Otago Regional Council

Document Id:

MEMORANDUM

To:	**Natasha Pritchard & Sam Walton**
From:	**Pete Ravenscroft**
Date:	**30/8/2023**
Re:	**Fish screening advice**

Name	**Role**	**Date Completed**
Richard Allibone	Reviewer 1	11/11/2023

Purpose

The purpose of this memo is to provide information to inform policy development regarding the management of fish screening. This memo expands on the advice previously provided by Science on Permitted Activity rules dated 5/7/2023.

After this memo Policy has sought additional advice / information covering the following aspects:

1. Add in commentary around the need for case-by-case specificity in the need and design of fish screens in the Otago context.
2. Add in commentary regarding the likely location of fish screens – i.e. off the river and how this is managed by Environment Canterbury (e.g. provision for 15% of flow for bypass, residual flow measured at the point of discharge).
3. Update Table based on Wedge Wire requirements for mesh size. Add commentary on pros and cons of mesh versus Wedge Wire
4. Outline specific minimum requirements for a permitted activity take within a river or lake (e.g. buried pipe at right angles to flow in riffle habitat with a gauze of 3 mm for rivers)

5. Outline the methodology and minimum requirements for determining fish presence within a 150 metre (currently stated as 100 m) radius from the point of take. If you can add in the reference to the 150 m (versus 100 m) guidance as a footnote or reference that would be helpful
6. Outline the minimum requirements if screening for fish presence is not to be undertaken and a fish screen is to be installed (i.e. in accordance with New Zealand Fish Passage Guidelines).

Context/Background

Otago setting

Otago is home to New Zealand's the most diverse native freshwater fish communities with 30species of native freshwater fish (excluding marine wanderers), seven ix sports fish and one other introduced goldfish. The life history strategies of Otago's fish community means they can be broadly split into two categories: diadromous and non-diadromous. Diadromous species migrate between freshwater and saltwater during some stage of their life cycle. Non-diadromous (non-migratory) fish species do not tend to migrate great distances and they complete their life cycle in the confines of freshwater.

Diadromous species can be split into three categories. 'catadromous' (e.g., eels and inanga), live in freshwater, but migrate to sea to spawn, with larvae returning on ocean currents and subsequently entering freshwater as juveniles (e.g., glass eels and whitebait; McDowall, 2000). Inanga are termed marginally catadromous as adults will spawn in estuarine waters. 'anadromous' species (e.g., lamprey) are those where adults live at sea and then migrate upstream from the sea to spawn in fresh water. For these species, the larvae and fry rear in fresh water before migrating out to sea as juveniles. 'amphidromous' species (e.g., large galaxiids and bullies (i.e., bluegill, redfin, common, giant), torrentfish and common smelt) undertake a migration between fresh and salt water for a purpose other than breeding. In general, adults breed in the freshwater environment, with larvae rearing at sea, and then migrating upstream into freshwater as juveniles several months later for growth to adulthood (McDowall 1990).

The non-diadromous species, complete their life cycle within the confines of freshwater. Upland and common bullies do not tend to mitigate but the fry of these fish do drift in the current. There is limited upstream migration of adult non-migratory galaxiids, but, to a varying degree the larvae of all species are exposed to downstream drift.

The life history strategies of fish, be they native or sports- fish, diadromous or non-diadromous, adult, or juvenile or larvae fish requires that they move both upstream and downstream. The distance of this movement between species varies from a 200 m to over a100 kilometres. This movement exposes fish at different life stages to potential entrainment into water intakes.

Hickford (et al 2023) stated "that the fundamental purpose of a fish screen at a water intake is to ensure safe passage for all fishes around, or through, the intake structure within or back to the source river. The screening material is only one part of this process. It is also important that the intake design allows for, and incorporates, known fish behaviours to protect the fish community.

He also added that there is no simple recipe for an effective water intake and fish screen that applies across all situations. The physical conditions (e.g., gradient and flow) and biological conditions (i.e., fish species and life stages present) at every intake are different. Guidelines, such as Jamieson et al. (2007) and this report, can help identify issues and considerations, and provide good reference information, but because each case is different it is not straight forward to go from that fundamental knowledge to a practical solution".

