential changes that could be made to the existing screen to achieve compliance with NIWA Guidelines. These are based on a concept design level only and would require more detailed assessment to confirm what is required.

6.1 Approach Velocity

From simple site measurements of active screen area, the current screen has an approach velocity approximately two times greater than the guidelines. Due to water depths less than half of the current screen area is active. If the depth of water was increased by approximately 800mm the current screen would have an average approach velocity of approximately 0.12m/s. It is likely that the screen would need to be extended a little given it is unlikely that all of the screen area could be actively used.

The distribution of the approach velocity along the screen may need to be checked and a baffle might be required behind the mesh screen to improve the distribution of velocities if there is a problem. A baffle is typically a steel plate with variable size holes but requires specific design in regard to the hydraulics. The head loss through the flat screen will be very low and therefore only small changes in the water level along the screen can have significant effects on the distribution of flow through the screen and this can only be improved through baffles or changes in the upstream and downstream canals.

6.2 Sweep Velocity

The shape of the channel at the fish screen could be modified to ensure a more consistent sweep velocity past the screen. The ideal would be to have a constant sweep velocity or an increasing velocity as it heads towards the bypass. To achieve this will be designing the shape of the channel upstream and at the fish screen.

6.3 Bypass

At the end of the screens an open channel could be constructed to replace the culvert and convey water back to the bypass outlet to the river.

6.4 Water level

The upstream overflow weir and control gates has in the order of an 800m drop in normal operation. An option would be the removal of the gate at this location which would increase the flow depth at the fish bypass screen. The downstream channel could be modified to covey this deeper flow and the control located here with an 800mm drop into the existing canal with a new control gate. This would result in water levels being the same in the downstream canal as current after the new control gate. The existing overflow weirs at the control gate to manage flows would also remain.

It is likely given simple measurements that the fish screen would need to be extended by a small amount to have sufficient capacity to meet the approach velocity requirements even with the increase in flow depth.

The fixed flat screen would also need the last mesh panel replaced with 3mmm mesh. The hydraulic design of this screen is likely to find some uneven distribution of the approach velocity which may require a baffle design to improve that.

The effectiveness and reliability of the cleaning system would also need to be confirmed.

7.0 Fish Screen Type

There are several different types of fish screen that have been considered. The NIWA guidelines include a summary of several different types of screens. Appendix A includes a table with the various parameters for a fish screen to be considered in the selection of a suitable screen. The screens considered as potentially appropriate for the Level Plains intake based on the flows, previous trials on physical screens, results from recent testing of screens, and the design of recent fish screens are:

- Rotary cylinder screen with an electric motor.
- Rotary cylinder screen with a hydraulic turbine.
- Cone screen
- Fixed Flat screen.
- Travelling flat screen.
- Other Screen Options

7.1 Rotary Cylinder Fish Screen

There are a number of manufacturers of rotary screens. We are familiar with the screens provided by AWMA as have observed them in New Zealand, Australia and USA. There are other manufacturers in New Zealand. AWMA provide both types of rotary screen mentioned based on design by Intake Screens Inc (ISI), Sacremento, United States. These screens are rotated by a motor and have either bush cleaning system or water jets to facilitate cleaning from within the screen. Figure 6 shows an example of a design for an installation in the United States of these cylinder screens (ISI). These types of screens have recently been installed by Amuri Irrigation, Kurow Duntroon Irrigation, Pukaki Irrigation and are the basis of current design being undertaken by the RDR.

Figure 7: Cylinder Screens Design in United States (Intake Screens, Inc.)

The screens in Figure 7 would be installed at an angle to the flow. The first one is a "T" shape and has electric motor to rotate occasionally when required for cleaning and usually on a timer. The second screen is driven by a propeller and continuously rotates. The screens can be installed on rails so that they can be retrieved for maintenance. The alternative would be to dewater the race to undertake any maintenance work which may be a better option for the Level Plains scheme.

The screen with an electric motor can operate over a full range of flows and only rotates as required. The screen with a propeller requires a minimum of approximately 40% of the full flow to operate and rotates continuously. The operating range can be extended by using more than one screen or having different sizes.

These screens include an internal baffle and also have a slide gate to control the flows which is important where multiple screens are required to balance overall flows. The baffles have been designed based on modelling and physical testing.

7.2 Cone Screens

These screens are similar in design and concept to the cylinder screens but are designed to sit on the invert of a channel and have main advantage of being suitable for shallow channel water depths. They include the same brush cleaning system and baffle to distribute the flow evenly across the surface.

Figure 8: Cylinder Screens for Cohuna and Trangie Nevertire Irrigation (AWMA, Australia)

7.3 Travelling Flat Screens

Travelling screens are mechanical screens installed vertically. The screens operate by rotating around a drum at the top and bottom of the screen with the motors above the water. The screens are self-cleaning through air or water jets at the top of the screen. Like the rotary cylinder screen, they are widely used in the United States and considered to be very effective. Figure 9 shows an example of a screen from Hydrolox and located at Fall River in the United States.

