Ngā Rerenga ki te Moana

Pathways to the Sea Strategy: Fish passage through pump stations

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

	Name	Date
Approved by:	Pathways to the Sea Project Steering Group, Waikato Regional Council (Greg Ryan, Dave Wade and Mike Scarsbrook)	15 October 2024
Adopted by:	Integrated Catchment Management Committee, Waikato Regional Council	7 November 2024

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Publication date	November 2024
Document ID	24017153

Acknowledgement

The success of Pathways to the Sea (PTTS) would not have been possible without the support of our iwi and funding partners. Our funding partners include:

Bay of Plenty Regional Council
Department of Conservation
Environment Southland
Greater Wellington Regional Council
Hawkes Bay Regional Council
Lottery Grants Board
Marlborough District Council
Ministry for Primary Industries
Nelson City Council
One New Zealand (Vodafone)
Waikato Catchment Ecological Enhancement Trust
Waikato River Authority
Waikato-Tainui College for Research and Development

Additionally, support from our internal Waikato Regional Council operations, asset management, science, communications and business support teams has been second to none. We have had a range of summer students help with this project including Amy Yasutake-Watson, Aiden Rowlingson, Lauren Empson, Abbie Chaytor and Olivia Avery.

Multiple iwi, hapu and mana whenua have been involved since the inception of this project and have provided extremely valuable insights, feedback and fieldwork assistance. Waikato-Tainui College for Research and Development provided significant funding for the modified MacEwans pump project. The Te Kauwhata eel factory was extremely helpful with the supply of live eels for two of our research projects and Duncans Canvas designed, built and installed multiple eel catch nets. Multiple landowners must be thanked for allowing access over their land.

This project would not have been possible without Mike Lake and Peter Roberts forming the project and guiding the research direction. Many key people were involved in reviewing reports, providing guidance and fieldwork assistance, that were not part of the PTTS team, such as Bruno David, Michael Pingram and Josh Smith. Finally, thank you to our external reviewer from Horizons Regional Council.

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Executive summary

Flood control and land drainage schemes were extensively installed throughout Aotearoa New Zealand over 50 years ago to maintain ground conditions suitable for agriculture. At the time little consideration was given to the ecological impacts. Today, we recognise the need to operate the schemes within a broader set of objectives. This directive for change has come about because of strong legislative requirements, increased public awareness, large scale fish kill events, community expectations, new research and information, and the availability of new pump technologies.

Studies overseas and in Aotearoa have shown the devastating impacts that traditional pumps can have on native fish, in particular larger species like freshwater tuna. Within the Waikato region, research at Orchard Road and Steiners pump stations clearly demonstrated that traditional pumps inflict high mortality and injury rates. European countries have set a strong statutory response to a significant decline in the eel population. The provision of fish passage through infrastructure is now standard practice (if not mandatory) in some European countries. While the statutory response in Aotearoa has improved, regional councils and scheme managers also need to start implementing measures to improve fish passage through pump stations.

To help combat these effects, the Pathways to the Sea (PTTS) programme was formed in 2019, with the overarching mission to improve the safe downstream passage of fish at Waikato Regional Council (WRC) pump stations. As part of the programme, international research and relevant legislation was reviewed, and mitigation tools and new pumping systems were tested. Mitigation tools tested included trap and transfer, an electric barrier, gravity bypass outlet, and a passive acoustic tool. New pumping systems tested included a modified MacEwans pump, Encased Archimedes Screw pump and Bedford submersible pump. A tuna behavioural study was also undertaken.

This strategy brings together all the research and development undertaken as part of PTTS. Collation of this information guides decision making within an Aotearoa context, providing significant guidance, both internally and externally for other regional councils, territorial authorities, stakeholders and industry.

A review of legislation has highlighted that there is significant risk to WRC if non-fish friendly pumps continue to be installed. This is because they are non-compliant under the Waikato Regional Plan and objectives of the NPS-FM (2020), which require safe fish passage. Replacing pump stations on a like for like basis is no longer the default option and traditional axial pumps generally have no place in our schemes.

The best means of reducing the impact of pump stations on downstream migrating fish is to use mitigation tools to either prevent fish from entering pumps and provide a safe and effective alternative route or install fish friendly pumps. Trap and transfer was successfully employed as a mitigation tool at two pumped catchments in 2024 and is a considered simple and effective tool until fish friendly pumps are installed. This method is a key area where iwi, hapu and mana whenua can be actively involved in the work.

The tuna behavioural study demonstrated the importance of gravity bypass outlets as a safe alternative passage, when the floodgates are open (and the pump is not in use). Tuna actively used the outlet to leave the system as well as re-enter. This is currently the only option for upstream passage at pump stations and should only be included at sites with fish friendly pumps. The behavioural study and international literature also indicate that operational changes to pump stations could play an important role in reducing fish mortality and injury. Operational changes such as turning pumps off during dusk and keeping floodgates open for longer periods of time, should be further scoped and trialled.

Trials of new pumping systems clearly demonstrated the success of the encased Archimedes screw pump (EASP) and modified MacEwans pump. These pumps are 97-99% effective at passing tuna without injury or mortality and are the most fish friendly pumps on the market for use in Aotearoa. These results are a significant milestone for flood pumps in Aotearoa, particularly the modified MacEwans pump, which is locally manufactured and can be installed at a much lower cost than overseas manufactured pumps. The EASP and modified MacEwans pumps are the preferred options for pump replacements, particularly at sites with high ecological and cultural values.

The fish friendly submersible Bedford pump provides some advantages over traditional axial pumps in terms of reduced mortality however it still inflicts considerable injury. This pump is not recommended; however, the larger version should be trialled to see if lower injury rates can be achieved.

To aid with decision making, a prioritisation tool and decision flow chart were developed. The prioritisation tool ranks all pump stations in the Lower Waikato and Hauraki from highest to lower priority for remediation, based on ecological and cultural values. The decision flow chart guides the user through a range of scenarios to determine the best mitigation or fish friendly pump option.

Implementation of this strategy will be ongoing and will need to be implemented via a number of other Council approved plans and strategies, with associated funding requirements. The strategy must be built into everyday programmes and thinking. Communication with key internal stakeholders is vital to raise awareness of the strategy and shift thinking to balance environmental and operational needs. Long term monitoring and recording is also required for the successful implementation of the strategy. New information should be continually added to the prioritisation matrices and decision flow chart to keep these up to date and relevant.

Besides implementing new technologies such as fish friendly pumps, greater thought and consideration needs to be given to the long-term sustainability of such flood protection schemes given the range of environmental impacts these schemes impose on aquatic life, as well as hydrological disconnections, peat subsidence and water quality effects. In addition to environmental impacts, economic impacts of increasing asset costs and associated scheme rates are extremely important factors to take into consideration over the long term.

PART A: INTRODUCTION & BACKGROUND

Kupu Whakataki, Kōrero Horopaki

1 Introduction

Over the last 150 years, humans have made significant changes to the landscape across Aotearoa New Zealand, with the clearance of many hundreds of thousands of hectares of native forests, and significant draining of wetland systems, generally to create open pasture environments. In place of natural wetlands, land drainage and flood control schemes have been constructed to maintain ground conditions suitable for agriculture. The schemes include infrastructure such as stop banks, pump stations, floodgates, control gates and detention dams. Flood control schemes have also been established to protect communities from extreme flood events. Schemes are typically operated by regional councils and territorial authorities on behalf of landowners who benefit directly from their operation. The schemes often require intensive management to maintain suitable ground conditions throughout the drier months, while preventing elevated water levels during the wetter months and flood events.

Many of the schemes in Aotearoa were installed in the 1950s and 60s when flood and drainage management goals were the primary objectives. Today, we recognise the need to operate the schemes within a broader set of objectives, that also take environmental factors into account, such as the impacts on migratory fish species.

These schemes are now home to taonga species such as freshwater eels (tuna). Tuna are migratory fish, meaning that they have to undertake extensive migrations between fresh and saltwater environments to complete their lifecycle. The installation of barriers such as pump stations, control gates, detention dams, culverts, weirs and hydro schemes can delay and impede upstream and downstream fish migrations (note: not all installed infrastructure are barriers). Pump stations in particular can have a devasting impact on fish species, killing and injuring fish that pass through them. It is important to understand taonga species and their inherit right to safe passage and a healthy habitat, when managing drainage and flood control schemes.

The best means to enable the safe downstream passage of fish would be to remove pump stations completely; however, pump stations fulfil an important role and this is not often a possible option. Instead, new technologies such as fish friendly pumps can be implemented.

Waikato Regional Council (WRC) has started the journey improve the safe downstream passage of fish via the ‘Pathways to the Sea’ (PTTS) programme. This Strategy describes the programme, documents the research and recommends actions moving forward.

2 Background

2.1 The importance of tuna

The most apparent effects of flood control schemes can be seen in freshwater tuna. They are the largest and most commonly found migratory species within scheme areas in Aotearoa. Tuna are integral species to the health and wellbeing of freshwater ecosystems and play a crucial role as the apex predator.

Tuna are taonga to Māori. They are important to tangata whenua for mahinga kai (food gathering) and manaakitanga (hospitality), and considered kaitiaki (guardians) of streams, rivers and lakes, and an indicator of health and wellbeing. Tuna also comprise a valuable commercial eel fishery in Aotearoa.

There are three species of tuna in Aotearoa – shortfin (*Anguilla australis*), longfin (*Anguilla dieffenbachia;* Figure 1) and the Australian spotted longfin tuna (*Anguilla reinhardtii*), however the latter is rarely found and when found, is often mistaken for a longfin tuna. The focus of this strategy is on shortfin and longfin tuna.

Nga taonga tuku iho – te tuna
The eel – an ancient gift from the gods

Figure 1: Image of a longfin tuna

Tuna are slow growing and long-lived, with longfin tuna living up to 80 years old, and historic records of females reaching up to 2 metres in length and weighing up to 40kg. In present times, tuna reaching 1.4m and around 15kg is around the upper limit now found. Tuna have a complex catadromous life cycle - they live in freshwater and migrate to saltwater to spawn. Tuna spend the majority of their lifecycle in freshwater environments (streams, lakes, rivers and wetlands) before maturing and undertaking long migrations into the South Pacific Ocean where they spawn and die. Tuna heke (adult migratory tuna) typically migrate downstream during late summer and autumn, with migrations triggered by large rainfall events, increases in catchment flow and dark phases of the moon. Once tuna have travelled downstream out of freshwater systems to the open ocean it is thought they migrate northwards near Tonga to spawn. After spawning, fertilised eggs develop into larvae called leptocephali which swim with the help of oceanic currents back towards Aotearoa estuaries, streams and rivers, at which stage they are known as glass eels. During the upstream freshwater migration, glass eels develop pigmentation and their skin darkens - they are then known as elvers or juvenile tuna. Elvers are good climbers and migrate further upstream, colonising inland streams, lakes and rivers.

Longfin tuna appear to be better climbers than shortfin and will often penetrate further inland. Longfin prefer cooler water temperatures, harder substrates and high dissolved oxygen levels. Shortfin tuna are more tolerant of poor water quality, and hence are the main species found in the lowland areas where flood control schemes are present. Although pump stations provide a barrier to upstream passage, there is evidence that tuna are being reseeded in some areas. It is uncertain how this is happening, but possibilities include commercial fishers reseeding catchments, movement overland and during floods, or leaky pump stations. This is an important fact and shows that excluding tuna from schemes isn't an option.

Longfin tuna are classified as 'At Risk - Declining' under the Department of Conservations freshwater fish threat classification system (Dunn et al 2017). This means that although they aren't considered threatened, they could quickly become so if their decline continues or if new threats arise. Shortfin tuna are classified as 'Not Threatened' under the same classification system.

The downstream migration in late summer and autumn is the key risk period for tuna mortality through pump stations. As tuna heke travel downstream they can encounter flood scheme infrastructure, including pump stations. Downstream migration is typically triggered by rainfall and increased flow events - these events often coincide with pump operation. Tuna can be entrained in the pump and severed into multiple parts as they pass through, making survival or passage without injury unlikely. Mortality and injury at pump stations therefore pose a significant threat to native fisheries internationally and nationally within Aotearoa. A recent study found 64% (64 eels) mortality of large migrant shortfin tuna when passing through one lower Waikato traditional axial pump station (Vaipuhi Freshwater Consulting 2017) and another with 84% (66 eels) having some level of injury or mortality (Lake & Williams 2020).

Injury and mortality can, however, occur at any time throughout the year when tuna are foraging after heavy rainfall events and the pumps are operating. It is likely that the same mortality and injury effects are happening to other native fish, although to a lesser extent, given their smaller overall body size and low overall presence in drainage systems due to poorer water quality and habitat availability. Tuna are particularly at risk to mortality and injury through pump stations because of their size and migratory behaviour. They are also the species for which previous observations have been made and information collected on the impacts of pump stations both within Aotearoa and overseas.

2.2 The need for change

While the impacts of flood pumps on native fish have been occurring for decades, the severity of effects has not been well understood nor managed. In recent years, a greater appreciation of these effects has led to a substantive case for change to better understand and manage the impacts of flood and drainage scheme infrastructure (Figure 2).

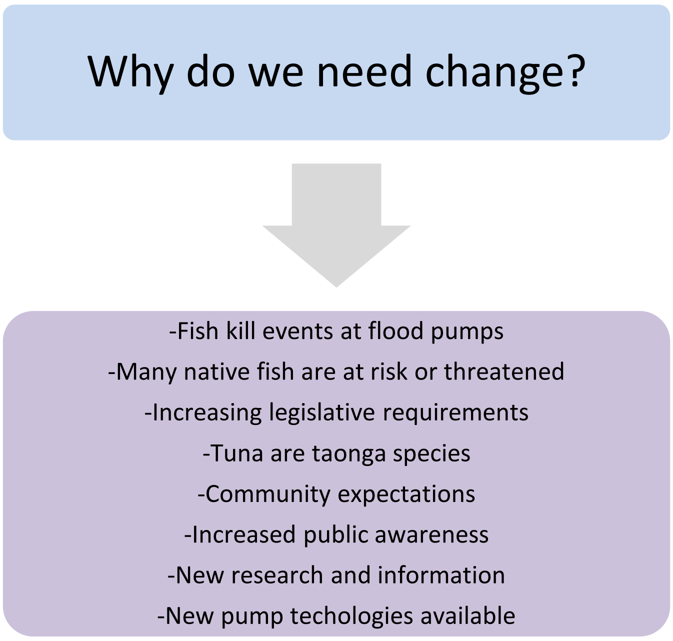

Figure 2: Why change is required when managing flood control schemes

A significant fish mortality event occurred at Motukaraka pump station in the Waikato region in 2015, killing and injuring large numbers of tuna. The significant scale of this event and compliance processes triggered a review of schemes nationally by Duirs in 2017.

The study made some important conclusions:

- The adverse effects of flood scheme activities on native fish cannot be overlooked and there is a need for scheme managers to begin to factor these requirements into design, maintenance, and budgeting for their land drainage infrastructure.
- Based upon the typical configuration and components of schemes in Aotearoa, it is reasonable to assume that adverse effects are relatively common and are resulting in both direct mortality and significant reductions in habitat utilisation by native fish.
- Scheme managers need to start considering and implementing measures to maximise fish passage through drainage scheme infrastructure in accordance with best practice methods.
- The implementation of fish passage measures are likely to present significant additional costs and will likely determine the need to reconsider current management and maintenance practices at drainage scheme sites.
- If remedial options are not considered and implemented, adverse effects on the native fisheries will continue and environmental compliance or enforcement actions should be anticipated.

Waikato Regional Council subsequently initiated the PTTS programme in 2019. The mission of PTTS is to provide native fish with safe passage to the sea for migration and spawning and will be achieved through a clear goal:

***Improved safe* downstream fish passage at Waikato Regional Council managed pump stations**

The objectives of PTTS are to:

a. Undertake research and test new tools to improve downstream fish passage at pump stations.
b. Develop a strategy (this document) to guide future decision making for the management of new and existing infrastructure to achieve better fish passage outcomes.

There are several assumptions underpinning the programme. Key elements in scope include - all native fish species, but the primary focus is on tuna because as the largest of our native fish, they are a good representative of fish requiring downstream migrations as adults. Key elements out of scope include upstream fish passage, fish passage through other pump stations not managed by WRC, passage of exotic fish species, and other barriers such as culverts.

Note: nationally there has been little work or research into a cost-effective solution for upstream passage of native fish. This is something that requires further investigation and investment.

2.3 How do we achieve our goal?

In order to achieve our goal, we need to identify the issues that we want to address, the outcomes we seek to attain, and how the outcomes will be achieved (Figure 3). This Strategy aims to do this.

Issues:	Outcomes:	How will the outcomes be achieved:
Uncertainty on WRC's legislative requirements	Clear direction on WRC's legislative requirements	Review the legislation - see **Part B**
Uncertainty on fish friendly options and tools currently available	Knowledge on fish friendly options and tools	Research existing tools and work with industry to develop new tools - see **Part C**
WRC's large number of pumped catchments and inability to upgrade them all at once	An approach to prioritise pump upgrades and mitigation	Develop a prioritisation matrix to prioritise pumped catchments for upgrade and mitigation - see **Part D**
Uncertainty on when and where to use the tools	Direction on when and where to use appropriate tools	Develop a decision support tool - see **Part D**
Lack of WRC direction on fish passage	Agreed direction on fish passage moving forward	Engage with stakeholders (see **Section 2.6**), provide recommendations (see **Part E**) and approval of this Strategy by council

Figure 3: Key issues and outcomes at Waikato Regional Council managed pump stations

2.4 International context

Land drainage and flood protection schemes

Land drainage and flood protection schemes are found around the world, particularly in countries with low-lying geography, intensive urban sprawl and land use change associated with pastoral productivity. Examples of extensive schemes in Europe are discussed below, including the Netherlands, Germany and the United Kingdom.

The Netherlands likely has one of the most well-known and long-established schemes which includes a network of leeves, dykes, dams and around 4,600 pump stations. Approximately two-thirds of the Netherlands is vulnerable to flooding, with half of the rainwater that falls requiring pumping out of the catchment, to stop the country going underwater (Wabe Jager of Landustrie Sneek BV *pers comm* in Duirs 2017). With the intensity and frequency of flooding increasing, the Netherlands government started the 'Room for the River' project in 2007 which provides more natural and sustainable measures to give rivers more space to safely discharge water flowing through them. Tailor made solutions were implemented at 30 locations including relocating dykes further inland, constructing high-water channels, removing obstacles, lowering floodplains, deepening riverbeds and strengthening existing levees[1]. The solutions have allowed catchment areas to be inundated during high water levels, mimicking a natural floodplain, giving the river more room and easing the pressure on leeves. There are several European and national legislative incentives to protect and improve the fish stocks in the Netherlands.

In Germany, infrastructure-based flood protection, especially dyke/leeve construction and flood pump stations, are an integral part of flood prevention. One scheme in the Ruhr region, is comprised of 180 flood pumps which protect low-lying land from flooding. The low-lying land has formed because of historic coal mining and land settlement (sinking the ground by as much as 20 metres in some places).

[1] Room for the River | The Netherlands

In this extreme case, there are a number of pumps that operate continually over a 24-hour period, to pump the entire river Boye, up 18 meters into the river Emscher[2]. Almost a fifth of the Ruhr region would be underwater if it weren't for pumping. As with the Netherlands, in some places in Germany, there has been a shift to more natural sustainable flood protection measures. The Isar River, which flows through the city of Munich in Germany, was engineered into a straight channel in the 1800s, and by the 1980s and 1990s, the risk of flooding had increased, and the water quality and health of the river was poor. The 'Isar Plan' was launched in 1995 as an integrated approach for flood protection, ecological restoration, landscape design and recreational use. The riverbed was widened, weirs were removed, gravel banks and islands created, and habitat fort fish and birds was restored[3].