The location of a water intake, and the associated fish screen, should permit the best design attributes to be achieved for the remaining criteria while maintaining infrastructure and fish within the river, or minimising the distance it diverts water and fish away from the natural waterway. The aim is to ensure all native and sports fish remain in natural water bodies where possible, and minimise fish being diverted away from natural habitat.

Table 1. Key criteria required for an efficient and effective water intake and fish screen (Hickford – adapted from Jamieson et al (2007).

Factor	Criteria	Description
Intake location		The water intake is located to minimise exposure of fish to the screen and minimises the length of stream channel affected while providing the best possible conditions for the other criteria.
Approach velocity (through-screen velocity	<0.12ms⁻¹	The water velocity through the fish screen is slow enough to allow fish to escape entrainment or impingement
Sweep velocity	≥5 x approach velocity	The water velocity past the fish screen is sufficient to sweep fish past the intake promptly and into the bypass.
Fish bypass at water intake		A suitable bypass (where needed) is provided so that fish are taken away from the intake and back into the active waterway.
Fish bypass design for connectivity		There is connectivity between any constructed bypass and somewhere safe, usually, the mainstem of the waterway.
Gap openings in intake structure	1.5 mm slot width in lower catchment or other important larval areas 2 mm slot width upstream of tidal areas ≤ 3 mm slot width for all other areas	Screening material and other joins/edges have openings small enough to exclude fish, and a smooth surface to prevent any damage to fish.
Operations and maintenance		The water intake needs be kept operating to a consistent standard with appropriate operation and maintenance.
Upstream fish passage		EITHER the water intake and fish screen does not impede upstream passage of migratory fish species during all flows and does not increase the risk of predation (see Section 4.1.8) OR the bypass outlet impedes fish passage into the bypass and keeps fish in the natural waterway but fish moving downstream through the bypass are not harmed while returning to the waterway.

Data and Methods

Otago context

Coastal Otago water takes.

Takes in the Otago coastal flowing rivers need to consider a relatively large number of diadromous fish species and cater for their different life stages. As many as fourteen different diadromous fish species will be passing through or residing in the coastal areas of Otago rivers. The galaxiids (whitebait) and bullies move out to sea as small larval fish and return as larger, but still small, juvenile fish these fish and are common in the lower reaches of coastal rivers and streams. However, the further upstream you penetrate the less diadromous species there are as some species naturally reside in the lower reaches (or lower gradient reaches) of rivers and streams (e.g., common smelt, black flounder, giant bully, bluegill bully). Other species penetrate well inland (e.g., longfin eel). The upstream limits of all diadromous can be fish passage impediments such as dams or culverts that prevent upstream fish passage further upstream in a catchment. The Clutha River is one example where Roxburgh Dam prevents access of fish past the Roxburgh Dam.

The balance of diadromous fish species compared to non-diadromous of species changes in an upstream direction. There is a greater number of diadromous species closer to the sea. However, even in non-diadromous species migration can take place.

For diadromous species screen requirements also should recognise when and where various life history stages are present. For instance, inanga spawn in the upper tidal reaches and the small larval fish move downstream from the spawning site to sea. These larval fish are only exposed to water takes if the take locations are downstream of the spawning site. Spawning and hatching also only occurs on the day of and up to three days after spring high tides. Therefore, fish screens could consider the larval inanga whitebait if the take is in tidal water with inanga spawning upstream and then only after late summer and autumn spring tides. However, upstream of the spawning areas any water takes, and screen should consider the screen requirements for whitebait (in the spring) and adult inanga in the summer and autumn.

Therefore, fish screen criteria can consider:

- The diadromous species and non-diadromous species present at the take and the diadromous species upstream of the take;
- The life history stages that move past the take;
- The timing of up and downstream fish migration; and
- The size of fish and hence their swimming ability of fish passing a take.

Small Central Otago water takes.

The fish communities in these inland areas are often generally low diversity communities where a species of non-migratory galaxiid or brown trout is present. Most of the streams with non-migratory galaxiid populations have no other fish present in the reach where the galaxiid resides.

The only exception being streams occupied by Central Otago roundhead galaxias where salmonids are almost always present in the same reaches and up and downstream of the galaxiid. If there are no fish passage restrictions longfin eel, lamprey and koaro can also occur in inland streams. Additional sports fish, rainbow trout and brook char are present in some areas and perch are becoming more widespread as irrigation storage ponds and water races provide new habitat or access to new habitat. An additional factor adding to the diversity of some inland fish communities is the ability of koaro and common bully to landlock and form migratory populations that move between lakes and the lake's tributaries.