Travelling screens require a longer length of screen in comparison to rotary screens but are more suited for narrow channels.

Figure 9: Example of Travelling Screen (Fall River, Hydolox Screen)

Flat screens are installed vertically. The screens operate by rotating around a drum at the top and bottom of the screen with the motors above the water. The screens are self-cleaning through air or water jets at the top of the screen. Like the rotary cylinder screen, they are widely used in the United States and considered just as effective.

7.4 Fixed Flat Screen

The existing screen is a fixed flat screen with a travelling brush cleaning system. As with the travelling flat screen an advantage of this type of screen is that they are constructed on the side of the channel and therefore there is less disturbance to the flow than what a cylinder has. They also allow for a narrow section at the downstream end to help maintain good velocity to a bypass.

The proposed flat screen being designed for the RDR will include an adjustable baffle system which is needed in this case due the combination of rotary and flat screens. However, this does highlight the possibility of this approach for providing greater ability to distribute flows evenly.

7.5 Other Screen Options

Other screen options have been identified by the Technical Group and are noted in the Decision Tables (see appendix A)

7.6 Screen Selection

Appendix A includes a table with some of the common issues associated with various screen types and this needs to be considered in selecting a suitable option. The selection of the preferred screen type will depend on the following:

- Location and geometry of the location.
- Depth of water and available head loss through screen.
- Intake flow and available flow for the bypass
- Issues of flow control.
- Sediment/debris management.
- Electricity at site (or alternatives)
- Construction and operational costs.
- Specific species consideration (e.g. important whitebait or sports fish spawning location, near sea, threatened species location)

For a cylinder screen there needs to be sufficient water depth both below and above the cylinder, whereas a cone screen or flat screen can operate in a shallower depth of water. The current site has power for the control gate and screen cleaner.

Given the type of screen selected for the differing water depths, the length of the screen will differ. For a flat screen, if we assume a 1m water depth the screen would need to be 20.8m long and similarly, 1.5m water depth would require a 13.9m long screen. For a cylinder screen, if we assume a 1m water depth, the screen would be 16.6m long with a maximum cylinder size of 0.4m diameter. Similarly, for 1.5m water depth, the screen would be 7.4m long with a maximum cylinder size of 0.9m diameter. For the cylinder screen this would allow for a 0.3m water depth both above and below the screen.

8.0 Construction Issues

The construction of a new fish screen or modification to the existing Level Plains fish screen, unless located at the river intake, should be relatively straight forward. The construction could be undertaken outside normal irrigation period and the scheme shut down. A screen at the intake would require management of water from the river and be at risk from floods during construction.

The screen could be constructed on a concrete wall or using embankments with the screens on the ends of a pipe through the embankment. Figure 10 shows a variety of different options for construction of a cylinder screen including at the end of a pipe through an embankment, on an embankment slope with pipe through embankment or on a concrete wall.

If modifying the existing screen was the preferred option, there would be less work done than the construction of a new screen. For all options a new fish bypass would be required.

Figure 10: Cylinder screen construction types

8.1 Construction Costs

When a preferred location and screen type is selected then a cost estimate can be undertaken. The cost of the construction of a new mechanical fish screen including all of the civil works is typically in the order of $100,000 to $400,000 per 1 m^3/s. It would be expected that the cost of modifying the existing screen would be significantly lower than cost of a new screen.

9.0 Recommended Option

The initial assessment of the location of a fish screen by the FSWG has concluded that the best location for a fish screen is at the existing location. This does require significant improvements to the bypass back to the river. As discussed in Section 8.0 there may be an opportunity to modify the existing screen and make use of some of the existing infrastructure.

At the existing location a flat screen remains a suitable option and it may be possible to modify the existing screen and other infrastructure as discussed in Section 8.0. The current water depth at the screen is in the order of 0.6m but could be modified to achieve 1.2 to 1.5m. A flat screen or cylinder screen would be suitable.

10.0 Next Steps

The main purpose of the fish screen concept report is to consider options for the location of a fish screen including consideration of the bypass and possible screen types. The order of this process is to first agree on the best location for the fish screen which requires consideration of the fish screen requirements, existing infrastructure and all aspects of the intakes design. Once a location or locations are selected then a more detailed assessment of the hydraulic conditions at that location and confirmation of most suitable screen type can be progressed. This assessment may require a topographical survey if LiDAR is not available or suitable which may be due to vegetation around the intake and fish screen location. A survey of the channels from the intake to the fish screen and downstream and proposed fish bypass will also need to be undertaken.

11.0 Limitation

This report has been prepared solely for the benefit of MPI, Irrigation New Zealand and Opuha Water Ltd as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such parties' sole risk.

The hydraulic analyses and recommendations contained in this report are based on our understanding and interpretation of the available information. The recommendations are therefore subject to the accuracy and completeness of the information available at the time of the study. Should any further information become available, the analyses and findings of this report should be reviewed accordingly.