In the United Kingdom, risk management plans for flooding see continued investment in infrastructure to improve resilience from flood risk (Department for Environment Food & Rural Affairs, 2021). Investment into these schemes is seen as increasingly important with the effects of climate change resulting in more frequent and intense rainfall events. The United Kingdom has 246,000 flood and coastal risk management assets including pump stations. The Anglian region, eastern England, has more than 450 pump stations, reflecting the naturally low-lying land in the region. Much of the land has been drained for agriculture, lowering the ground level, and increasing the requirement for pumping. Many of the pump stations incorporate gravity outlets, to be used when water levels allow; however, most water is removed from the catchments via pumps (Solomon and Wright 2012).

Relatively recent flooding in Germany and Belgium in July 2021 resulted in the loss of c.220 lives and the cost of clean-up was high with Germany setting aside €300 billion to repair the flood damage[4]. The effects of climate change are likely to result in increased extreme weather events and in turn the risk of flooding. While there is a shift towards investment in nature-based solutions such as restoring wetlands and reconnecting rivers with their floodplains, these measures will likely need to work alongside existing infrastructure such as pump stations. Pump stations play an important role in drainage control, and their widespread removal is unlikely. However, there may be marginal schemes that will become unsustainable to manage or schemes with high ecological benefits where removal may be considered.

Effects on freshwater fish and fisheries management

The effect of land drainage infrastructure on freshwater fish has been a long-standing issue internationally, particularly in European countries. There is a lot of literature internationally documenting the negative effects of pump stations and turbines on fish (Hadderingh 1979, Čada et al 2007, van Esch 2012, Buysse et al 2014, Bierschenk et al 2018 and Bolland et al 2018). One study, which tested damage and mortality of three different turbines across eight sites found that impellor speeds, number of turbine blades and turbulence at the turbine outlets were the most important factors resulting in damage and mortality (Mueller et al 2022).

Cyprinids and other coarse fish as well as eels are common in European rivers and pumped systems, although the latter makes up a smaller proportion than other species. At least 37% of all European species are threatened. There is an ongoing extinction crisis affecting Europe's freshwater fishes with at least 13 species now globally extinct. The high overall threat level of Europe's freshwater fishes is an indicator for the vulnerability of Europe's freshwater habitats. The European eel (*Anguilla anguilla*) is now classified as critically endangered and has been in decline for several decades. It is thought that the eel may have suffered as much as a 99% decline since the 1980s (Freyhof and Brooks 2011). The cause of the decline has been attributed to many factors including barriers to migration (dams and pump stations), over-fishing, disease and parasites, climate change, predation, habitat loss, pollutants and changing hydrology (Pike et al. 2020).

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[2] The pumps that keep Germany dry
[3] Isar-Plan | Germany
[4] Germany must invest in nature to defend against floods – DW – 02/02/2022

The significant decline in global freshwater eel populations has resulted in the development and implementation of stringent policies in some countries to address impacts on eel populations. Legislation requiring provision of fish passage through drainage assets is now considered standard practice in European countries with an emphasis on measurable fish friendliness. To protect eel populations, the European Union has implemented specific legislation requiring member states to develop eel management plans (EMP). The content of these EMPs differs significantly between the various countries dependent upon the state and value of the eel fishery within the country, with the cessation of the commercial eel fishery and closure of the market in Ireland. Some of the key management requirements implemented through EMPs include screening intakes, stocking of waterways with eels, monitoring populations, fishery-free zones, and the reduction of eel mortality at pump stations and hydro-electric stations.

The measures taken across Europe have had a rapid impact and since 2011 there have been signs that the long-term decline in eel recruitment has halted or even reversed (Dekker & Casselman 2014). Although there has been an improvement, there is still concern over the effectiveness of the EMPs to allow the recovery of eel populations to their historic numbers (European Commission 2020).

In Europe there appear to be more solutions to facilitate upstream migration than downstream passage. Downstream technologies are much less advanced and this is partly due to the focus often being on dams rather than pump stations. Fish friendly bypasses are used internationally as a solution for upstream passage and are often referred to as fishways, fish elevator, fish ladders or fish passes. The principle of an upstream bypass is to divide the height difference of the barrier over a number of steps which are designed at a gradient and flow that fish are able to negotiate (including low flow resting areas) (Moira 2008).

Downstream technologies include fish friendly pumps, screens/barriers and bypasses. Fish friendly pumps are designed to pump water and have the capability to pass live fish and eels without causing internal or external damage. Fish friendly pumps are an emerging technology and some (as shown by our research) are more fish friendly than others.

Changing the operational management of pumping stations has also been indicated in overseas literature (Moira 2008). Pumps can be managed differently in order to minimize damage when fish pass through a pump. The rotation speed of pumps can be lowered, and floodgates can be opened for longer periods of time.

2.5 Aotearoa context

Land drainage and flood protection schemes

Flood control schemes are operated extensively throughout Aotearoa to maintain the productivity of large areas of pasture and to protect communities (Table 1).

Table 1: Flood control schemes operated across Aotearoa

Council	Scheme details
Whangarei District Council	The Hikurangi flood scheme comprises seven pump stations which includes 20 horizontal submersible (Pleuger) and axial pumps (MacEwan, Flygt and KSB), none of which are considered fish friendly. A large-scale fish kill incident occurred within the scheme in February 2016 and has continued to be an issue to present day. Frequent tuna mortality events have been observed. Pump operating protocols have been adjusted to minimise mortality.

Bay of Plenty Regional Council	Owns 13 pump stations and manages another 34 private pump stations, comprising axial and submersible pumps. No large-scale mortality events have been documented, but the assumption is that fish are occasionally killed when the pumps are operating. Some of the pump stations have gravity inlet/outlets and some have tuna screens. A trap and transfer operation has been recently trialled. Fish passage solutions such as fish friendly floodgates have been implemented.
Waikato Regional Council	Operates over 120 pump stations. Most are conventional axial flow impeller driven systems. Two pump stations contain fish friendly encased Archimedes screw pumps, one has a fish friendly modified MacEwans pump and two have Bedford pumps. Two pump stations house traditional open style Archimedes screw pumps. A significant fish kill incident occurred in April 2015 at Motukaraka pump station through traditional axial pumps. See below for further details.
Hawkes Bay Regional Council	Operates approximately 20 pump stations, none of which are considered to be fish friendly designs.
Horizons Regional Council	Operates 22 pump stations on the lower Manawatu floodplain, of which 17 use axial flow pumps. Tuna have been occasionally reported being wrapped around pump shafts. Most (21) of the pump stations incorporate a gravity bypass outlet. The floodgates are being replaced with fish friendly floodgates.
Greater Wellington Regional Council	Operates schemes within the Wairarapa including a significant scheme in the Lake Wairarapa catchment, as well as some smaller schemes within the Kapiti Coast area.
Selwyn District Council	Operates a flood scheme within the Lake Ellesmere catchment and has implemented measures to minimise the potential impacts on native fish.
Environment Southland	Operates a comprehensive flood protection scheme that helps to protect Invercargill city and Invercargill airport. Invercargill airport is close to sea level and is surrounded by a comprehensive drainage network, including stop banks, ring drains and pump stations. The Stead Street pump station is part of this scheme and has been upgraded with two fish-friendly Encased Archimedes Screw Pumps.

Note: this is not an exhaustive list of schemes in Aotearoa (source: Duirs 2017)

Waikato region

The Waikato region has the largest number of pump stations (over 120) operated by any council in Aotearoa, most of which are located within the Lower Waikato and Waihou Piako catchments.

The majority of flood pumps used in Waikato schemes are conventional axial flow impeller driven systems. While these systems are effective at moving water, they can inflict significant damage on fish. Four pump stations contain Archimedes screw pumps - a traditional style at both Motukaraka and Mangatawhiri and new fish friendly encased Archimedes screw pumps (EASP) at Mangawhero and Churchill East. 'Fish friendly' submersible Bedford pumps are present at two sites, Orchard Road and Paeroa Main Drain.

Gravity outlet systems have been incorporated into some pump station designs and can provide an alternative route for fish to pass in and out of the catchment. While these systems are considered better than 'pump only' systems, there is still significant risk to fish when the outlet is closed and the pump is operational.

Most of the pump stations in the Hauraki have a combined pump and gravity outlet system (although due to increased sedimentation in the Waihou Piako river catchments, the floodgates can get silted shut). Most of the pump stations in the Lower Waikato are pump only.

Significant fish kill incidents have been documented in the Waikato, and staff have observed the direct mortality effects at several pump stations. In April 2015 a large number of tuna (estimated at 100-200) were killed at the Motukaraka flood scheme in the lower Waikato River catchment. The dead tuna were mostly shortfin migrants, ranging in size from 400-500 mm. The scheme includes a single traditional Archimedes screw pump and three impeller type axial pumps. The screw pump was disestablished for a short period of time for repairs, however, during the shutdown period, a significant, unanticipated rainfall event occurred which triggered the downstream migration of tuna along with the automated operation of the axial pumps. The incident was formally investigated by WRC's Resource Use Directorate. This incident was one of the key drivers for PTTS.

Effects on freshwater fish and fisheries management

There are a combination of factors contributing to the decline in freshwater fish species in Aotearoa, including habitat loss, water quality and habitat deterioration, barriers and loss of connectivity for migratory fish. Other pressures arise from competition for food and space from introduced species, harvesting, predation, and diseases and parasites.

Aside from the obvious impact of pump stations (direct mortality from passage through the pump), they can also have other effects on fish, particularly tuna. Pump stations can create a barrier to upstream habitats, resulting in the loss and/or fragmentation of this habitat. There are 98 pumped catchments across the Waikato region which support a network of artificial, modified and natural watercourses. Most of the upstream areas comprise artificial drains (approximately 1230km in length based on TOPO50 drains GIS assessment) and include permanent and shallow ephemeral drains. Natural and modified watercourses make up approximately 740km of the upstream areas (total REC2P5). In total this equates to nearly 2,000 km of habitat that is effectively lost and inaccessible to fish because of the presence of pump stations. An example of watercourses that make up one of WRC's largest pumped catchments (Meremere Main) is shown in Appendix A.

The catchments modified by pump stations often result in degraded, low value, homogenous habitat with little or no riparian vegetation and almost no connectivity to the natural floodplain. Water quality is often degraded in pumped catchments, with high temperatures and low dissolved oxygen for long periods of time during low flow conditions. There is also limited flushing ability in these systems, which causes stress and in some cases mortality of species. Under certain conditions, 'black water' events can occur at pump stations, with very low dissolved oxygen levels, resulting in fish deaths. Routine maintenance activities in managed waterways (such as weed or silt removal) can contribute to the degradation of habitat and water quality. This can cause fish mortality, or stress which can affect their condition and therefore ability to successfully undertake their spawning migration.

Tuna were once abundant in the Waikato River catchment but today, this is no longer the case. Tuna fisherman and iwi have been concerned about the decline in tuna numbers for many years. Tuna have been commercially harvested in Aotearoa since the 1960s, expanding rapidly until the early 1970s. Management constraints were introduced in the 1980s following concerns of overexploitation[5]. Commercial catch records reveal a trend of decreasing size of all eels caught with very few large eels being caught nowadays[6].

[5] Tuna - commercial fisheries | NIWA
[6] Extinction Crisis | Manaaki Tuna - Lifeline for longfins (longfineel.co.nz)

The longfin tuna is currently listed as 'At Risk - Declining' due to their predicted ongoing decline, while the shortfin tuna is for now, not a threatened species. Shortfin tuna are the most abundant species found above pump stations and although they are not currently listed as having a declining population their numbers are likely to have significantly reduced since European settlement from the 1840's onward. This has been caused by a number of pressures, particularly loss of habitat through the modification and drainage of wetlands (with a c.90% reduction in wetlands in some areas)[7].

Historically, much of the fish passage focus in Aotearoa has been on barriers such as culverts, weirs, fords, tide and floodgates. For example, Boubée et al (2001) reviewed fish passage at culverts with potential solutions for native species. More recent advances have seen the development of the New Zealand Fish Passage Guidelines in 2018 with updates in 2024 (Franklin et al 2024), and the Fish Passage Assessment Tool (FPAT).

Aotearoa has only in recent times started its journey to manage the effects of pump stations on native fish. Recent guidance on improving fish passage at pump stations was shared on the Department of Conservation website[8] in January 2023. Note: this was produced based on WRC information from PTTS, which will be explained in further detail in this document.

2.6 Partners and stakeholder engagement

Fish passage issues are not unique to the Waikato region, and there is currently limited information about the effectiveness of approaches to resolve fish passage issues in the Aotearoa context. Given this, other councils around Aotearoa were interested in becoming involved and financially contributing towards the project. The project was fortunate to receive funding from other sources as well, in particular Waikato-Tainui College for Research and Development, who contributed significant funding towards the modified MacEwans pump project. This funding has allowed thorough and robust research and development. The funding partners include:

- Bay of Plenty Regional Council
- Department of Conservation
- Environment Southland
- Greater Wellington Regional Council
- Hawkes Bay Regional Council
- Lottery Grants Board
- Marlborough District Council
- Ministry for Primary Industries
- Nelson City Council
- One New Zealand (Vodafone)
- Waikato Catchment Ecological Enhancement Trust
- Waikato River Authority
- Waikato-Tainui College for Research and Development

[7] Microsoft Word - 25_EEL_09.doc (fish.govt.nz)
[8] Improving fish passage at pump stations (doc.govt.nz)

Engagement was ongoing throughout the project to build support for the tools to address fish passage and share knowledge. Engagement was limited to key stakeholders including Waikato-Tainui and Hauraki iwi, internal staff, council and funding councils. A Consultation and Engagement Plan was prepared to guide engagement activities and identify key messages from the project.

The engagement promise for the project was to collaborate, involve and inform:

- Collaborate: work together with internal staff to formulate solutions and incorporate advice and recommendations.
- Involve: involve Waikato-Tainui and Hauraki iwi, in recognition of the cultural values associated with tuna as a taonga species and co-management.
- Inform: keep our funding partners and council informed on progress made and the final outcomes of the project.

Engagement goals for the project were to:

- Articulate what, why and how of PTTS.
- Understand the expectations of iwi and key stakeholders.
- Fully understand what is needed to make WRC flood infrastructure compliant.
- Collect, where needed, key information to inform the different workstreams.
- Identify and understand proposed decisions iwi and stakeholders might not support.
- Involve local iwi in understanding the outcomes of remediation options through field monitoring opportunities.
- Demonstrate our genuine commitment to making WRC flood infrastructure compliant and improving downstream fish passage or, where this is not possible, undertaking offset mitigation.
- Help shape the PTTS Strategy.

A number of communication methods were used throughout the duration of the project (Table 2).

Table 2: Key methods of communication

Method	Description
PowerPoint presentations	PowerPoint presentations were developed to help communicate background information and status updates to stakeholders. PowerPoint presentations were given to council, internal staff and iwi.
Brochures	A four-page brochure was created to provide 'what, why and how' in a nutshell. The brochure provided a touchstone for conversations and was used to introduce the project to stakeholders and interested parties. The brochure was distributed to people who heard about the project and requested background information.

Newsletters	Newsletters were published one-two times per year, providing an update on progress made to date. The newsletters were circulated to iwi and our funding partners.
Letters	Project introduction letters were sent to iwi and adjoining district councils.
Emails	Email correspondence has been the main form of communication for the project. Emails have been sent to internal staff, funding councils, iwi and landowners.
Photographs and videos	Photographs and videos have been captured and used for reporting purposes, to support media releases, and to tell the story of the project.
Workshops and meetings	Workshops and meetings were held with internal stakeholders and iwi to discuss and get feedback on research and development.
Site visits	Iwi were invited to participate in field work with WRC staff to learn and share knowledge.
Media releases	Media releases were published to communicate PTTS to a wider audience and the community.

Iwi have been engaged and actively involved in the research and development workstreams.

Waikato-Tainui was involved in the trap and transfer research, cultural prioritisation of pumped catchments, and the modified MacEwans pump project. Waikato Tainui College provided interns and resources for the trap and transfer research. The College provided significant funding for the project.

Wāhi Whānui led the blessing of the modified MacEwans pump and had a keen interest in the monitoring work at Huntly Golf Course pump station.

Ngāti Te Ata was involved in the blessing and monitoring of the Archimedes screw pump at Mangawhero pump station. Ngāti Te Ata representatives assisted with the netting and tagging of tuna in the field.

At the commencement of PTTS an informal working group was established with iwi whose rohe included the pumped catchments within the Waihou and Piako river schemes, including:

- Ngāti Maru
- Ngāti Tamaterā
- Ngāti Whanaunga
- Ngāti Tara Tokanui
- Ngāti Rāhiri Tumutumu
- Ngāti Paoa Iwi Trust
- Te Ruunanga O Ngāti Pu
- Te Kupenga o Ngāti Hako Inc
- Hauraki Māori Trust Board

The aim of the group was to provide input and guidance on cultural aspects within the Hauraki rohe. The group was involved with two projects - tagging of tuna at Steiners pump station and cultural prioritisation of pumped catchments.

Hauraki iwi representatives were involved in trial blessings and field work at Steiners pump station, building knowledge and information sharing between iwi and staff. As part of the prioritisation of pumped catchments, Hauraki iwi helped in the field to ground truth the ecological values. Multiple hui have also occurred and will continue to ensure that there is agreement between both Hauraki iwi and WRC on cultural priorities.

Upon completion of the draft version of this Strategy, engagement and consultation with iwi, mana whenua, and internal stakeholders was undertaken to allow review of this document and seek support, consensus and direction on implementation going forward. This was achieved through targeted hui and other forms of communication as had been done previously and continuously throughout this project.

2.7 Focus catchments and pump stations

Pump stations managed by WRC are located in the lowland areas of the lower Waikato and Waihou Piako zones, and as such PTTS is focused on these two areas. These make up two of the eight catchment zones across the Waikato region (Figure 4). The lower Waikato zone consists of the Waikato River catchment between Ngāruawāhia and Port Waikato. The Waihou Piako zone is dominated by the Waihou and Piako river systems.

In the lower Waikato zone, there are a total of 57 pumped catchments (Table 3 and Figure 5). In the Hauraki catchment, there are a total of 41 pumped catchments (Table 3 and Figure 6). Where multiple pump stations drain the same catchment, these pump stations are combined into one pumped catchment.