In general, across Otago, agricultural intensification combined with historic gold mining and water abstraction has led to the to a reduction of surface flows in a number of creeks and rivers. Much of the water taken is transported via various types of water races, generally open channels. These open channel water races have provided a network of permanently flowing water to supply stock water, irrigation purposes and domestic use. Depending on several contributing factors (habitat, substrate, temperature) and the permeance of surface flows, macroinvertebrates as well as fish communities have now become well established in many of these water races. The utilisation of historic mining infrastructure for irrigation purposes is reasonably common, throughout the Central Otago region. Generally, water is taken from high in the catchment, the benefit of taking at this point is two-fold: firstly, it provides sufficient 'head' to transport the water to the desired location, without the expense of pumping. Secondly, surface flows in headwater streams tends to be permanent. Many of these streams as they descend from the foothills and move onto valley floors, can experience a loss of surface flow to groundwater, and many surface flows would naturally disconnect. Another feature of the water race system is that some water race systems connect many streams as some of the water races has been built along an altitude contour and intersects (and generally abstracts from all the streams it crosses. In these cases, with no fish screens at the race/stream confluences, fish can move along the water race to all the connected streams.

Finally for these inland streams fish screening is not simply for the protection of the fish in the stream with the water take. The water races have provided pathways for fish to move upstream and non-migratory galaxiids, koaro and sports fish have gained access to streams that without the water race they would not have reached. To prevent the movement of fish via water races in an upstream direction fish screens or fish passage barriers are required not at the water take location but somewhere downstream where the water race connects to a water body with fish not present in the abstraction stream. This may be either a natural water course or artificial water body such as a storage pond. Therefore, the fish screen consideration should also consider whether unwanted movement can occur in an upstream direction.

One additional feature of the inland Otago fish community is the presence of stunted populations of small stream resident sport fish that do not contribute to the sport fishery. These populations are common in stream used for water abstraction and are often the only fish species present. For the purposes of fish screening, one consideration is whether these populations of no sports fish value require fish screens. They will be required if the water take provides a pathway to a new stream but otherwise fish screens for no-value sport fish populations could be considered unnecessary.

One of the disadvantages of having water takes high up in the catchment is they are exposed to frequent flashy flows, which create bed disturbance. Any associated water take infrastructure is regularly damaged. Therefore, if fish screening is deemed to be necessary, then the screen should be within the water race and outside of the flood plain to avoid frequent flood damage.

With the fish screen installed within a water race this requires a bypass that allows entrained fish passage back to the main-stem of the waterway from which the water was taken. Figure 1 provides a schematic diagram that depicts a typical scenario across the Otago Region.

However, you do need to determine whether the instream value should be bypassed or a simple fish screen at the pump is sufficient to achieve the desired outcome. Therefore, the initial stage in the fish screening process is to determine the local fish community and the diadromous fish upstream of the water take. This will establish the objective of fish screen. (Fish survey method is described within this memo).

Criteria to consider:

- Does the water race have permanent flows. If so, are there resident fish or invertebrate community occupying the water race.
- Does the water race transport water into a sensitive environment .
- Does the water race connect to a waterbody with an undesirable species.
- Is the stream an important spawning stream for a wider sport fishery.
- Can a gauze at the pump provide sufficient protection.

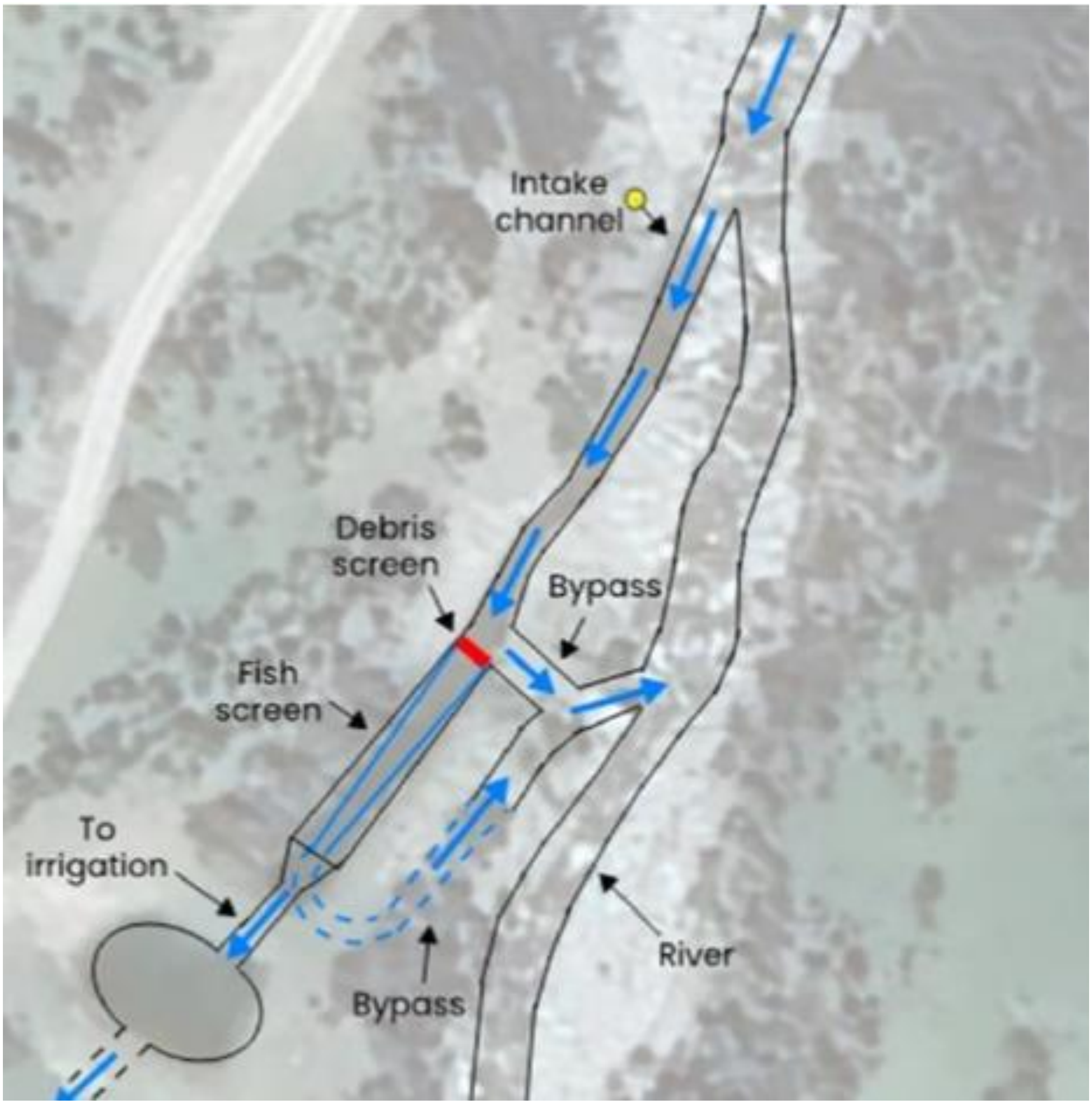

Figure 1: Schematic diagram of a likely water take scenario across the Otago region.

Bypass water

The installation of a fish screen within a water race will require a bypass with sufficient flow that it would adequately provide fish passage for any entrained fish back to the waterway from which the water was originally taken. There could be some unintended consequences of water race bypass:

A consent for a diversion will be required to construct the bypass.

A residual flow condition may be required as a condition as part of the resource consent process for a water take. These residual flow conditions are typically at the point of the water take, with the objective of maintaining instream values downstream of the point of take. The additional water taken to make the bypass fit for purpose, is non-consumptive, in a water allocation sense. However, the reach of stream from point of take to the discharge point of bypass is consumptive to the waterway. During periods of low flows when water takes are restricted and there is insufficient water to provide for a residual flow + bypass water + water take. This could result in less water being available for the water user, as the residual flow will need to be maintained. (NPS-FM 2020 Objective 2.1(a).

When considering the appropriate quantity of water to make the bypass functional would depend on firstly, the distance between the fish screen and the creek. Secondly, there is need to provide sufficient water to attract fish to the bypass. A general rule is 10% of the water allocated however for smaller water takes then there is need to consider increasing the quantity of bypass water. Table 2 outlines a suggested percentage of water required for a bypass in relation to the quantity of water allocated.