Figure 4: Catchment zones for the Waikato region

Table 3: Pump stations in the Lower Waikato and Waihou Piako zones

Lower Waikato zone		Waihou Piako zone	
1	Aireys pump station (Franklin Murphy)	1	Ahikope pump station
2	Austins pump station	2	Alexanders pump station
3	Bell Road pump station	3	Appletree pump station
4	Blairs pump station	4	Arnets pump station
5	Churchill East pump station (Holmes)	5	Awaiti South/ Tee Head pump station
6	Churchill East Watts pump station	6	Bancrofts pump station
7	Churchill Secondary pump station	7	Carters Block pump station
8	Deroles pump station	8	Drents pump station
9	Eastern Drain pump station	9	Fisher Road pump station
10	Freshfield pump station	10	Heale Street pump station / floodgate
11	Furniss Downstream pump station	11	Hubbard Road pump station
12	Furniss Upstream pump station	12	Johnstones pump station
13	Golf Course pump station	13	Julians (Island Block) pump station
14	Guests pump station	14	Kaihere pump station
15	Halls pump station	15	Kurere (Komata North) pump station
16	Harveys pump station	16	Louch McDuff pump station
17	Higgins pump station	17	Mangaiti pump station
18	Hills pump station	18	Mangawhero pump station (Piako)
19	Hoods Landing pump station	19	Mill Road pump station
20	Huntly North pump station	20	Ngarua Central pump station
21	Huntly South pump station / floodgate 1	21	Ngatea Town pump station
22	Huntly South pump station / floodgate 2	22	No.10 (Kerepehi North)/ Reservoir Canal/ Kerepehi Extension pump station
23	Huntly South pump station / floodgate 3	23	North Road pump station
24	Island Block North pump station	24	Opukeko pump station
25	Island Block South pump station (main)	25	Paeroa Main Drain pump station
26	Johansens pump station	26	Paul Leonard pump station
27	Kimihia Internal pump station	27	Phillips Road/ Torehape/ Stitchburys pump station
28	Kitcheners pump station	28	Pouarua pump station
29	Lake Hakanoa pump station / floodgate	29	Poulgrains/ Wani Road/ Handleys/ Awaiti West pump station
30	Mangatawhiri Compartment 2 pump station	30	Prices pump station
31	Mangatawhiri Compartment 3 pump station	31	Pukahu/ Roger Harris (H Drain) pump station
32	Mangatawhiri Compartment 4 Main pump station	32	Rangiora Road North pump station
33	Mangatawhiri Compartment 5 (Miller Farlane) – pump station Submersible	33	Rangiora Road pump station
34	Mangawhero (Waikato) pump station	34	Rawe Rawe pump station
35	Manor Park pump station	35	Robinsons (Island Block) pump station
36	Masseys pump station (Franklin District Council: Finleyson)	36	Rolleston Street pump station / floodgate
37	Meremere East Main pump station	37	Rowes East pump station
38	Meremere West Henrys pump station	38	Steiners pump station
39	Meremere West Peters pump station	39	Stocks pump station
40	Motukaraka pump station	40	Waikaka North pump station
41	Muirs pump station	41	Waikaka South pump station / floodgate
42	Okowhao pump station		
43	Onewhero West Drainage pump station		
44	Orchard Road pump station		

45	Orton pump station
46	Parish Polder pump station
47	Pattersons (Horohoro) pump station
48	Rangiriri North pump station
49	Sandy Muirs pump station
50	Saxton pump station
51	Sharpes pump station (Franklin District Council: Harker)
52	Swan Road pump station
53	Tabenels pump station
54	Tuakau pump station / floodgate
55	Vrsaljkos pump station / floodgate
56	Waller Commins pump station / floodgate
57	Whangamaire pump station

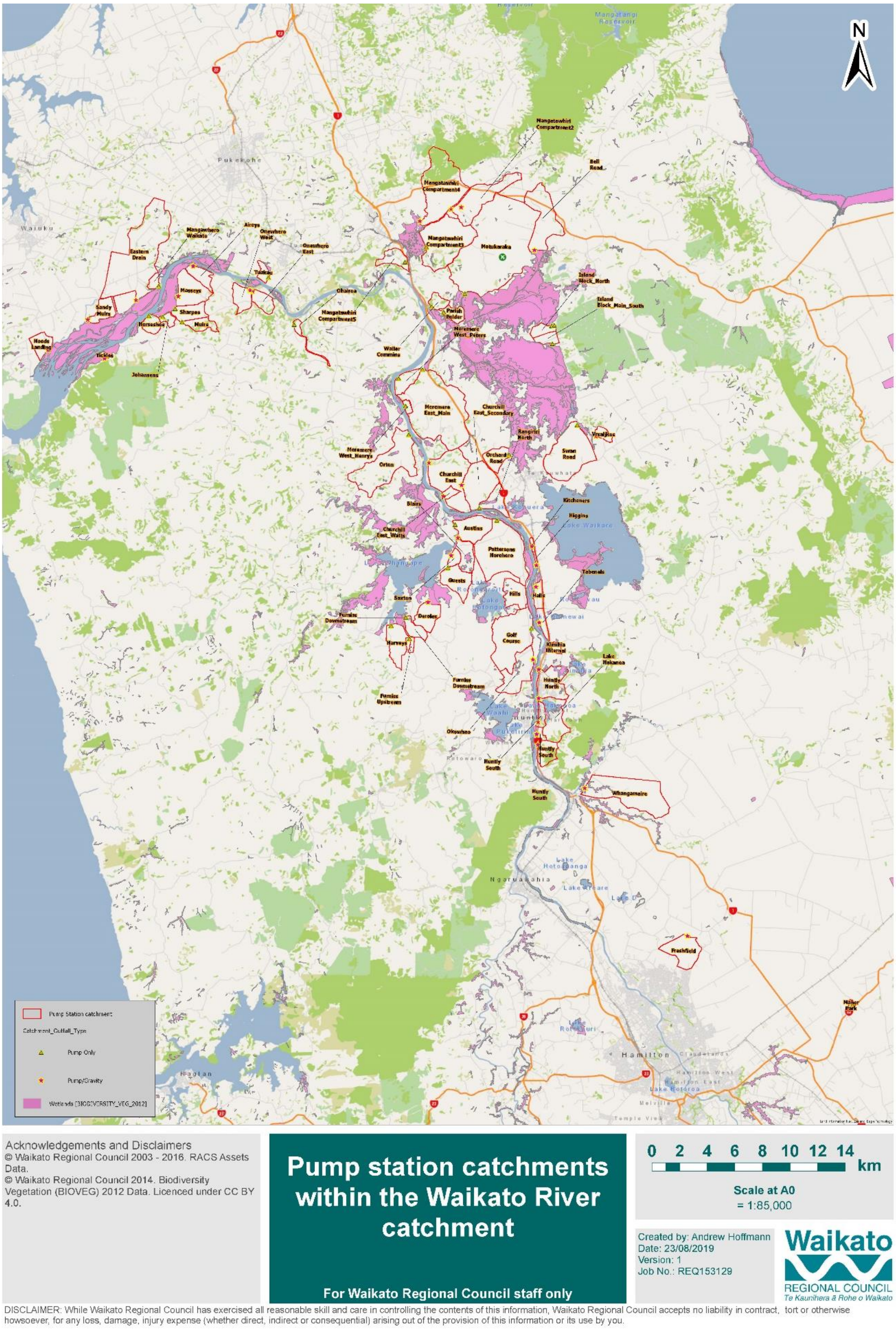


Figure 5: Pump station catchments of the Lower Waikato River scheme

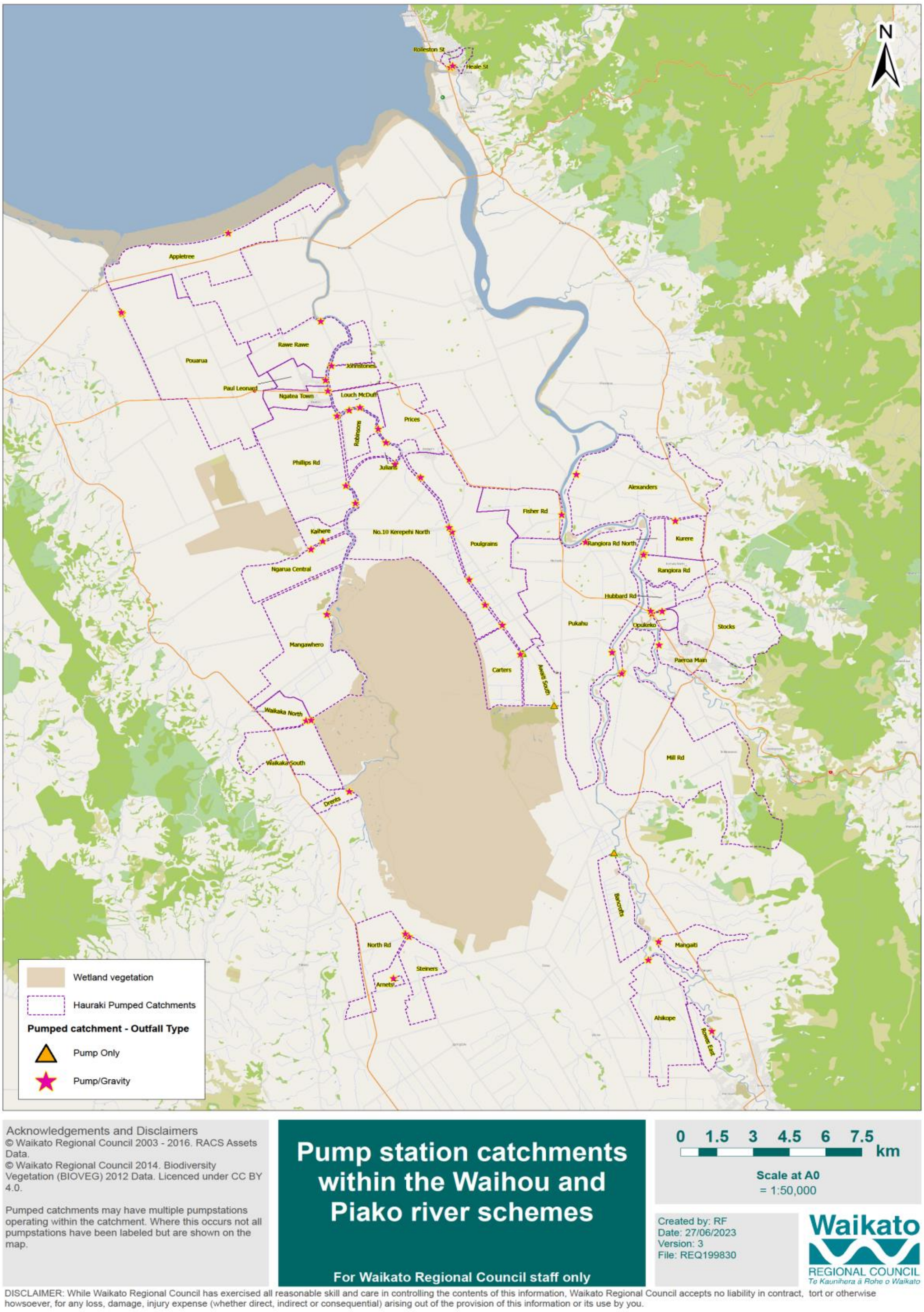


Figure 6: Pump station catchments of the Waihou and Piako River schemes (Hauraki)

PART B: LEGISLATIVE & POLICY FRAMEWORK

Te Pou Tarāwaho Kaupapa Here me te Ture

An external legal review was undertaken as part of PTTS to document current and future legislation relating to fish passage. The below provides a summary of the review.

Legislation is constantly evolving and is driven top down by national direction. Changes in central government can significantly shift the landscape and priorities at a national level (as is currently the case in 2024). Most legislative changes tend to increase standards and operating requirements. Legislative change has and will likely continue to require a greater focus on the environmental health of our land, waterways, native flora and fauna, and the health and safety of people.

Fish passage is currently managed under two regulatory regimes - the Resource Management Act 1991 (and its supporting instruments) and the Conservation Act 1987 and associated Freshwater Fisheries Regulations 1983.

3 Legislation & statutory plans

3.1 Resource Management Act

The Resource Management Act 1991 (RMA) seeks to promote the sustainable management of natural and physical resources, while also requiring that adverse effects of activities on the environment are avoided, remedied or mitigated.

Flood control schemes involve the following activities for the purposes of the RMA:

a. Using, erecting, placing, altering, extending structures in, on, under, the bed of a river; and reclaiming or draining the riverbed (section 13).
b. Damming or diverting water (section 14).
c. The discharge of contaminants or water, into water (section 15).

It is noted that section 13 controls would not apply to activities within an artificial watercourse, while the section 14 and 15 controls relate to 'water' whether or not it is in an artificial watercourse.

All of the above activities must be expressly authorised (i.e. permitted) by a national environmental standard or other regulations, a rule in the regional plan or a resource consent. The key issue in determining the compliance of the schemes with the RMA is whether they are permitted under the National Policy Statement for Freshwater Management (NPS-FM), National Environmental Standards for Freshwater (NES-F) and Waikato Regional Plan (WRP).

The Government is currently taking a phased approach to reform the resource management system. The first two phases are underway and involve the introduction of a Fast Track Approvals Bill and targeted amendments to the RMA. The third phase is to permanently replace the RMA.

3.2 National Policy Statement for Freshwater Management

Of particular relevance to the PTTS project, is the specific direction contained in the National Policy Statement for Freshwater Management 2020 (NPS-FM). The NPS-FM provides councils with direction on how they should manage freshwater under the RMA.

Central to the NPS-FM is the fundamental concept of Te Mana o te Wai which recognises that protecting the health of freshwater protects the health and well-being of the wider environment. The hierarchy of obligations under Te Mana o te Wai prioritises: first, the health and wellbeing of water; second, the health needs of people; and third, the ability of people and communities to provide for their social, economic and cultural wellbeing, now and in the future.

Unlike the NES-F, the NPS-FM does not include rules that are directly enforceable. Instead, the NPS-FM contains objectives and policies that must be given effect to by district and regional plans, and that must ”have regard” to when applications for resource consents are considered (Part 2). The NPS-FM also provides a list of activities that local authorities must do to give effect to the objectives and policies (Part 3). The objectives and policies apply to all freshwater - whether or not it is in a river or artificial watercourse. Accordingly, the NPS-FM would apply to all schemes in the Waikato region (with freshwater i.e. not containing coastal or geothermal water).

Relevant policies include:

- Policy 1 - manage freshwater in a way that gives effect to Te Mana o te Wai.
- Policy 5 - manage freshwater to ensure that the health and well-being of degraded water bodies and freshwater ecosystems is improved, and the health and well-being of all other water bodies and freshwater ecosystems is maintained and (if communities choose) improved.
- Policy 9 - protect the habitats of indigenous freshwater species.

Clause 3.26 addresses fish passage directly. Relevant activities under this clause 3 are:

1. Every regional council must include a fish passage objective in its regional plan.
2. Every regional council must make or change its regional plan to include policies that:
    a. Identify the desired fish species, and their relevant life stages, for which instream structures must provide passage.
    b. Identify rivers and receiving environments where desired fish species have been identified.
3. Every regional council must make or change its regional plan to require that regard is had to at least the following when considering an application for a consent relating to an instream structure:
    a. consistency with the fish passage objective, over the life of the structure.
    b. the extent to which the structure:
        i. does not cause a greater impediment to fish passage than occurs in adjoining river reaches
        ii. provides efficient and safe passage for desirable fish species at all life stages
        iii. provides the physical and hydraulic conditions necessary for the passage of fish
    c. any proposed monitoring and maintenance plan for ensuring that the structure meets the fish passage objective.
4. Every regional council must make or change its regional plan to promote the remediation of existing structures and the provision of fish passage (other than for undesirable fish species) where practicable.
5. Every regional council must prepare an action plan to support the achievement of the fish passage objective. The action plan must:
    a. Set out a work programme for instream structures to achieve the fish passage objective
    b. Set targets for remediation of existing instream structures
    c. Achieve environmental outcomes and target attribute states for fish abundance and diversity

Note: An RMA amendment Bill has made changes to the NPS-FM and the hierarchy of obligations in clauses 1.3(5) and 2.1 are no longer considerations for resource consent decisions.

3.3 National Environment Standards for Freshwater

The National Environmental Standards for Freshwater 2020 (NES-F) sets requirements for activities that could pose a risk to freshwater and freshwater ecosystems. The NES-F contains several rules, including rules in subpart 3 of Part 4 that address the effects on the passage of fish resulting from the placement, use, alteration, extension, or reconstruction of culverts, weirs, flap gates, dams or fords, in, on, over or under the bed of any *river or connected area.* Most WRC schemes are located in artificial watercourses, rather than in a "river or connected area" and therefore the NES-F would not apply.

3.4 Waikato Regional Policy Statement & Regional Plan

The Waikato Regional Policy Statement (WRPS) specifically includes a policy and implementation method on the migratory patterns of indigenous species - providing for and addressing adverse effects on (LF-P3 and LF-M18). The WRPS also incorporates Te Ture Whaimana o Te Awa o Waikato - Vision and Strategy for the Waikato and Waipa Rivers in its entirety.

The key document that provides for the operation of flood control schemes under the RMA is the Waikato Regional Plan (WRP). The WRP contains permitted activity rules providing for the ongoing operation of the schemes subject to compliance with certain conditions. The key permitted activity rules are:

- 3.5.10.1 - take, diversion and discharge of water from drainage and flood control schemes
- 3.6.4.6 - existing lawfully established stopbanks
- 3.6.4.7 - existing lawfully established diversions and discharges
- 3.6.4.8 - diversions and discharges in artificial watercourses and drainage systems
- 4.2.5.1 - existing lawfully established structures

Rules 3.6.4.6, 3.6.4.7 and 3.6.4.8 all contain conditions requiring provision for 'safe passage of fish both upstream and downstream'. Safe passage for fish arguably requires no mortality or injury. Alternatively, it could be assessed in terms of the ability of fish to complete their lifecycle. Pumps that cause 100% mortality are unlikely to meet this condition but pumps that cause minimal mortality may (arguably) meet this condition.

Of the approximately 120 pump stations in the Waikato, only four (Mangawhero, Motukaraka, Orchard Road and Muggeridges) are authorised to operate under resource consents. The remainder were existing structures when the WRP was notified in 1998 and are therefore lawfully established provided they comply with the permitted activity rules.

If resource consents are required to authorise a new pump, the NPS-FM and relevant WRP provisions would apply. It would be challenging to obtain consent for flood pumps that are non-fish friendly, given the directive to maintain and improve fish passage. However, pumps that cause some fish mortality may arguably be acceptable in some cases, again depending on degree to which the fish's lifecycle is impacted, and Council's ability to show that it is taking steps to 'improve' the quality of freshwater ecosystems.

The WRP is currently being reviewed to give effect to the NPS-FM. The implications for schemes could be significant and may lead to more stringent requirements to enable fish passage. In the meantime, a new objective has been inserted in the WRP, and all current provisions should be interpreted in ways that are consistent with the NPS-FM. Any resource consent applications to authorise replacement flood pumps will need to "have regard" to the NPS-FM.

The new objective in the WRP is as follows:

> *Objective 3.A.1: Fish Passage*
>
> *The passage of fish is maintained, or is improved, by instream structures, except where it is desirable to prevent the passage of some fish species in order to protect desired fish species, their life stages, or their habitats.*

3.5 Conservation Act

The Conservation Act 1987 promotes the conversation of New Zealand's natural and historic resources. The Department of Conservation has specific responsibilities under the Act to manage freshwater fish. Under Section 6, the Department of Conservation is required, as one of its functions, to *"preserve so far as is practicable all indigenous freshwater fisheries, and protect recreational freshwater fisheries and freshwater habitats"*.

Section 48A(1) of the Conservation Act allows special regulations to be developed, for the following purposes:

- (n) requiring and authorising the provision of devices and facilities to permit or control the passage of freshwater fish or sports fish through or around any dam or other structure impeding the natural movement of fish upstream or downstream.
- (na) Prohibiting, restricting or regulating any structure or alteration to a water body that could impede or affect the passage of freshwater fish.
- (r) In relation to indigenous fish - specifying activities that are reasonably likely to injure or kill specified indigenous freshwater fish and regulating, restricting or imposing conditions on those specified activities that are necessary to prevent the killing or injuring of those fish.

Currently, no regulations have been made pursuant to (na) and (r) of section 48A. However, it is possible that in the future regulations could be made that would apply to flood control schemes.

3.6 Freshwater Fisheries Regulations

The Department of Conservation also has responsibilities under the Freshwater Fisheries Regulations 1983 to manage fish passage in any natural New Zealand waterway. This applies to physical barriers (i.e. dams, diversion structures, culverts and fords) in any natural river, stream or water. The regulations generally apply to all structures built after 1 January 1984, however, regulation 42(2) (i.e. the occupier of any land shall maintain any culvert or ford in any natural river, stream or water in such a way to allow the free passage of fish) can be interpreted as applying to all culverts or fords regardless of age.

It is considered that a flood pump is both a 'dam' and a 'diversion structure' under the Regulations, as it is designed to direct or control water and divert or abstract water. Replacement of a pump would trigger Regulation 43 if it can be regarded as a 'proposal to build' a dam or diversion structure. If so, the Director General of Conservation must be notified who then decides whether a fish facility should be provided in accordance with Regulation 44.

The extent to which the regulations apply to existing scheme structures is not clear. The Department of Conservation's advice is that each structure must be assessed on a case-by-case basis to understand the impacts and that different locations may have different requirements.

3.7 Animal Welfare Act

While tuna are not considered to be wild animals (as defined by the Wild Animal Control Act 1977), they may meet the definition of 'animals in the wild state'.

The only provision that may relate to pump stations is under Section 30A of the Animal Welfare Act 1999, which relates to wilful or reckless ill-treatment of wild animals or animals in wild state. This may be offset by section 30(4) where Council is performing functions for the purpose of another Act (e.g. Land Drainage Act).

3.8 Te Ture Whaimana o Te Awa o Waikato - The Vision and Strategy for the Waikato River

Te Ture Whaimana o Te Awa o Waikato applies to the Waikato and Waipa rivers and is incorporated into the WRPS. The WRP must give effect to the WRPS. Te Ture Whaimana is intended by Parliament to be the primary direction-setting document for the Waikato and Waipa rivers.

The following words form part of the vision for Te Ture Whaimana and are taken from the maimai aroha, or lament, by Kīngi Tāwhiao, the second Māori King:

Tooku awa koiora me oona pikonga he kura tangihia o te maataamuri
The river of life, each curve more beautiful than the last

The Strategy sets out 13 objectives that will be pursued, including:

1. The restoration and protection of the health and wellbeing of the Waikato River.
2. The adoption of a precautionary approach towards decisions that may result in significant adverse effects on the Waikato River, and in particular those effects that threaten serious or irreversible damage to the Waikato River.
3. The recognition that the Waikato River is degraded and should not be required to absorb further degradation as a result of human activities.
4. The protection and enhancement of significant sites, fisheries, flora and fauna.

As outlined in the objectives, the Strategy requires the 'restoration and protection of the health and wellbeing of the Waikato River' including the 'protection and enhancement of significant fisheries'. Overall, this supports a view that effects on fish passage should be reduced over time.

3.9 Treaty Settlement Legislation

Treaty settlements may place obligations on local authorities and how they exercise their functions under the RMA. When implementing regional policy statements, regional plans, and district plans, local authorities will need to give effect to any relevant Treaty Settlement obligations.

Legislation relating to the Waikato and Waipa rivers include:

- Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010[9]
- Ngāti Tūwharetoa, Raukawa and Te Arawa River Iwi Waikato River Act 2010[10]
- Ngā Wai o Maniapoto (Waipā River) Act 2012[11]
- Maniapoto Claims Settlement Act 2022[12]
- Ngāti Tūwharetoa Claims Settlement Act 2018

The three river acts, amongst other objectives, establish a management framework to restore and protect the Waikato and Waipā river catchments, primarily through the Vision and Strategy, Te Ture Whaimana o te Awa o Waikato.

[9] Waikato-Tainui Raupatu Claims Settlement Act 2010
[10] Ngati Tuwharetoa, Raukawa, and Te Arawa River Iwi Waikato River Act 2010
[11] Nga Wai o Maniapoto Act 2012
[12] Maniapoto Claims Settlement Act 2022 No 50, Public Act – New Zealand Legislation

The recently enacted Maniapoto Claims Settlement Act 2022 contains provisions similar to the Nga Wai o Maniapoto (Waipā River) Settlement Act 2012 which outlines Joint Management Agreement (JMA) provisions for considering applications for resource consents; monitoring and enforcement activities; and preparing, reviewing, changing or varying a RMA planning document.

The Ngāti Tūwharetoa Claims Settlement Act 2018 provides for the establishment of a statutory joint committee and in preparing, reviewing, varying or changing a regional policy statement, regional plan or district plan, a local authority must recognise and provide for the vision, objectives, values and desired outcomes in Te Kaupapa Kaitiaki. Te Kaupapa Kaitiaki is a catchment plan for the Taupō catchment developed by the joint committee and made operative in November 2022.

4 Non-statutory policies & plans

4.1 Iwi Environmental Management Plans

Some iwi/hapū have produced environmental management plans. Iwi environmental management plans lodged with a regional council must be taken into account under the RMA as part of council decision making when preparing or changing a regional planning instrument. There are several environmental plans that cover the lower Waikato and Hauraki scheme areas.

Tai Tumu, Tai Pari, Tai Ao – Waikato-Tainui Environmental Plan (2013)[13] describes the Waikato-Tainui fisheries as taonga. The fisheries provided a cornerstone food source for the tribe. The significance of the fishery resource to Waikato-Tainui cannot be underestimated. The Plan also identifies tuna as taonga fish, stating that taonga fish species are a critical component of achieving a healthy and abundant life for the Waikato River. The Plan sets methods to achieve a coordinated approach to fisheries management (Section 22.3):

- The impacts of resource use and activities on fisheries are considered in any resource use, activity planning and implementation.
- Consideration of the impacts of resource use and activities on fisheries is demonstrated in decision-making.

Whaia te Mahere Taiao a Hauraki – Hauraki Iwi Environmental Plan (2004)[14] recognises the decline of freshwater fish and sets objectives to increase and monitor the recovery of the tuna and whitebait fisheries (Part 3):

- To determine and achieve an acceptable 50% recovery rate for tuna and whitebait fisheries.
- Develop a programme to monitor recovery of the tuna and inanga (*Galaxias maculatus*) whitebait fisheries.

Te Rautaki Tāmata Ao Turoa o Hauā – Ngāti Hauā Environmental Management Plan (2018)[15] also recognises the decline of freshwater fish and the degradation of habitat for our taonga species. The Plan's key freshwater objective is to restore, sustainably manage and enhance our freshwater fisheries. This means that habitat for taonga fish species is restored and enhanced, and fish stocks are healthy and plentiful.

[13] Waikato-Tainui Environmental Plan
[14] Hauraki Iwi Environmental Plan
[15] Ngaati Haua Iwi Environmental Plan

The Ngāti Whanaunga Environmental Management Plan (2019)[16] measures success as an abundance of freshwater taonga and the ability to use freshwater for customary use and mahinga kai.

4.2 Waikato River and Waipa Restoration Strategy

The purpose of the Waikato River and Waipa Restoration Strategy is to guide on the ground activities for all organisations funding and/or undertaking river and catchment restoration activities. The Strategy covers a wider range of restoration and protection activities in the catchment and focuses on six core work streams, including erosion and sedimentation, water quality, biodiversity, fish, access and recreation, and iwi cultural priorities.

5 Summary of key legislative and policy framework

Figure 7 provides an overall summary of the key legislative and policy framework relevant to the management of fish passage.

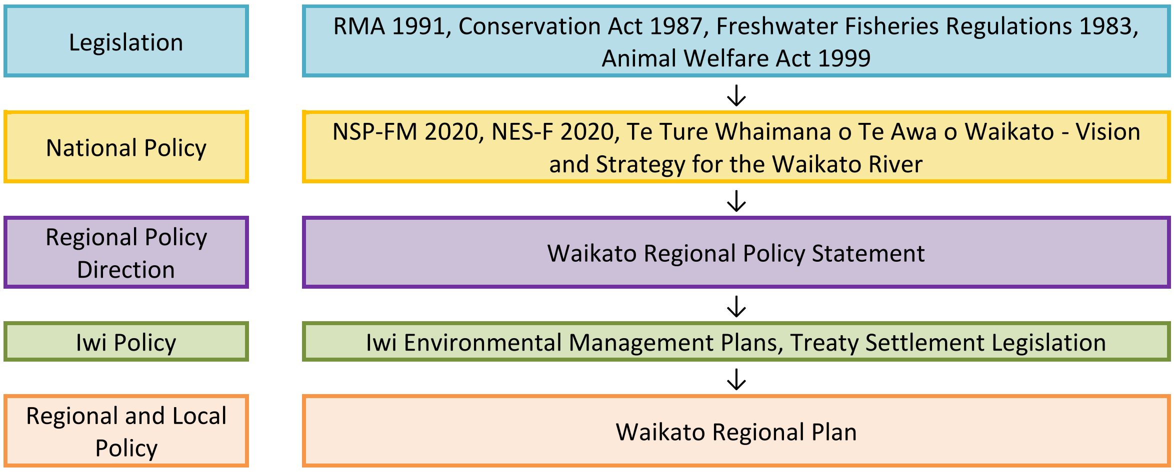


Figure 7: Key instruments relevant to the management of fish passage

Key conclusions from the legal review are:

- Flood control schemes involve activities under the RMA that must be expressly authorised by a national regulation, a rule in the WRP or a resource consent.
- The WRP is the primary source of rules that determine whether the schemes are permitted and, if not, what must be addressed through a resource consent.
- **Existing** flood pumps that cause 100% fish mortality are unlikely to comply with the WRP permitted activity requirement for existing structures to provide 'safe passage' for fish. Fish friendlier pumps may comply, depending on the degree to which they impact fish's ability to complete their lifecycle.
- **Replacement** with pumps that are not fish friendly (i.e. traditional axial pumps) is unlikely to be acceptable and it will be challenging to obtain consent given the directive to maintain and improve fish passage.
- **Replacement** with pumps that cause some injury or mortality (e.g. Bedford) may be acceptable in some cases, depending on the degree to which they impact fishes ability to complete their lifecycle and Council's ability to show that it is taking steps to improve fish passage.
- The WRP must 'give effect' to the NPS-FM, including provisions that seek to provide for fish passage through in-stream structures. When the WRP is reviewed to give effect to the NPS-FM the existing permitted activity standards that apply to schemes may need to be amended, likely making them more stringent.

[16] Ngaati Whanaunga Environmental Plan

- Objective 3.A.1 of the WRP directs that fish passage is maintained and improved. That likely requires that fish passage in degraded environments is improved, which could make obtaining resource consents for flood pumps that do not provide "safe passage" for fish challenging.
- Te Ture Whaimana o Te Awa o Waikato does not contain specific rules relating to fish passage, but it does refer to the ‘restoration and protection of the health and wellbeing of the Waikato River’ including the ‘protection and enhancement of significant fisheries’, and is incorporated into the WRPS, which the WRP must give effect to.
- Under the Conservation Act and Regulations, the Director General of Conservation must be notified of proposals to build flood pumps.

PART C: MITIGATION & REMEDIATION

Te Whakamauru me te Whakaora

The best means of reducing the impact of pump stations on fish is to either prevent them from entering pumps and provide a safe and effective alternative route or install fish friendly pumps. Fish friendly pumps are the ultimate long-term solution at all pump stations for the safe downstream passage of fish. Prior to 2023, fish friendly pumps were not manufactured in Aotearoa, which meant a reliance on imported technologies such as Bedford and Archimedes screw pumps.

With over 120 pump stations in the lower Waikato and Hauraki river systems, fish friendly pumps will require considerable resources and time to implement. In the meantime, temporary measures can be implemented to reduce mortality and improve passage of downstream migrants.

There are a wide range of remedial options available to address the downstream passage of fish at pump stations. These can be categorised into the following areas:

Mitigation tools - interim measures to reduce mortality rates

- Physical barriers to prevent fish from entering pumps e.g. screens, nets and drop structures
- Non-physical behavioural barriers used to prevent fish passage and induce fish movements e.g. electricity, strobe lights, acoustic deterrents, air bubble curtains, water velocity, chemical deterrents, pheromones and magnetic fields
- Harvest and transfer of fish e.g. trap and transfer
- Alternative routes for fish to migrate into and out of the catchment e.g. floodgate and gravity bypass outlet

New pumps systems - ultimate long-term solution

- Alternative pump systems e.g. fish friendly pump

Duirs (2017) provided a comprehensive review of many of these options, including literature from around Aotearoa and overseas. Limited conclusive information was found on the effectiveness of these measures, particularly within the Aotearoa setting which led to the need for further research.

Options selected to be trialled as part of PTTS include:

Mitigation tools
- Trap and transfer
- Electrical barrier
- Gravity bypass outlet
- Passive acoustic tool

New pump systems
- Modified MacEwans pump
- Encased Archimedes screw pump
- Bedford submersible pump

These options are outlined in detail in the following sections.

6 Mitigation tools

6.1 Trap and Transfer

Background

Trap and transfer is the name given to physically capturing and moving fish past barriers (i.e. collecting from one side of the barrier and then releasing them on the other side). Trap and transfer aims to minimise fish mortality, sustain fish stocks and ‘buy time’ while longer term mitigation options are implemented. Involving local communities in trap and transfer initiatives has many cultural benefits as well such as:

- Building stronger connections with waterways.
- Engaging in traditional kaitiaki responsibilities.
- Extending knowledge and understanding of mātauranga Māori in relation to tuna, ka whakauka ngā ika and freshwater ecology.
- Cultivating a deep sense of awareness and responsibility for the sustainable management, protection and restoration of tuna, their habitats and ecosystems.

Trap and transfer programmes are used in Europe and North America to manage the impact of hydro-electric schemes, water takes and flood control on eels (Piper et al 2020). Most overseas examples involve the capture of migrant eels from lake environments or hydroelectric schemes rather than small watercourses such as drains. However, in the Netherlands trap and transfer has been a key method for providing escapement of European eels from land drainage catchments (van der Meer 2012).

In Aotearoa, Meridian Energy carries out trap and transfer to move downstream migrant tuna caught above dams in the Manapōuri and Waitaki hydro schemes. The Manapōuri programme traps tuna from early December to May, using unbaited fyke nets. The programme involves local stakeholders and has delivered good results, with high levels of female tuna migrants (James 2021). Within the Waitaki catchment, Meridian Energy works with Arowhenua, Moeraki and Waihao rūnanga to trap and transfer longfin elver and migrant tuna[17].

There are also examples of commercial fishers incorporating trap and transfer into their harvest philosophies. For example, above the Karapiro Hydro Dam any tuna too large to be commercially harvested are released downstream of the dam.

2020/2021 trial

Research

A trap and transfer study was undertaken in partnership with Waikato-Tainui College for Research and Development to understand the feasibility, cost and benefit of implementing trap and transfer of migrant tuna at pump stations, while also developing the capacity of Waikato Tainui interns. The objectives of the study were to:

- Survey fish communities upstream of selected pump stations to identify a catchment most suitable for a trap and transfer trial.
- Develop a trap and transfer methodology for Waikato-Tainui College interns.
- Fully train interns in the trap and transfer methodology.
- Develop Waikato-Tainui endorsed micro-credentials for the training received by the interns.
- Compare the effectiveness of different net types.

[17] Elver trap and transfer | Meridian Energy

Eight pumped catchments were initially surveyed to identify the most suitable catchment for a trap and transfer trial. The catchments were all located in the lower Waikato scheme area. The greatest fish density was found in the Lake Okowhao catchment (north of Huntly) where there is an effective gravity bypass and consequently this catchment was chosen for the trap and transfer trial. Furthermore, site conditions enabled safe access for setting and checking nets at this site.

The trial was undertaken in December 2020 and January 2021. Different net types were used to compare their effectiveness. Two double-wing fyke nets were set across the channel in front of the pump station and at the outlet of Lake Okowhao. Seven fine mesh single-wing fyke nets were set upstream of the pump station. The nets were deployed before a predicted rain event in December 2020. In January 2021, ten coarse mesh single-wing fyke nets were also deployed further upstream by Lake Okowhao. All captured fish were identified, with those over 100mm measured. Only migrant tuna or those over 2kg were retained and released downstream of the pump station. Smaller tuna and other native fish including banded kokopu (*Galaxias fasciastus*), smelt (*Retropinna retropinna*), inanga and common bully (*Gobiomorphus cotidianus*) were released live at the point of capture.

Full details on the 2020/2021 trial and results can be found in Healy et al 2021.

Results

A total of 64 shortfin tuna were captured in the double wing fyke nets. The majority of these were captured in the net in front of the pump station and on day four of the trial when water levels were falling. Most tuna were classed as feeders and ranged from 100 to 800g. Only two tuna were migrants and transferred downstream.

A total of 71 shortfin tuna were captured in the single-winged fyke nets. As expected, the coarse mesh nets collected fewer fish and no small fish. The fine mesh nets collected numerous small catfish (*Ameiurus nebulosus*). All tuna were feeders and less than 2kg. No transfers were made downstream using this method.

Micro-credentials

Micro-credentials recognise learning that has taken place and skills and knowledge acquired. They work in a similar way to badges that are earned in the Scouts or Girl Guides and may be offered by universities, polytechnics, waananga, industry and private training organisations, employers and professional bodies. Waikato-Tainui College for Research and Development developed micro-credentials specifically to recognise the learning, knowledge and skills that Kaitiaki interns acquired during the trap and transfer project. Five badges were established (Figure 8).

Three interns received certification for achieving all five badges.

Figure 8: Micro-credential badges develop for trap and transfer kaitiaki

2024 trial

Research

A second trial was undertaken in April 2024 at two pumped catchments to better understand the costs, methods and catch numbers - with the overall aim to see if it's feasible to implement an annual programme. A Waikato Tainui contractor was engaged to undertake the work. Two high priority sites (see Appendix C) were selected for the trial including Bell Road and Motukaraka pump stations. The contractor was fully trained with their own monitoring equipment and nets.

The nets were designed by the contractor and consisted of customised wings to match the width of the watercourse. A 10 m single wing net was deployed at Bell Road while a 20 m double winged net was set at Motukaraka. The nets were set with floats to allow air gaps. The nets could be safely deployed and retrieved from the bank, without the need to enter the watercourse. The nets were set over two nights before predicted rain events. The weight of each catch bag was recorded. Tuna were transported and released into the Waikato River.

Details on the 2024 trial and results can be found in Rawiri 2024.

Results

Upstream of Bell Road pump station, 102kg of shortfin tuna were captured and 139kg at Motukaraka pump station (Table 4). In total, across both sites 241kg of tuna were captured, which equates to approximately 345 tuna (based on the average weight of 0.7kg per tuna). The tuna were all in good condition, mostly migrants (approximately 95%), and released into the Waikato River.

Table 4: Shortfin tuna catch records for Bell Road and Motukaraka pump stations

Date	Weight (kg)	Total
Bell Road pump station		
5 March 2024	101.55	
6 March 2024	0.42	101.97
Motukaraka pump station		
15 March 2024	59.1	
16 March 2024	80.35	139.45

The cost to undertake trap and transfer depends on a number of factors including weather conditions, availability of equipment, methods used and the location of the site. For this trial, the contractor had their own field equipment and vehicle, was fully trained, and set nets over two nights. The total cost was approximately $10,000 (or $5,000 per site).

Evaluation

Trap and transfer is a relatively low cost and simple tool that can provide a short-term interim measure for reducing mortality and enhancing downstream tuna migration at pump stations. It has considerable benefits from an iwi perspective and presents major partnership opportunities between councils and iwi. It provides an opportunity for collaboration with iwi partners due to the alignment with kaitiaki aims of iwi and potential to extend traditional knowledge and understanding of mātauranga Māori.

The tool does have a number of constraints though, which should be considered when employing trap and transfer. Trap and transfer of migrant tuna can be labour intensive given the need for manual setting of nets and subsequent transfer of fish, especially when dealing with extended migration periods. It requires the mobilisation of staff for a limited duration, usually at short notice, in response to weather events. The labour requirements, mean that trap and transfer can only be feasibly implemented in a small number of catchments in any given year. Achieving catch rates that are high enough to justify the effort used to capture migrant tuna is also a key concern. Tuna are generally transferred into mainstem habitats downstream of the pump station, and often at or near the Waikato River. While the transfer of feeder tuna into a new habitat may have an impact on the resident fish there, it is anticipated that most of the tuna transferred will be migrants which will continue their downstream journey.

The cost depends on a number of variables and for a totally new start-up operation, the upfront costs for specialised equipment can be costly (e.g. nets, fish bins and bags, health and safety gear, and a suitable off-road vehicle). It is recommended to engage or work with local iwi and use existing equipment held by councils or contractors to keep the cost down.