Table 2: Calculation of the quantity for bypass water required in proportion to consented water take.

Quantity of consented water (L/s)	**Percentage of bypass water in proportion to water take (%)**
<10	50
10 – 20	30
20 - 40	20
40 - 80	10
>80	10

The original fish screening advice memo (Table 1) captured mesh size for the different fish species and their respective life stages. Table 3 updates this and now includes wedge wire dimensions.

Table 3: Recommended maximum aperture size in intake structures to exclude native and sports fish from freshwater intakes.

Species	Common Name	Life Stage	Mesh Size (mm)	Wedge wire (mm)
Anguilla dieffenbachii *Anguilla australis*	Longfin eel Shortfin eel	Glass eel Elver Adult	1.5 3 3	<1.5 < 2 -
Galaxias maculatus	Inanga	Whitebait Adult	3 3	1.5 -
Galaxias fasciatus	Banded kōkopu	Whitebait Adult	3 3	1.5 -
Galaxias argenteus	Giant kōkopu	Whitebait Adult	3 3	1.5 -
Galaxias brevipinnis	Kōaro	Whitebait Adult	3 3	1.5 -
Gobiomorphus cotidianus	Common bully	Juvenile Adult	3 3	3 -
Gobiomorphus hubbsi	Bluegill bully	Juvenile Adult	3 3	3 -
Cheimarrichthys fosteri	Torrentfish	Juvenile Adult	3 3	- -
Geotria australis	Lamprey	Ammocoete	1.5	- -
Multiple lineages	Non-migratory galaxiids	Juvenile Adult	2 3	3 -
Salmo trutta	Brown trout	Fry	3	
Oncorhynchus mykiss	Rainbow trout	Fry	3	

- Outline specific minimum requirements for a permitted activity take within a river or lake (e.g., buried pipe at right angles to flow in riffle habitat with a gauze of 3 mm for rivers)
- Water take pipe is buried a minimum of 150 mm beneath the bed with a 3mm gauze mesh.
- A pipe is perpendicular to stream flow, with a 3mm gauze mesh and
- in fast flowing habitat (riffle, rapid, cascade)

Establishing the fish species that will move past the intakes is a key criteria for determining the need for a fish screen and or the type of fish screen required. Other considerations are the stage of the fish's life- cycle when it passes past the water take. (i.e. adult, juvenile, larval fish life history stages). Additional useful design information is the time of year fish migrations are likely to pass the intake as it may be possible that a screen is only required for some months of the year.

- To determine what fish species, move past your intake you can:
- Determine the fish present near the intake.
- Refer to the NZ Freshwater Fish Database https://niwa.co.nz/information-services/nz-freshwater-fish-database for information on diadromous fish anywhere upstream of the intake. This is a significant consideration as the diadromous species, no matter how far upstream of the take point must at least twice in their life move past the intake.

Contact your nearest Fish and Game or Department of Conservation Office

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 in the absence of any other data.

- If there is insufficient information available within these websites, databases, then a field survey will need to be undertaken. If it considered necessary then survey should follow the protocols outlined in: New Zealand Freshwater Fish Sampling Protocols "*Wadeable Rivers and Streams*" (Joy, M. David, B. Lake, M)
- New Zealand Freshwater Fish Sampling Protocols

Fish screen design

There are several research documents now available that provide guidance in determining the key criteria provided in Table 1:

- Toward national guidance for fish screen facilities to ensure safe passage for freshwater fishes; Hickford. et al (2023.

- Fish screening: good practice guidelines for Canterbury: Jamieson et al (2007).

- Fish screening guidance tool

- [Fish Screens : IrrigationNZ]()

Toward national guidance for fish sc

fish-screen-guideli nes.pdf

TEMPLATE - Fish Screen Guidance To

In the past 15 years fish screening research has made significant advancements, there are tools to assist practitioners, yet fish screening still needs to be considered on a case-by-case basis. To ensure that the fish screens are effective, considerations need to go beyond purely installing a mesh screen at the point of take. To ensure the screen is fit purpose the design, location, mesh type needs to be considered and ideally this should be undertaken by an expert.