Results from the trial provided some good insights into the most effective method when employing trap and transfer. A double-winged fyke net set across the channel in front of the pump station proved to be the most productive method, and less labour intensive than using a fleet of single-wing fyke nets. Similarly, the net used in the 2024 trail, set across the channel proved successful with a good catch rate. Double-winged fyke nets, however, will not be suitable for all sites. The fine mesh single-wing fyke nets collected a lot of small exotic species, which was time consuming to process. For any routine trap and transfer, where single wing fyke nets are used, coarse mesh is recommended.

Another key factor aiding in the number of tuna caught, was the falling water levels. For the 2020/21 trial, most tuna were caught on day four of the trial when the water level began to fall. This is supported by customary and commercial fishers who indicate a clear preference to fish in flooded channels as water levels recede.

6.2 Electrical Barrier

Background

An electric barrier is a non-physical barrier which is used to prevent and deter fish passage and induce fish movements to a safer route. An electrical current is passed through the water column creating an electric field which causes a physiological reaction in aquatic species, particularly fish. Behavioural guidance with the use of electric barriers has the potential to be a low-cost method for deterring fish movements toward non, fish friendly infrastructure. Tuna are known to be extremely responsive to electric fields, especially with increasing size.

Three key behaviours (twitch, loss of orientation, and tetany[18]) depend on the field strength and wave form to which the fish is subjected.

Electric barriers to deter or prevent upstream migration are easier to achieve safely. This is because upstream migrants are actively choosing to move upstream and can be discouraged by making the electrical field stronger so fish are temporarily immobilised and swept downstream away from the field. Downstream migrants have a high incentive to move due to strong migrational cues and may be less able to move away from the electrical field.

Internationally, electric barriers have been used successfully to control fish movement and have been applied to solve a wide variety of fish control problems[19]. Low voltage electrical barriers have also shown promising results when combined with physical barriers. Applying an electrical current to bar racks screens has been found to increase fish protection rates, potentially allowing wider bar spacings to be used (Haug et al 2022, Meister et al 2021). A new-generation 'electric fish fence' was found to increase fish turning rates in front of a pumping station in Germany (Egg et al 2019). Miller et al (2022) found a positive correlation between field strength and avoidance of European eels at fish screens, although only tested in flume settings.

In Aotearoa, low voltage electric barriers have been trialled on a few occasions and while anecdotal reports suggest that tuna mortality has subsequently reduced, no robust data has been collected to support that assertion (Duirs 2017). Low voltage electrical barriers have been trialled at the Meremere Main and Motukaraka pump stations in Waikato, Mountain Road pump station in Northland, and several pump stations in the Bay of Plenty. Tuna were reported to have caused damage to Motukaraka pumps located behind the barrier in 2019 suggesting the barrier was not deterring all tuna. Monitoring the effectiveness of the electric barrier at Mountain Road pump station was inconclusive although some promising results were obtained. Vaipuhi Freshwater Consulting (2021) acknowledged that the electrical barrier at Mountain Road has not been fully tested (Lake 2020).

Research

In 2020, an experimental electrical barrier was designed and installed at Steiners pump station in the Piako River catchment on the Hauraki Plains. The pump station services a 398ha catchment, which is almost entirely used for intensive agriculture. The Steiners pump station has two outlets from the catchment, either through the gravity bypass channel or through the MacEwans axial flood pump (Figure 9). This pump station was selected for the electrical barrier trial because it could be integrated with a tuna behavioural study that was already taking place (see Section 6.3).

[18] Tetany is forced muscle contraction which may lead to injury or even death
[19] Electrical Fish Barriers | Gila River Basin Native Fishes Conservation Program

Figure 9: Aerial view of the Steiners pump station showing the two outlets and the direction of water flow (blue arrows). The experimental electric barrier system (orange rectangle) was installed behind the debris screen (yellow line)

The electrical barrier was developed and installed through a collaboration between Vaipuhi Freshwater Consultants and Kiwi Control Systems Ltd (KCS). The design was constrained by the presence of deep sediment layers partially burying the intake screen and the Passive Integrated Transponder (PIT) system already in place. Instead of developing an electric field in front of the pump, as with Mountain Road and Motukaraka pump stations, an electric field was installed immediately downstream of the intake debris screen, between two sets of droppers spaced 1.3 m apart (Figures 10 and 11).

The electrical field was created using pulsed direct current (DC) and was designed to be too weak to immobilise, injure or kill fish or other wildlife that might encounter it. The electrical barrier began generating an electrical field in December 2020 and was deactivated and removed in March 2022. An electric field measuring probe was installed between the two sets of droppers to record and log the electric field at 15-minute intervals.

Full details on the trial and results can be found in Vaipuhi Freshwater Consulting 2021.

Figure 10: Pump station inlet debris screen. White pipes are PIT antennae

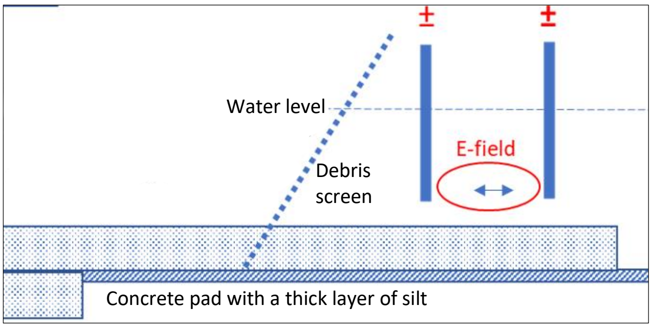


Figure 11: Electric field design with two droppers installed behind the debris screen

Results

Consecutive droughts were experienced during the study period in summer/autumn 2021 and 2022. Records show that water levels remained low and the pump did not operate from February through to the last quarter of June 2021.

On occasion there were marked variations in the daily recorded voltages for the droppers; it is not known if these recorded changes affected the size and strength of the electric barrier. However, the changes in voltage between the sets of droppers were small and at all times the field strength was always well above levels that are known to induce a twitch response in tuna.

The shape of the electric barrier field was measured on two occasions and in general the strength of the field decreased with distance from the droppers and along the wall of the structure, which may have allowed tuna to pass unaffected along the bed.

Several tuna were detected passing through the pump station when the electric barrier was operating in December 2020 and October 2021. However, it is important to note that these results do not indicate that the barrier was ineffective because it is not known how many tuna approached or attempted to enter the intake. The results only demonstrate that the barrier did not prevent all tuna from passing through the pump.

Evaluation

The effectiveness of the electrical barrier was hampered by the presence of deep sediment layers within the inlet, the need to avoid interference with the PIT system, and the consecutive droughts that were experienced.

The presence of deep sediment layers within in the inlet resulted in difficulties producing the required field, such that tuna were able to pass along the bed uneffaced by the electric field. Deep sediments are an environmental condition that is likely to be found at most pump stations and this therefore represents a considerable design flaw that will need to be overcome.

The combination of these two issues meant that it was not possible to assess the effectiveness of the electrical barrier with regard to:

- The degree to which the barrier had influenced the number of downstream migrant tuna that passed through the pump station.
- Enabling a comparison of tuna deterrence with and without the barrier turned on (i.e. an experimental control).

While a potentially promising technology, the presence of sediment deposits will need to be considered when selecting future locations for trials and/or implementation. Further investment is required to deliver an electrical barrier that is fully effective. This would involve either further development of the Vaipuhi/KCS design or the importation of existing technology being developed overseas. Electrical barriers are also only an interim measure to reduce mortality – tuna are still trapped by a barrier and unable to migrate downstream. Low voltage electrical barriers are not currently recommended as a tool for implementation.

6.3 Gravity Bypass Outlet

Background

A gravity bypass outlet allows water to passively flow out of the catchment during low water levels/flows. The water flows with gravity and bypasses the pump station, allowing an alternative and safe exit route for fish from the catchment. Depending on the level that these outlets are set, they can allow unobstructed movement of water and the safe passage of fish from the catchment for most of the year. However, it is unknown the extent to which native fish approach or pass through these outlets.

The outlet of the gravity bypass is controlled by a floodgate which is an adjustable gate that is used to control water levels in a catchment. Floodgates only allow water to flow in a downstream direction. When the downstream water levels increase the floodgate closes to prevent water flowing upstream and cause flooding. Floodgates are used in Aotearoa and internationally and are relatively inexpensive with low maintenance costs. Maintenance is required to ensure that debris and sediment do not hinder the function of the gates, either by holding it open and/or shut. Internationally, the benefits of keeping flood gates open outside of the flood period is well established and this has gained traction in Aotearoa in recent years, with the retrofitting of fish friendly floodgate designs where floodgates are kept open by mechanical means.

In the Waikato region, gravity outlet systems with floodgates have been incorporated into some pump stations ('gravity/pump') to provide an alternative route for fish to pass in and out of the catchment. While these systems are considered better than 'pump only' systems, there is still significant risk to fish when the outlet is closed, and the pump is operational.

During times of flood, the downstream water levels rise, forcing the floodgate to close, and at the same time the high-water levels in the catchment trigger the flood pumps to turn on. When this occurs the only route out of the system is through the pump and depending on the type of pump, fish can be injured or killed.

Research

A tuna behaviour trial was undertaken at Steiners pump station in 2020. Steiners pump station has two outlets from the catchment, either through the gravity bypass outlet or through the flood pump. The gravity outlet has a floodgate on the downstream side, which allows water to drain during low tide, but limits ingress of water during either high tide or flood conditions in the Waitoa River. The gravity outlet is the primary outlet from the catchment for much of the year.

The objective of this study was to determine:

- The proportion of tuna that left the catchment via the gravity bypass outlet compared to the flood pumps.

A total of 314 shortfin tuna were captured over two nights in January 2020, of which 225 (>150 mm) were tagged with PIT tags. The majority of the tagged eels were feeders (no migrant characteristics), with 13 migrants and 12 developing migrants (some migratory characteristics). To track tuna movements in and out of the catchment an array of five stationary antennae were set up (Figure 12). When tagged tuna came within approximately 2 m of any antennae reader, they were automatically detected, and the date and time recorded electronically. Data analysis was focussed on any one-way downstream movements through either the pump station or gravity bypass since those movements would indicate that tuna had out-migrated.

Full details on the trial and results can be found in Franklin et al 2020.

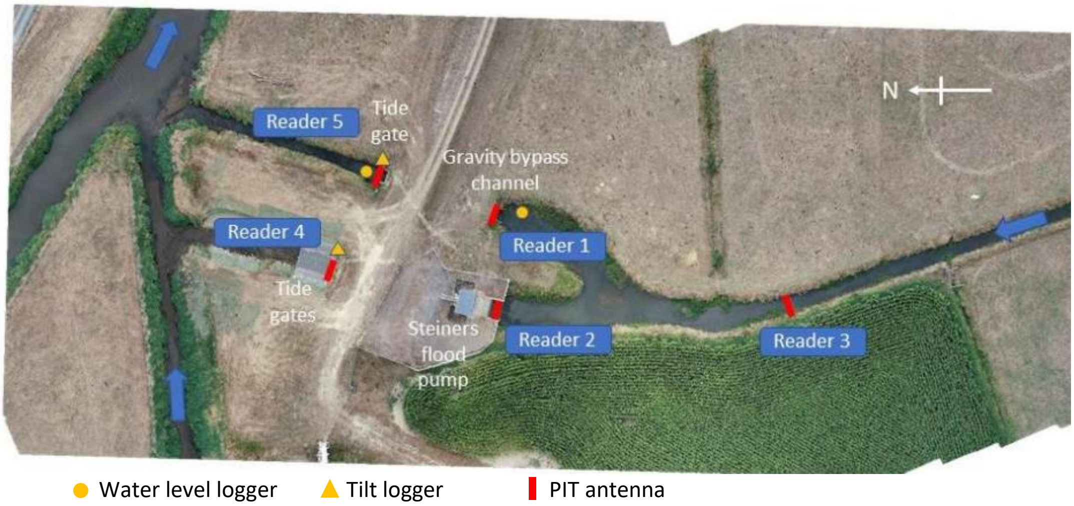


Figure 12: Layout of the five PIT antennae (red lines) installed to track eel movements at Steiner's pump station and bypass channel

Results

Between January and July 2020, 35.5 million detections were recorded across the five PIT antennae. Of the 225 eels that were tagged, 142 (63%) were detected at least once in this period. The largest number of tuna movements occurred between Reader 3 (upstream channel) and Readers 1 and 2 (bypass outlet and pump station; Figure 13). There was a high number of return movements back upstream to Reader 3.

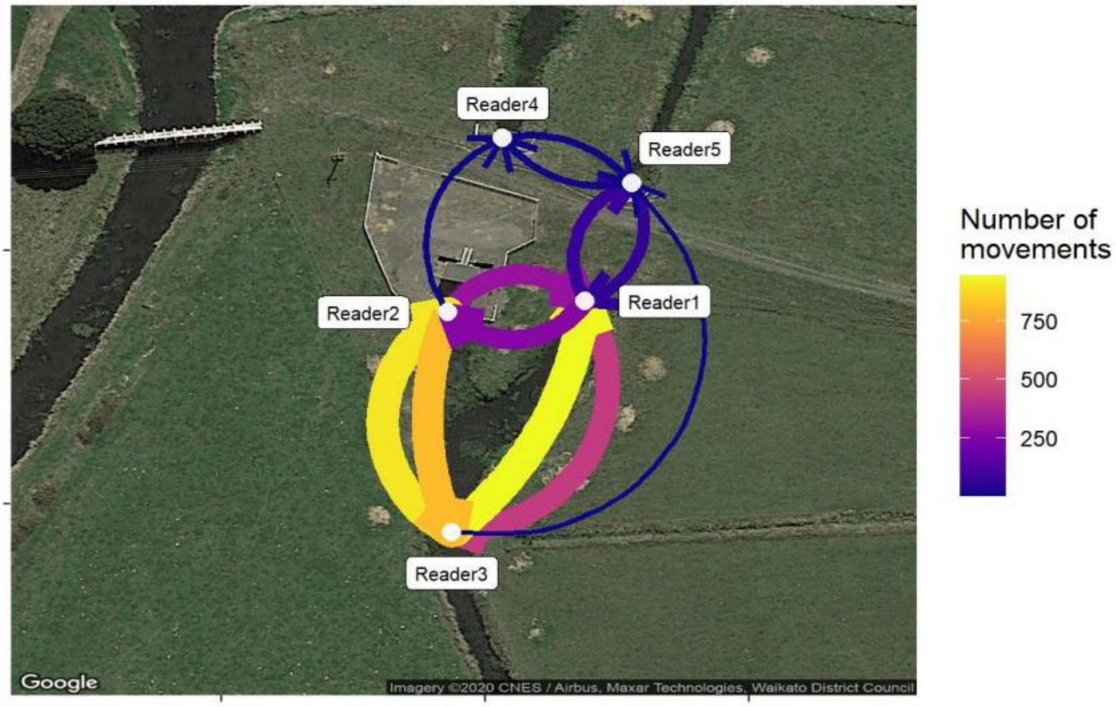


Figure 13: Arrows show the movement of tagged tuna between 28/01/20 and 31/07/20. The width and colour of the arrows reflect the number of movements recorded (Franklin et al 2020)

Tuna movements were both temporal and water level dependent, with more movements detected in summer and a peak in eel activity at around 14/15°C. Tuna movements also showed a diel pattern with more movements recorded at dusk and then decreasing throughout the night.

The PIT tagging data showed a total of 28 individual tuna left the catchment through the gravity bypass outlet, with 13 of those tuna returning upstream though the gravity bypass outlet; this return journey likely indicates foraging behaviour. During the same period only three feeder tuna were detected exiting the system via the flood pumps. The study showed that 83.3% of the tuna that left the system left via the gravity bypass outlet, noting that due to the drought, the flood pumps did not operate during the peak downstream migration season.

Evaluation

The tuna behavioural study at Steiners pump station showed that during low flow conditions, tuna used the gravity bypass and were able to leave the system, as well as re-enter. Key findings from the study were:

- Tuna can find and exit the Steiners pump station through the gravity bypass outlet when the floodgate is open.
- When the pumps are operating, most downstream movements are via the pumps because the floodgate is barely open or completely closed.
- The tracking system worked very well, and a large dataset of tuna movements was collected.
- Tuna are more active during periods of increased water temperatures c. 14-15 degrees and water levels, and are therefore more likely to migrate out of the catchment.
- The majority of movements occurring at dusk and tapered off throughout the night.
- Operational management can be considered a key tool to minimise entrainment, for example avoiding or minimising pump operation between dusk and dawn.

The study was constrained by drought conditions (as the pumps didn't run during the peak downstream tuna migration season) and it is still unclear what proportion of tuna migrate from the catchment via the gravity bypass compared to the flood pumps.

Making changes to the operational management of pump stations has the potential to be a key tool to improve the safe downstream passage of fish.

6.4 Passive acoustic tool

Background

Knowledge of mortality and injury rates of fish at pump stations can provide extremely useful information to help prioritise pumped catchments for remediation. Traditional monitoring assessments to measure mortality and injury rates at pump stations can be labour intensive and costly. A potential alternative is to use passive acoustic technology to detect fish impellor strikes and therefore injury and mortality at pump stations. Passive acoustic technology records the noise signature of fish as they pass through the pump. There are a number of applications for such a monitoring tool including:

- Determining the mortality risk at individual pump stations as part of priority setting or renewal programmes.
- Evaluation of remediation tools (e.g. changes in pump type, pump speeds, behavioural or physical barriers).
- Determining migration patterns in relation to rainfall and pump operation across multiple pump stations.

If further developed, it could also potentially be incorporated into pump operation management systems to reduce impacts on fish by slowing pumps when impellor strikes are detected. Pump speed is known to be a key factor determining fish injury and mortality.

Research

This study began after WRC staff noticed a noticeable and discernible sound when tuna passed through a pump station. An initial feasibility study was conducted at Orchard Road pump station in 2017.

The objective of the study was to establish if the sound of tuna passing through the pump is in fact discernible from the pump noise. Two soundtraps were deployed at the pump and freshly euthanised tuna and goldfish of differing sizes were passed through the pumps. Each sound event was manually identified in the dataset by matching the time stamp of the recording with the time the fish were fed into the pump.

A second study was undertaken at Steiners pump station in 2020, where a concurrent tuna behavioural study and mortality assessment was taking place. The objective of the second study was to further develop the detector algorithm for quantifying tuna passage through pumps. Steiners pump station has significantly larger and slower pumps than those assessed at Orchard Road, which provided an appropriate comparison for the tool. A soundtrap recorder was deployed at the pump using the same settings as the first study undertaken at Orchard Road pump station. The concurrent behavioural and mortality study meant that results from the acoustic logger could be compared to fish recovered in the outlet net.

Full details of the 2017 study can be found in Pine 2018. Full details of the 2020 study can be found in Pine 2020.

Results

The study at Orchard Road pump station showed that sound events from fish strikes were constantly detectable over pump noise (Figure 14). Thirty-six tuna (out of 40) and 16 goldfish (out of 20) were acoustically detected. The sound events associated with goldfish were short and usually characterised by a single spike in the data. Sound events associated with tuna were different, being longer in duration and often characterised by several spikes in quick succession. The tuna strikes made the basis for a reliable and accurate classification for an automated detection system.

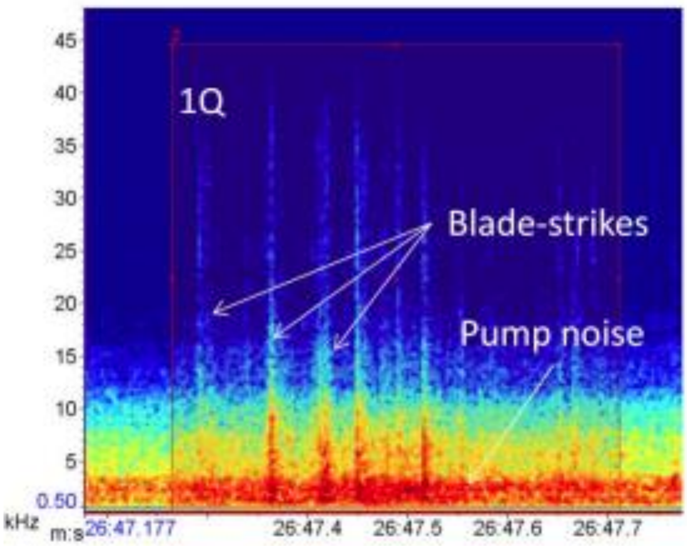


Figure 14: Spectrogram showing blade strikes at Orchard Road pump station

There was a widespread drought during the second study at Steiners pump station and the pump did not operate during the peak tuna migration season (February to May). Around 21 tuna were detected passing through the pump station in June and July. The background noise from the Steiners pump differed to that of the Orchard Road pump but this could be removed. The acoustic signature of the tuna detections was also similar to that of Orchard Road (Figure 15).

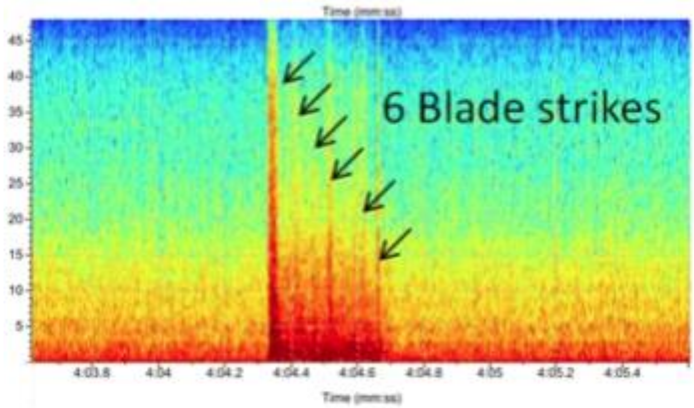


Figure 15: Spectrogram showing blade strikes at Steiners pump station

Evaluation

Results from the trials undertaken at Orchard Road and Steiners pump stations show that passive acoustic technology can detect tuna mortality and injury at pump stations. This technology could provide a lower cost alternative to traditional monitoring assessments.

Recommendations from the trials were to undertake the monitoring again during a typical migration season with high rainfall events and therefore more tuna and detections. Additionally, to trial the detector on a different sized or type of pump (with a different noise profile) to assess whether the tool can be applied across a range of pumps and pump types with little to no modification.

Despite the tool showing promising results, further investigations and investment are required to have full confidence in the detectors abilities and applicability across the WRC flood protection scheme. Furthermore, we now have a better understanding of the impact of non-fish friendly pumps and generally assume that mortality and injury is widespread, hence the need for this tool has lessened.

7 New pump systems

7.1 Modified MacEwans pump

Background

MacEwans pumps represent the majority of flood pumps in the Waikato region and are used extensively throughout the country. These pumps are manufactured by MacEwans Pumping Systems in Aotearoa. Traditional MacEwans pumps comprise axial flow impellor driven systems which are now known to injure and kill fish that pass through them. This led to the formation of a joint project between MacEwans Pumping Systems, Callaghan Innovation, WRC and Waikato-Tainui College for Research and Development to design and manufacture a new fish friendly pump – that could replace existing MacEwans pumps without the need to rebuild the civil structure. If successful, this would present a much lower cost option and could increase the rate of uptake nationally. Approximately half of the pump stations across the Waikato region could be good candidates for a fish friendly design.

The process to develop the new pump was complex (Figure 16), from concept design, to modelling, developing a 3D and scale model, manufacturing the full-scale parts, testing and assembly. The process took several years and was unfortunately delayed due to Covid-19 lockdowns. The pump was completed in December 2023 and tested at Auckland University.

Features of the new pump that make it fish friendly include:

- Slower rotational speed than traditional axial pumps
- Having only two blades, compared to four with traditional pumps
- A scroll type impellor rather than traditional blades
- Rounded blades rather than being sharp

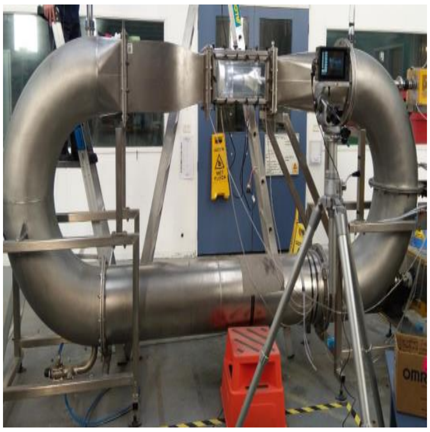
These features reduce the areas where injury and mortality can occur. However, the fish friendliness of pump stations relies not only on safe passage of fish, but also safe passage of the larger fecund female tuna, i.e. tuna of 600mm or greater. As tuna are semelparous, ensuring their safe outmigration to breeding grounds is of utmost importance for population dynamics and recruitment.

The site selected for the new pump was Huntly Golf Course pump station. The pump station drains a 970ha catchment consisting entirely of pastoral land and is known to have a population of large tuna. The pump station contained three traditional MacEwans pumps (24/30). Fish kills have been documented from these pumps. In December 2023, the duty pump (the pump that functions most frequently) was removed and the new fish friendly pump installed. The pump was set at 350rpm for the duration of the monitoring period. The fish friendly pump was set as the duty pump and the other two pumps were turned off.

Waikato Tainui College for Research and Development actively supported the project and contributed funds towards the purchase of the new pump.

3D printed model of the pump

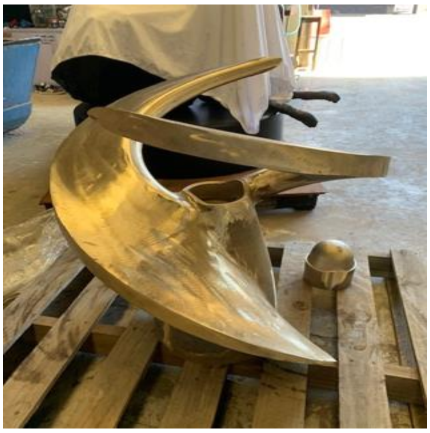
Scale model of the impeller



Closed circuit tunnel to test the scale model of the pump

Flexible 3D printed eels that were manufactured to pass through closed circuit tunnel

Full scale impeller mould



Impeller after being cast and extracted from the mould

Impeller being machined

Pattern for the housing

Completed housing for the implellor

Completed impellor and housing

Pump being tested at Auckland University

Pump installed at Huntly Golf Course pump station

Figure 16: Process to develop the modified MacEwans pump

Research

To investigate the fish friendliness of the new pump design, a monitoring study was developed with the following objectives:

- Assess the injury and mortality rate of tuna passing through a standard MacEwans PPF24/30 pump.
- Assess the injury and mortality rate of tuna passing through the new modified pump and compare this to other fish friendly and traditional axial pumps in Aotearoa.

Two assessments were undertaken - first on the existing traditional axial MacEwans pumps during the 2021 migration season (pre-upgrade), and second on the new modified MacEwans pump during the 2024 migration season (post-upgrade). The gap between monitoring was due to delays with the new pump, centred around the Covid-19 pandemic and the complexities of developing a new technology.

To ensure all tuna that passed downstream through the new pump could be retained and assessed for any injury, a 15 m funnel net was attached to the outlet of the pump (Figure 17). The net was secured to a steel box structure attached to the concrete apron.

Figure 17: Funnel net and box structure at the outlet of the modified MacEwans pump

All tuna recovered from the net were identified, measured, weighed and assigned a migrant status. The external condition of each tuna was also assessed according to a five-point injury score used in previous New Zealand pump station mortality assessments (Vaipuhi Freshwater Consulting 2017 and 2018, Lake & Williams 2020):

0. No damage (apart from abrasions due to netting and handling)
1. Moderate bruising and fin damage (including haemorrhaging within the fins)
2. Small cuts and severe bruising
3. Survivable large cuts and/or loss of orientation, un-confirmed fracture of the spinal column
4. Death or fatal wounds, confirmed fracture of the spinal column

Once assessed, tuna were transferred to holding nets for 24 hours, then reassessed and released downstream of the pump to continue their migration.

Some additional information was captured for the post-upgrade assessment in 2024. A sensor fish was passed through the new modified MacEwans pump, recording pressure, rotational velocity and acceleration. A sample of 12 tuna were also taken for x-ray analysis.

Full details on the monitoring programme and results can be found in Williams 2021a and Bartels 2024.

Results - pre-upgrade 2021

A region wide drought was observed over the 2020 and 2021 summers and the pump didn't start operating until April 2021, when it only ran intermittently during periods of rain. There were no rain events considered large enough to trigger migration.

Only one tuna was recovered from the net during the 2021 assessment period, which was completely macerated (100% mortality). Multiple very large shortfin tuna (900mm+) were observed trying to pass through the debris screen in front of the pump to out migrate with no success. This had not been observed at other pump stations, with tuna generally able to pass through the debris screens, however tuna of this large size (900 mm+) are rare in pumped catchments. Results from the State of the Environment monitoring site located upstream of the pump station suggests that there is a small population of tuna, averaging in size greater than 800mm in length. Due to their long-lived nature, these tuna were likely in the catchment prior to the construction of the pump station and have been unable to exit the catchment (once of mature, migrant status) due to the 42mm screen gap and the absence of a floodgate.

Based on the outcome of the 2021 monitoring, it was concluded that the debris screen would need modifying to allow tuna passage and the catchment would need to be stocked with large tuna (that are likely to migrate) to increase the population and therefore sample size for the study.

Results - post-upgrade 2024

As recommended from the 2021 assessment, the catchment was restocked with predominantly migrant and developing migrant shortfin tuna and a new section of screen was installed with larger bar gaps. Two hundred and twenty-five (225) tuna ranging in size from 548 to 1030mm were sourced from the New Zealand Eel Factory in Te Kauwhata and released upstream of the pump.

A total of 114 shortfin tuna and just over 1,000 catfish were captured in the net during the 2024 assessment period. Most tuna were developing migrants or migrants (94%) and ranged in length from 657 to 1210mm. Six feeders were observed in the net but because there is no gravity bypass outlet (and hence no recruitment upstream), it's likely that these tuna entered the net from downstream to find refuge. The feeders are not included in the analysis.

All 108 developing migrant/migrant tuna captured in the net were alive and passed through the pump with 100% survival. Most tuna (97.2%) scored 0 and had no or minor injuries. Some of the tuna that scored 0, had minor injuries such as scuff marks and tail fin damage. These injuries may have been caused from netting, handling, passing through the pump or discharge chamber, and for the tuna sourced from the Eel Factory, from being held in nets and tanks.

Two tuna suffered head damage including the localised loss of scales and were scored 1 (Figure 18) and 2. The tuna with a score of 2 had a depression along with scale loss. One tuna died overnight in the holding net (score of 4; 0.9%). The tuna that died exhibited normal behaviours upon capture and no obvious signs of injury; its cause of death is unknown. The tuna with scores of 1, 2 and 4 measured between 759 and 848mm in length, showing no size bias, when compared to the size class of tuna that passed through the pump.

These three tuna, along with seven others were euthanised for x-ray analysis. X-ray analysis did not show any obvious fractures to the vertebrate or head on nine of the tuna. The tuna with a score of 2 showed possible offset opercular bones (Figure 19).

Figure 18: Tuna assessed with a score of 1 due to head damage and scale loss.

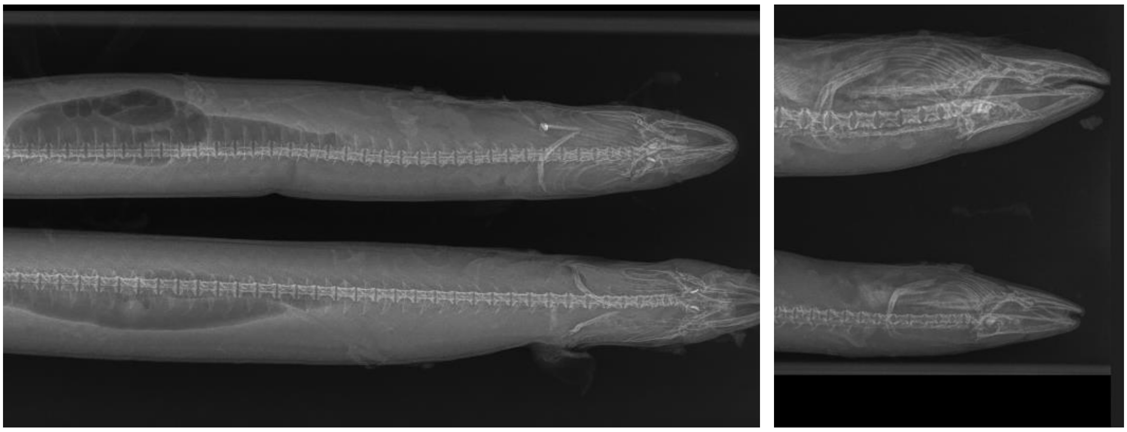


Figure 19: X-ray plate of the two tuna with head damage and scale loss. The left image is a top-down view while the right image is side on. The top image shows possible offset opercular bones.

The sensor fish trial indicated that there were two main points where pressure, rotational velocity and acceleration peaked – entering the pump and at the outlet (Figure 20). This could indicate a potential collision, but it is likely the peaks are associated with flow acceleration and turbulence.

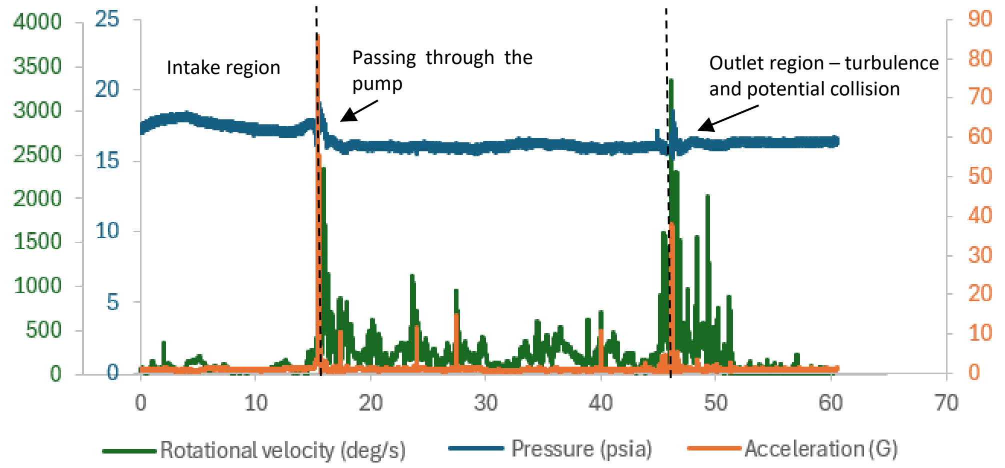


Figure 20: Sensor fish passage through the modified MacEwans pump, showing rotational velocity, pressure and acceleration against time in seconds

Evaluation

The monitoring at Huntly pump station showed excellent results with 99% survival of all tuna that passed through the modified MacEwans pump. Overall, 97% of tuna safely passed through the pump. Less than 2% of tuna suffered moderate injuries and there was no size bias. It is unknown how the one tuna died but it had no obvious signs of injury upon inspection.

The monitoring has proven that the modified MacEwans pump is fish friendly and meets a high level of safe fish passage. The largest tuna through the pump was 1210mm in length, proving that the pump is also safe for large migrant tuna. This is a significant finding as the fish friendliness of pump stations relies not only on safe passage of fish, but also safe passage of the larger fecund female tune i.e. tuna of 600mm or greater.

These results are a significant milestone for flood pumps in Aotearoa – as a locally source and manufactured fish friendly pump is now available. Given the number of MacEwans pumps across the Waikato region and country, the change to a modified MacEwans pump when infrastructure comes up for renewal or for new construction, will be valuable for fish passage in Aotearoa. Being able to replace existing pumps without the potential need to rebuild the civil structure and sourcing the pump locally, presents a much lower cost option that could increase the rate of update nationally.

The pump has shown that it performs very well in terms of safety passing native fish. However, it is also important to note here the operational performance of the pump. The modified pump is less efficient at pumping water and because of this it uses more current and amps to pump the same amount of water. It therefore may not be suitable for all sites.

7.2 Encased Archimedes screw pump

Background

Archimedes screw pumps have been used for centuries and can transfer large volumes of water over significant vertical distances and allow for the passage of large debris. It is well documented from overseas research, that while traditional Archimedes screw pumps are better at passing fish than axial flow pumps, there are still many design features that can cause fish injury and mortality (approximately 19% mortality; Buysse et al 2015). Screw pumps typically have a blunt angular leading edge at the entrance of the pump, and nip points between the screw and trough (Figure 21). Traditional screw pumps also create significant turbulence and noise, which is likely to deter fish from entering the pump.

Two traditional type Archimedes screw pumps are in operation in the Lower Waikato drainage scheme. No research nationally has been undertaken on these pumps to assess fish passage.

FishFlow Innovations in The Netherlands has designed a new ‘fish friendly’ Encased Archimedes Screw Pump (EASP). The new design differs from a traditional Archimedes screw by having a fully encased trough which rotates together as one unit, and blades that taper towards the tips of the screw (Figure 22). The EASP is considered to be the optimal solution for providing downstream passage for large tuna and offers other operational benefits such as being highly efficient, quieter, with low maintenance and a very long-life expectancy (c. 80 years).

Figure 21: Traditional Archimedes screw pump showing blunt angular leading edge

Figure 22: FishFlow encased Archimedes screw pump showing encased design and tapered blades

Research has been undertaken on the EASP in Europe, looking at how safely it can pass European coarse fish (perch, roach, bream, ruffe and pike) and eels. Vriese (2009) found 100% survival of coarse fish ranging in length from 100 to 440mm and eels ranging in length from 550 to 820mm, with no documented injuries. Waternet (2014) assessed the EASP on 8 eels (250-900mm) and 876 cyprinids and found 100% survival of all species and no injuries except damage on one eel (which was thought to be due to other causes).

The first EASP in Aotearoa was installed at Mangawhero pump station near Aka Aka, Lower Waikato, in March 2022. The pump was installed as part of a shovel ready project in response to Government’s Covid-19 recovery package and also has formed a key research focus of the PTTS project. Although the EASP has shown very little impact on fish in Europe, the pump had not been tested on New Zealand eel species, which tend to grow larger than other anguillids. European eels tend to be smaller than native species in Aotearoa, generally growing to a maximum of 1m in length. This is markedly smaller than tuna in Aotearoa of which shortfin eels can grow up to 1.2m and longfin eels up to 2m in length.

The Mangawhero catchment located in Aka Aka, Northern Waikato, discharges primarily through the EASP into an outlet that runs around the boundary of a floodplain wetland, into the mainstem of the Waikato River (Figure 23). Additionally, as part of the pump station replacement, a gravity bypass outlet was installed to the left of the EASP inlet, which allows water to drain out of the catchment at low tide but prevents the backflow of water during high tide and/or flood conditions and discharges into the outlet channel connecting into the Waikato River. At this location, the site and outlet experience tidal movement, delayed one hour from times set at Port Waikato, but are not affected by saltwater intrusion.

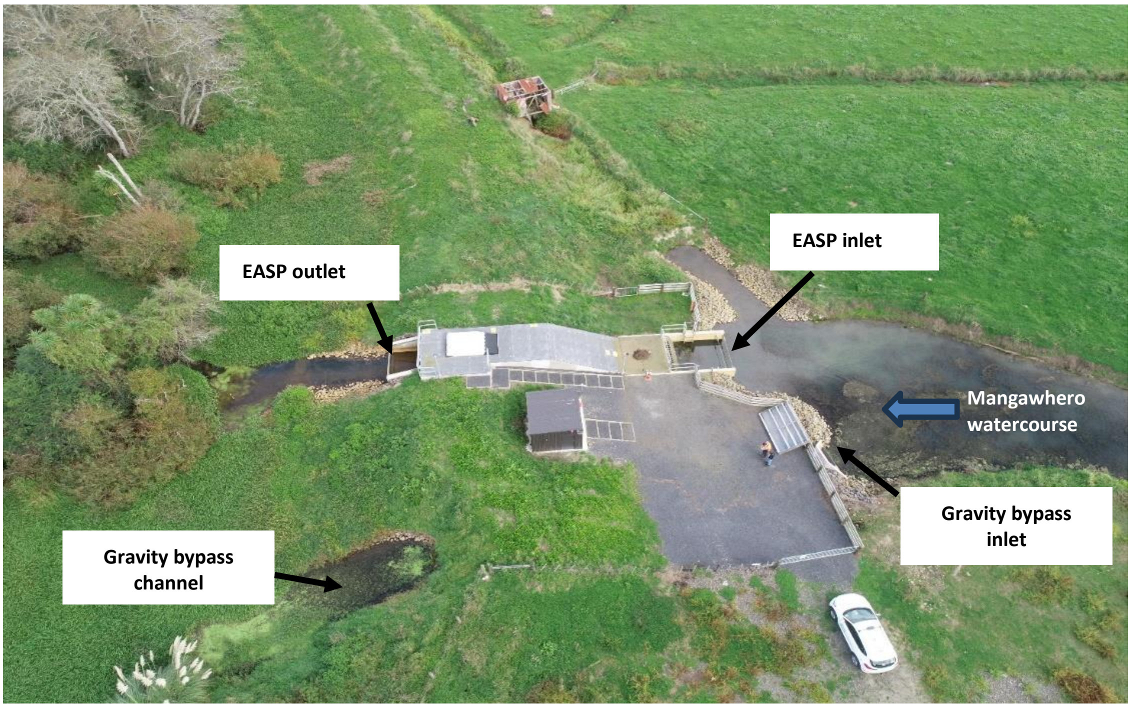


Figure 23: Aerial view of Mangawhero pump station showing the inlet and outlet to the EASP, and adjacent bypass channel. Tuna can also exit the catchment via a floodgate at the upstream end of the catchment

The EASP at this site is 7.95m in length and 1.6m in diameter, and can push out up to 520 litres per second during a flood event. The EASP sits at an angle of 19.9 degrees within the pump station sump. There is a sloping debris screen located on the inlet to the pump, with 16mm thick vertical steel bars spaced at 65mm to prevent debris and aquatic macrophytes entering and blocking the pump. One of the advantages of the EASP is that debris screens with larger bar spacings can be used, as opposed to traditional axial pumps where screen spacings of 45mm are common. Larger bar spacings are preferred to allow large tuna to pass through the screen and the EASP. However, it widely accepted that tuna can manoeuvre and contort their bodies to squeeze through pump inlet screens and is why eel mortality is a known issue from flood pumps, although research at Huntly Golf Course has shown that a standard screen size (of 45 mm) can prevent large tuna (1 m+) from moving through the screen.

Research

A monitoring programme was developed to assess fish friendliness of the EASP on tuna at Mangawhero pump station. The objectives of the monitoring were to:

1. Assess the injury and/or mortality rate of tuna passing through the pump.
2. Determine the size ranges of tuna that can safely pass through the pump.
3. Assess whether there is any pump avoidance exhibited by tuna.

The monitoring programme was undertaken in January-February 2023 and repeated in January-May 2024.

Based on previous surveys, the Mangawhero Catchment did not have enough tuna or large migrant tuna to adequately assess the EASP. To overcome this constraint, tuna were translocated from another pumped catchment in the lower Waikato (Sandy Muirs pump station catchment which has a traditional axial pump). Tuna were also sourced from the NZ Eel Factory in Te Kauwhata to ensure certainty in tuna numbers, migrant status and length required for the project.

The main objective of the 2024 monitoring was to determine if large (1m+) tuna could safely pass through the pump. In order to test this, large tuna were translocated into the Mangawhero catchment. An eel fisher was engaged to source 1m+ tuna however it was difficult to find large tuna and only three were released into the catchment.

To understand whether tuna exhibit avoidance of the EASP (Objective 3), a telemetered PIT system was installed and tuna over 450mm were tagged. All tagged fish had weight (g) and length (mm) measurement taken, a migrant status assigned and were released/translocated upstream of the Mangawhero pump station.

To ensure all tuna that passed downstream through the EASP could be retained and assessed for any injury, a 10m funnel net was attached to the outlet of the pump (Figure 24). The net was secured to a timber box structure attached to the concrete apron.

Figure 24: Funnel net and box structure at the outlet of the Mangawhero EASP

All tuna recovered from the net were identified, measured, weighed, scanned for PIT tags and assigned a migrant status. The external condition of each tuna was also assessed according to a five-point injury score used in previous New Zealand pump station mortality assessments (Vaipuhi Freshwater Consulting 2017 and 2018, Lake & Williams 2020):

0. No damage (apart from abrasions due to netting and handling)
1. Moderate bruising and fin damage (including haemorrhaging within the fins)
2. Small cuts and severe bruising
3. Survivable large cuts and/or loss of orientation, un-confirmed fracture of the spinal column
4. Death or fatal wounds, confirmed fracture of the spinal column

Once assessed, tuna were transferred to holding nets for 24 hours, then reassessed and released downstream of the pump to continue their migration.

Full details on the monitoring programme and results can be found in Williams 2023.

Results - 2023 assessment

A total of 255 fish, comprising 206 tuna and 49 exotic species were captured in the net during the 2023 assessment period. Shortfin tuna made up a large proportion of the fish with 203 individuals ranging from 328 to 956mm in length. Three longfin tuna were also recovered (533 to 664mm) as well as 46 catfish (*Ameiurus nebulosus;* 82 to 411mm) and 3 goldfish (61 to 145mm). Most tuna were developing migrants or migrants (79%).

All tuna captured in the net at the outlet were alive and passed through the EASP with 100% survival. Most tuna (204) passed through the pump with no or minor injuries (score of 0) equating to 99%. Only two shortfin tuna suffered moderate bruising at their heads (score of 1; 1%) and measured 372 and 776mm in length, showing no size bias and were not tagged.

Of the 204 tuna that scored zero, 23 suffered minor injuries such as scuff marks, mouth sores and abrasions. These injuries may have been caused from passing through the EASP, netting, handling, discharge chamber and/or being kept in the outlet net until assessment.

NIWA undertook the PIT study in relation to Objective 3, to see whether tuna exhibited any avoidance of the EASP (Mahlum et al 2023). Assessment of the PIT data showed that tuna of all sizes and migrant status (feeder, developing or migrant) were observed to move through the EASP. There was consistent detection of eels moving towards the EASP, with residence times in proximity to the pump being significantly shorter than their residence time above the EASP intake. There was minimal avoidance or even delay, particularly for migrant eels passing through the EASP, but some delay for feeder tuna. Feeder tuna were shown to inhabit areas around the outlet of the EASP, whereas developing migrants and migrants had no residence times in this area, likely due to these individuals leaving the catchment to continue their onward migration. Feeder tuna have also been seen to move in and out of the catchment for foraging, as shown in Section 6.3.

Results - 2024 assessment

A total of 35 shortfin tuna and 13 catfish were captured in the net during the 2024 assessment period. Most tuna were developing migrants or migrants (91%) and ranged in length from 434 to 1210mm. The three large tuna that were released into the catchment passed through the pump and into the net. These tuna measured 1040, 1100 and 1210mm in length.

All fish captured in the net were alive and passed through the EASP with 100% survival. The tuna were in good condition, with no or minor injuries (score of 0). Slight tail damage and rubbing was observed on some of the tuna, with no scuff marks observed. Nine tuna were euthanised for x-ray analysis, with no spinal damage observed. These tuna ranged in size from 602 to 822 mm. The three large tuna were also in good condition after passing through the EASP, with no obvious signs of injury or damage.

Evaluation

The study at Mangawhero pump station showed excellent results with 100% survival of all fish that passed through the EASP. Overall, across both assessment periods, 241 tuna passed through the pump, providing a good sample size for the study. The pump passed 99.2% of tuna with no damage or with minor injuries. Less than 1% of tuna suffered moderate injuries and there was no size bias. These results are in line with the overseas studies undertaken on the FishFlow EASP in the Netherlands (Vreise 2009, Waternet 2014).

The study at Mangawhero pump station has provided evidence and affirmation of the fish friendliness of the EASP, as has been shown overseas. There was no apparent avoidance of tuna, particularly of migrant status when migrating downstream towards and through the EASP.

These results highlight the potential for other territorial authorities and regional councils within New Zealand to install these types of pumps to continue to provide flood protection, and allow for safe downstream passage for fish.

7.3 Bedford submersible pump

Background

Bedford Pumps in the United Kingdom design and manufacture fish friendly submersible pumps. Fish friendly variants were developed following EU legislation which was brought into effect in 2007 to tackle the rapid and widespread population decline of the European eel. The fish friendly variants comprise fish friendly impeller blades, increased spacings between the casing and impeller, have relatively low impeller speed and high hydraulic efficiency. Studies have been undertaken in Europe on a larger Bedford model (SAF 90.05.12) with results indicating negligible mortality and minor injury in eels less than 600mm in length, at low rotational speeds. At higher rotation speed (518rpm and 2.3m^3/s capacity) mortality of eels did increase slightly but were still below 8%. These pumps were also 97% effective at providing safe passage for European coarse fish (perch, roach and bream) of lengths ranging from 170 to 500mm (Spierts & Vis 2012).

Three fish friendly Bedford submersible pumps are in operation in the Waikato region. Two SAF 45.05.06 pumps were installed at Orchard Road pump station in Te Kauwhata in 2017. This model has two screw shaped impeller blades that operate from 790 to 987rpm. These pumps were the first fish friendly pumps installed in the Waikato region (and Aotearoa, as far as we are aware). A larger SAF 70.05.12 pump is housed at the Paeroa Main Drain pump station in the Hauraki zone.

It is widely known that Aotearoa *Anguilla* species grow a lot larger than their European counterparts and so a fish assessment study was performed on the Bedford pumps at Orchard Road.

Research

To investigate the fish friendliness of the Bedford pump, a monitoring study was developed with the following objectives:

- Assess the injury and/or mortality rate of tuna passing through the old axial pumps.
- Assess the injury and/or mortality rate of tuna passing through the new Bedford pumps.
- Determine the size ranges of tuna that can safely pass through the pump.

Two assessments were undertaken – first on the existing traditional axial MacEwans pumps during the 2017 migration season (pre-upgrade), and second on the new Bedford pumps during the 2018 migration season (post-upgrade).

To understand tuna behaviour around the pumps, a telemetered PIT system was installed and tuna of varying sizes were tagged. The catchment was not expected to have a large number of migrant tuna, so additional migrant eels were captured by commercial fishers from nearby catchments, tagged and released upstream of the pumps in both 2017 and 2018. All tagged fish were weighed, measured and assigned a migrant status before being released.

To ensure all tuna that passed downstream through the Bedford pumps could be retained and assessed for any injury, a 15m funnel net was attached to the outlet of the pump. All tuna recovered from the net were identified, measured, weighed, scanned for PIT tags, and assigned a migrant status.

The external condition of each eel was categorised according to the following five-point injury score:

0. No damage (apart from abrasions due to netting and handling)
1. Moderate bruising and fin damage (including haemorrhaging within the fins)
2. Small cuts and severe bruising
3. Survivable large cuts and/or loss of orientation, un-confirmed fracture of the spinal column

4. Death or fatal wounds, confirmed fracture of the spinal column

Once assessed, tuna were placed in holding bags and observed for three to five days. Any eels that were already dead or showed severe stress, slow response, extensive damage and/or low chance of recovery were euthanised and classified as suffering from 'delayed mortality'. At the end of the holding period healthy eels were released into the nearby Waikato River so they could more easily continue their migration to spawning grounds at sea.

As some of the eel bodies that were recovered did not show extensive external damage, a few were dissected to examine the state of internal organs. A selection was also X-rayed, and the plates used in making the final injury rating. As defined by Spierts & Vis (2012), eels with obvious fractures of the spinal column were considered unable to reach spawning grounds so were classified as lost.

Full details on the monitoring and results can be found in Vaipuhi Freshwater Consulting 2017 and 2018.

Results

Pre-upgrade

Sixty-four recognisable eel bodies were recovered from the net in March 2017. By far the greatest biomass recovered consisted of mutilated eel bodies and body parts (Figure 25). Most of this material was on the bottom of the net so would not have been visible to an observer without the net being present.

Figure 25: Typical collection of eel bodies retained by the net set at the outlet of the Orchard Road Pump Station in March 2017

Overall, 36% of all eels that passed through the traditional axial pump had no or minor injuries, but 64% were killed. Small eels (under 600mm) fared better than large eels, with the majority (88 %) showing only small or no external injuries, and most were alive when captured.

However, it must be noted that some of the small eels captured may not have passed through the pumps and instead entered the net by pushing through existing gaps or holes that developed over the two days the net was deployed. There was 100% mortality for any fish over 600mm that passed through the pump.

Post-upgrade

All tuna that passed through the new fish friendly Bedford pumps in 2018 were swimming actively, and apart from one eel that was profusely bleeding from the gills, no immediate impact of pump passage was apparent. Assigning an injury score in 2018 was more difficult than in 2017 as the injuries were a lot less obvious, and instead of cuts, blunt object strike marks were more common. This type of injury was more obvious when carrying out autopsies of euthanised eels. Damage to the skull, spine and gills was likely to have been missed by the visual analysis undertaken. Consequently, it is likely that the levels of injury sustained was higher than recorded.

Overall, 44.8% of eels had no or minor damage, 49.6% had moderate to severe injuries, and 5.6% were killed from passing through the new pump (Table 5). As found in 2017, large eels (over 600mm) suffered the most injuries in 2018. Fatal and sublethal effects were recorded on at least 16% of eels over 800mm. The fish friendly pump is above the yellow line and highlighted in blue text and traditional pump below.

Table 5: Comparison of injury scores between the fish friendly pump (blue text) and traditional pump

		Injury score					
		0	1	2	3	4	**Total**
Pump type	**Site**	No damage (apart from abrasions due to netting and handling)	Moderate bruising and fin damage (including haemorrhaging within the fins)	Small cuts and severe bruising	Survivable large cuts and/or loss of orientation, un-confirmed fracture of the spinal column	Death or fatal wounds, confirmed fracture of the spinal column	
Bedford SAF.45.05.06	Orchard Road Pump station	44.8% (56)	36.8% (46)	10.4% (13)	2.4% (3)	5.6% (7)	125
MacEwans axial PPF 15/18	Orchard Road Pump station	36% (23)	-	-	-	64% (41)	64

Note: number of fish in each category is noted in brackets

Evaluation

This was the first mortality assessment undertaken on pumps in New Zealand. The pre-upgrade assessment highlighted the severity of traditional pumps in passing tuna, with 64% mortality and 100% mortality for tuna over 600mm.

The post-upgrade assessment on the Bedford pumps showed a significant improvement in terms of tuna mortality, with only 5.6% of tuna being killed passing through the pumps. However, the new pump still inflicted moderate to severe injuries (bruising, cuts and spinal column fractures) on almost half of the tuna (49.6%) that passed through.

Determining the level of injuries sustained by tuna passing through the Bedford pumps was difficult, as rather than the mutilated bodies with axial pumps, most tuna came through the new pump alive with little skin markings. However, it was apparent that the pump had inflicted internal injuries and the chance of large migrant females reaching spawning-grounds is poor. Based on the results, this sized Bedford pump is not considered fish friendly and is not recommended for pump stations in the Waikato region.

Correspondence with Bedford Pumps has indicated that larger pumps operating at a slower speed would reduce injury rate in large tuna. Consequently, it is recommended that research be undertaken on the larger Bedford pump at the Paeroa Main Drain pump station.

7.4 Pump comparison

A comparison of the different pump types researched is provided in Table 6.

The EASP and modified MacEwans pumps by far had the best results with 99-100% survival rate and a high percentage of tuna with no (or minor) damage. The Bedford pump at Orchard Road showed a good survival rate (94%) but around 50% of tuna still suffered moderate to severe injuries. Traditional MacEwans axial pumps showed poor results at Orchard Road and Steiners pump stations. At Steiners pump station, 83% of tuna exhibited some level of injury or mortality.

When comparing the results for large eels over 600mm (generally fecund females), the EASP and modified MacEwans pumps again showed the best results, with no increased damage or injury on larger eels. The MacEwans axial pumps had devastating results for large tuna with 100% mortality. The Bedford pump at Orchard Road showed some improvement passing large tuna, but 56% still suffered moderate to fatal injuries. Fish friendly pumps are above the yellow line and highlighted in blue text and traditional pumps below.

Table 6: Comparison of injury scores for tuna across different pumps researched as part of PTTS

		Injury score					
		0	1	2	3	4	**Total**
Pump type	**Site**	No damage (apart from abrasions due to netting and handling)	Moderate bruising and fin damage (including haemorrhaging within the fins)	Small cuts and severe bruising	Survivable large cuts and/or loss of orientation, un-confirmed fracture of the spinal column	Death or fatal wounds, confirmed fracture of the spinal column	
FishFlow EASP	Mangawhero pump station	99.2% (239)	0.8% (2)	-	-	-	241*
Upgraded to Bedford SAF 45.05.06	Orchard Road pump station	44.8% (56)	36.8% (46)	10.4% (13)	2.4% (3)	5.6% (7)	125
Upgraded to modified MacEwans	Huntly Golf Course pump station	97.2% (105)	0.9% (1)	0.9 (1)	-	0.9% (1)	108*
MacEwans axial PPF 24/30	Steiners pump station	16.5% (13)	48.1% (38)	1.3% (1)	2.5% (2)	31.6% (25)	79
MacEwans axial PPF 15/18	Orchard Road pump station	36% (23)	-	-	-	64% (41)	64
MacEwans axial PPF 24/30	Huntly Golf Course pump station	-	-	-	-	100% (1)	1

Notes:
*Tuna only are included in the analysis
The number of fish in each category is noted in brackets

8 Untested mitigation tools & pump systems

8.1 Fish barrier screens

Background

Barrier screens are a physical exclusion or deterrent measure which can be placed in front of a pump to prevent downstream migrating fish from entering the pump and being injured or killed. The use of a screen would only form part of the fish passage solution. Fish would need the ability to safely exit the catchment and continue their downstream migration with alternative outlet options such as a bypass channel, trap and transfer or a fish friendly pump.

Fish screens need to consider the fish species they are designed to exclude including their behaviour.

Fine fish screens

Fine mesh fish screens are used to protect fish from structures that can cause damage and mortality from entrainment and/or impingement. These screens are commonly used at water intake structures and often constrain fish during their upstream migration, as this is when they are smallest and have the weakest swimming ability (i.e. are at greatest risk of entertainment or impingement). Several factors need to be considered to ensure the effectiveness of the fish screen (Jamieson et al 2007), including a suitable location, screen material (and smoothness to prevent damage), approach velocity to reduce impingement, ongoing maintenance and a safe exit route/bypass. Also, the objectives of the screening (i.e. total exclusion), the biology of the fish species identified, design features and practicality of operation, need to be considered.

Within the Waikato region, section 3.2.4.2 of the Waikato Regional Plan sets the fine fish screen requirements. For the Surface Water Class (which is the class that covers most of the pump stations), water intakes shall be screened with a mesh aperture not exceeding 3mm in diameter at locations <100m above mean sea level or 5mm >100m above mean sea level. The maximum intake velocity shall not exceed 0.3m/s. Compliance of these rules would be extremely difficult when pumps are operating, and in addition, such a fine screen would cause blocking issues by debris and other materials that would require extensive maintenance and staff labour.

Fish screens for tuna

Tuna behave very differently from other fish species for which deterrent structures have been successfully employed to date. Tuna tend to swim into structures through which flows are passing and try to force their way through them, rather than be passively guided by them.

All pump stations within the Waikato region are already fitted with debris screens with steel bars (spacing of around 50mm) to stop large debris entering the pumps and causing damage. The bar spacings are generally too large to be effective in preventing most fish (notably tuna) from entering pumps. However, it has been observed that debris screens can exclude large tuna from entering pumps (e.g. at Huntly Golf Course pump station).

Overseas studies have shown that eels up to 700mm in length are able to pass through debris screens with 25mm spacing (noting that this is a European species of eel). These results and subsequent work led to a European recommendation for bar spacing at no more than 10 to 15mm at power plants (Duirs 2017). Information on bar spacings and tuna size in New Zealand are sparse and are mostly limited to hydro power scheme intake structures where very large eels are excluded from entering the intake screens. Boubée (2001) found that a 30mm mesh screen excluded large eels from entering the turbines, with most eels being over 1000mm in length and few had a head width below 30mm (smaller eels may have passed through the screen).

Studies at Mokauiti and Wairere Falls power stations with screens of 30mm, found that tuna over 1000mm long could pass through the intake screens (Boubée 2001). This may have been due to damaged screens and bars pushed apart by debris resulting in screen gaps wider than first installed.

It is considered that a screen of 10 to 15mm bar spacings would need to be adopted to prevent adult tuna from entering pump intakes. However, it is unknown what proportion of eels would be protected by this given that eels attempt to force their way through obstacles. And bar spacing of 10 to 15mm would inevitably result in functional and operational issues for flood pump operations through both reduced hydraulic efficiencies and increased maintenance requirements.

Several studies have noted that physical screens are not a viable option for preventing fish passage as the bar spacing required would result in screens rapidly blocking with weed, leaves and other debris (Moria 2008, Solomon & Wright 2012). Clogging of wastes against screens enhances flow velocity, decreasing its functionality as impingement becomes more likely. Screens would require a lot of maintenance and although motorized cleaners can be used, they are very costly.

Flow velocity is another consideration. Overseas research has found that eels attempted to escape after a collision with a 5 to 20mm screen by immediately doing a 180 degree turn and where flow velocities do not exceed 0.5m/s most eels were able to free themselves. Screens with flow velocities over 0.5m/s can lead to mortality due to impingement, with mass eel mortalities recorded overseas due to screen impingement at high water velocities (DWA 2005). It is likely that when pumps are operational, velocities <0.5m/s would not be met.

Recommendations
At face value fish barrier screens could provide a simple and cost-effective method to exclude downstream migrating tuna from entering pumps, thereby reducing injury and mortality. The Waikato Regional Plan has limits on the screen aperture size and velocity for water intakes and these have not been installed at pump stations for practical reasons, as they would become clogged very quickly, limiting the ability of the pump to work and causing upstream flooding. Instead, vertical debris screens with a spacing of 50mm have been installed to stop debris but maintain flows, however, screens with this spacing generally do not stop fish from entering the pump.

For the reasons outlined above, it is not recommended that fish barrier screens be investigated or implemented at pump stations in the Waikato region.

8.2 Fish friendly floodgates

Background
As described in Section 6.3, a floodgate is an adjustable gate that is used to control water levels in a catchment. Floodgates only allow water to flow in a downstream direction. When the downstream water levels increase, the floodgate closes to prevent water flowing upstream and causing flooding. Internationally, the benefits of keeping floodgates open for longer periods of time is well established and this has gained traction in Aotearoa in recent years, with the retrofitting of fish friendly floodgate designs.

Opening floodgates for longer periods of time can provide many ecological benefits. Firstly, it allows floodplain inundation which is a key ecosystem process, allowing for increased feeding grounds and refuges for native fish through both juvenile and adult stages.

Additional food resources and organic carbon sources are returned back into the main channel, providing optimal access to key nutrients and food resources for aquatic biota. During the months of March to May, these inundated areas are also pivotal areas for inanga spawning, which spawn in inundated vegetated habitat during spring high tides. Water quality improvements may also be provided through hydrological connection, allowing for stream flushing and oxygenated water back into the catchment.

In Aotearoa, there is limited guidance and research on retrofitted fish friendly floodgates. This is generally because floodgates in lower lying areas are large and heavy structures and traditional retrofitting methods don't work (e.g. delayed closing mechanisms). The modifications needed to make these gates fish friendly require a lot of time and can be very expensive to remediate.

Aka Aka example

There is a lot of potential with floodgates and given this, WRC has been researching tidal floodgates in the lower Waikato River, near Aka Aka. The Aka Aka floodgates were built by the Franklin County Council around 1976. The floodgates are now managed by WRC and form part of the wider Franklin flood protection scheme to prevent upstream flooding on pastural land, especially during high tidal cycles and periods of heavy and continuous rainfall. The floodgates are made of three box culverts of 2.2 x 2.2m protected with square flapvalves hung from above. The floodgates interfere with two natural processes – fish migration and flushing of the system through hydrological connectivity.

The Aka Aka catchment has known populations of longfin tuna and inanga both of which are classified as 'At Risk'. Other native fish recorded in the catchment include shortfin tuna and common smelt.

If this project is a success, this could provide some valuable insight to the complexities of tidal flood gate remediation and allow for a case study to be shared on a national level for other regional councils and industry.

Research

A project was formed in 2018 with NIWA to improve fish passage at the Aka Aka floodgates. The objectives of the research project were to:

- Investigate different fish friendly floodgate options.
- Assess changes in ecological connectivity (e.g. fish passage) and water quality before, during and after the floodgates are closed.
- Implement the change without adversely impacting on the level of service (flood protection and drainage) in the surrounding catchment.

Six floodgate options were investigated/trialled including:

1. Counterweight: a fish friendly counterweight modification was installed to delay the closing time of the floodgate when the tides rise.
2. Winch: two of the three floodgates had manual winches installed to allow the gates to be opened in summer and assess how long they could stay open before the land was inundated (Figure 26). Water quality loggers were also installed to test the water quality before and after the winch install.
3. Fish-friendly Torrent floodgate: this option was investigated but not trialled. The Fish Friendly Torrent floodgate works with springs that hold the gates open until the head pressure in the downstream side of the gate overpowers the springs.
4. Flotation device: at the request of the landowners, a flotation device was trialled.
5. Bookcase/side mounted floodgate: this option was investigated but not trialled. An engineer was engaged to prepare a design for this option.

6. Automated sluice gates: this was agreed as the best option to pursue and is currently ongoing. Three new sluice gates will be installed with hydraulic rams. A much longer gate opening time will be achieved. Water quality and fish passage monitoring will also be undertaken.

Figure 26: Aka Aka floodgates when the winch was installed

Results

Floodgate options

Results of the floodgate investigations and trials at Aka Aka are shown in Table 7.

Table 7: Results of the floodgate investigations and trials at Aka Aka

Design option	Results
Counterweight	The counterweight was trailed for over a year and did not show positive results, likely due to the heavy weight of the floodgates.
Winch	This option proved unsuccessful because of the manual requirement to open and close the gate. The floodgates are in a tidal area which means that the gates need to be shut every day to maintain a catchment level of service. The work highlighted the importance of hydrological connection for improved water quality and fish habitat.
Flotation device	Results showed that the gate only stayed open by approximately 1 more minute, which is not significant enough to increase fish passage. The main reason that the flotation devices failed was due to the heavy weight of the individual floodgates (i.e. 1 tonne each) and that large enough flotation barrels could not be sought or would not be practical on the site. Other flotation devices from around the world are much more sophisticated in design or are larger in size (based on ratio of gate size). After the trials, flotation devices were removed as a feasible option.

Torrent floodgate	Investigation into the Fish Friendly Torrent floodgate found that it is designed to attach to round barrels and consequently when the floodgate is attached to a box culvert, the surface area of flow is restricted. In the case of the Aka Aka floodgates, each box culvert has a maximum flow surface area of 4.84m^2, while the largest Fish Friendly Torrent floodgate has a maximum flow surface area of 2.54m^2. This decrease in flow area reduces the flood protection levels of the floodgate and increases the velocity of the flow through the gate (which will inhibit or limit fish passage). This was not considered a feasible option.
Bookcase/side mounted gate	An engineer advised that the current design would require significant modification to accommodate a bookcase/side mounted gate and recommended exploring alternative options.
Automated sluice gate	The new sluice gates are expected to be commissioned early 2025 and upstream fish passage monitoring undertaken August-December 2025.

Water quality results

Continuous water quality monitoring was undertaken before and after the winch install in 2021, to compare catchment conditions during periods of unobstructed against managed flow. At 14:30 on 9 March 2021 on a 3.4m tide, the western gate was opened to assess how unrestricted hydrological connectivity affected water quality, upstream water levels, inundation and level of service (Figure 27). Drone surveys were undertaken at the same time in the catchment to assess the above objectives. The tide further increased to 3.5m over the opening period.

Figure 27: Aka Aka stream upstream catchment during the two-day period when gates were left open on a spring high tide in 2021

The assessment showed that opening the gates resulted in partial floodplain inundation through the catchment, and increased water levels of internal watercourses up to 9km upstream of the floodgates.

Despite the flooding and level of service concerns, the opening of the gates highlighted many benefits. During the gate opening, dissolved oxygen, a key factor for aquatic life, increased from an average of 2.65% to 67% saturation in a 7-hour period and remained high over the two days the gates were opened.

Once the gates were closed, dissolved oxygen dropped from 52% to 21% within 6 hours and continued to drop over time. Temperature decreased by 1.2 degrees when the gate was open. Temperatures were much more settled during the open period compared to before and after. Conductivity, pH and turbidity observed no obvious change during the opening period.

Recommendations
Recommendations on the automated sluice gate will be made at the completion of the project.

8.3 Bedford submersible pump

Background
Bedford Pumps in the United Kingdom design and manufacture fish friendly submersible pumps. The pumps have been tested in Europe with minimal mortality. A study on a larger SAF 90.05.12, at a low rotation speed, showed negligible mortality and minor injury in eels less than 600mm in length. At a higher rotation speed, eel mortality increased slightly but was still below 8% (Spierts & Vis 2012).

Waikato Regional Council operates a Bedford submersible SAF 70.05.12 at the Paeroa Main Drain pump station in the Hauraki area. This pump is a larger version of the model installed at Orchard Road pump station (SAF 45.05.06). The pump station also houses an axial MacEwans PPF 24/30, Gwynnes pump and ASB submersible pump.

It is widely known that Aotearoa tuna grow a lot larger than their European counterparts and so a fish mortality study was initiated in 2024 to test the Bedford pump at Paeroa Main Drain pump station.

Research
The monitoring programme design is based on previous surveys undertaken at Mangawhero, Steiners and Huntly Golf Course pump stations. The objectives for the study are:

- Assess the injury and/or mortality rate of tuna passing through the Bedford pump.
- Determine the size ranges of tuna that can safely pass through the pump.
- Compare the injury and mortality rates of the larger sized Bedford pump against other fish friendly pumps trialled in Aotearoa.

An initial fish survey was undertaken in the catchment to assess the species diversity and particularly abundance and size structure of the eel population in March 2024. Twenty-one fyke nets were set overnight on the 18 March 2024. The nets were baited with meat steak.

An injury/mortality study will be undertaken in summer/autumn 2025.

Results
Initial survey
A total of 171 shortfin tuna were captured in the nets, along with one catfish, three common bully and two goldfish. Mosquito fish (*Gambusia affinis*) and shrimp were also common.

A good number of tuna were captured in the catchment with most ranging in length from 300 to 700mm (Figure 28). The largest tuna recorded was 920mm in length. All the tuna captured were feeders. It is recommended that migrant or developing migrant tuna be translocated into the catchment prior to the mortality/injury study to stock the catchment and ensure a good sample size.

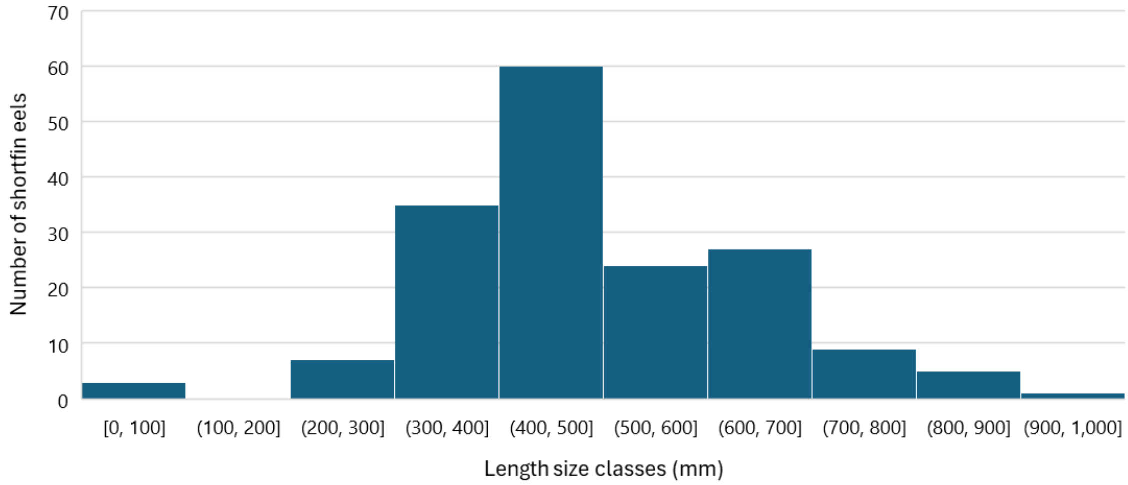


Figure 28: Length frequency histogram for the shortfin tuna captured upstream of the Paeroa Main pump station

Recommendations

Recommendations will be made following the injury/mortality assessment in 2025.

8.4 Traditional Archimedes screw pump

Background

It is well documented from overseas research, that while traditional Archimedes screw pumps are better at passing fish than axial flow pumps, there are still many design features that can cause fish injury and mortality. Traditional screw pumps have a blunt angular leading edge at the entrance of the pump and nip points between the screw and trough. Traditional screw pumps also create significant turbulence and noise, which is likely to deter fish from entering the pump.

A study in Belgium found a mortality rate of 17% for a small traditional screw pump and 19% for two large screw pumps (Buysee et al 2015). A further investigation of three large Archimedes screw pumps found significant differences in injury and mortality rates between the three species investigated with 37% mortality for bream, 19% for roach, and 3% for eels on average (Pauwels et al 2020). As noted in previous sections European eels grow to a much smaller size than tuna in Aotearoa and therefore these mortality rates are not directly comparable.

Two traditional type Archimedes screw pumps are in operation in the Lower Waikato drainage scheme at Motukaraka and Mangatawhiri Compartment 3 pump stations.

No research nationally has been undertaken on these pumps to assess fish passage.

Recommendation

Based on overseas research and availability of a new fish friendly Encased Archimedes screw pump, traditional screw pumps are not recommended for schemes in the Waikato region.

8.5 Bosman pump

Background

Bosman Water Management in the Netherlands design and manufacture fish friendly pumps, specifically designed to enable fish migration. The Bosman Vision 50 MC is a fish-friendly pump with a mixed-flow fan and one fish-friendly blade, in addition to a metal housing and three fish-friendly rotor blades (Figure 29).

The Bosman Vision MC can be installed at a range of sites, but preferably for smaller sized sites where other pumps would be too big or too expensive to install. The pump also runs at lower speeds than other axial pumps (~300 rpm) and if an oversized pump (for the site) was installed, the pump could be slowed down to improve fish passage.

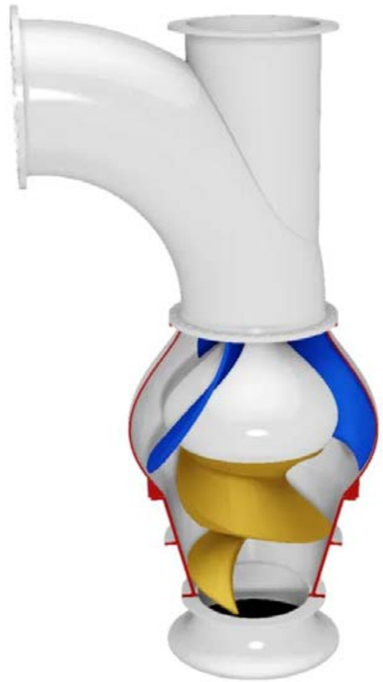


Figure 29: Bosman Vision MC fish friendly pump

A study in the Netherlands found a mortality rate of 2% for eels passing through a Bosman Vision MC pump (da Graça & Kemper 2019). One of the dead eels had haemorrhages and a broken spine, while another had blood coming from its gills. As noted in previous sections European eels grow to a much smaller size than tuna in Aotearoa and therefore these mortality rates are not directly comparable. Roach were also tested by de Graça and Kemper (2019) and showed more clearly recognisable damage compared to eels, with 5% mortality at design speed. Roach suffered damage to gills, bruising, haemorrhaging, broken spine, and open wounds – all likely caused by the pump.

Recommendations

It is recommended that a monitoring programme be developed to assess the fish friendliness of an oversized Bosman Vision MC pump at a suitable pump station, when its due for upgrade. The programme design should be based on previous surveys undertaken at Mangawhero, Steiners and Huntly Golf Course pump stations.

The recommended objectives for the programme include:

- Assess the injury and/or mortality rate of tuna passing through the Bosman pump.
- Determine the size ranges of tuna that can safely pass through the pump.
- Compare the injury and mortality rates of the larger sized Bedford pump against other fish friendly pumps trialled in Aotearoa.

An initial fish survey should be undertaken in the catchment to assess the species diversity and particularly abundance and size structure of tuna populations. If naturally occurring numbers are low (and lacking different size classes) then tuna will need to be sourced from other nearby catchments to ensure that there is a large enough sample size to test the pump.

9 Summary of options

Options researched as part of PTTS are summarised below in Table 8.

Table 8: Summary of options researched as part of PTTS

Option	Research	Recommendation
Mitigation tools		
Trap and transfer	Tested by WRC: Yes Research: WRC study – low cost and simple tool to provide an interim measure. Benefits from iwi perspective and provides partnership opportunities between iwi and council. But is labour intensive and requires good site access.	**Implement**
Gravity bypass outlet	Tested by WRC: Yes Research: WRC study – tuna can locate and exit the pump station via gravity bypass outlet when the floodgate is open. Both migratory and feeder tuna use the outlet and bidirectional movement is common, likely for foraging. Currently only option for upstream passage at pump stations. Should not be included at sites with non-fish friendly pumps – as this would allow access into the catchment and risk fish being killed when migrating out if the bypass is closed.	**Implement**
Fish friendly floodgates	Tested by WRC: In progress Research: WRC Aka Aka fish friendly floodgate project Regulations: floodgates must be kept operational (i.e. not blocked by silt) to ensure opportunities for safe fish passage are maintained.	**Trial**
Fish barrier screens	Tested by WRC: No Many factors need to be considered – screen size, velocity, impingement, maintenance, fish species. Tuna behave differently to other species and swim into structures and are able to force themselves through gaps. Research: Overseas studies – eels up to 700mm can pass through 20mm mesh. Flow velocities over 0.5m/s at screens can kill eels due to impingement.	**Not recommended**
Electrical barrier	Tested by WRC: Yes Research: WRC study – behavioural deterrence not 100% effective. Deep sediment layers interfere with the creation of the electrical field. Significant investment is still required to develop an effective tool. Investment better used in other areas.	**Not recommended**
Pumps		
FishFlow Encased Archimedes screw pump	Tested by WRC: Yes Likely mortality: Nil Research: Proven fish friendly in Europe and Aotearoa. WRC study – 100% tuna survival rate, 99.2% of tuna had no or minor injury, 0.8% suffered moderate bruising. Regulations: will meet permitted activity regulations as it provides 99.2% safe fish passage so consent will likely not be needed (unless footprint of structure is changed).	**Implement**
Modified MacEwans pump	Tested by WRC: Yes Likely mortality: Nil Research: NZ manufactured pump. WRC study – 99.1% tuna survival rate, 97.2% of tuna had no or minor injury, 1.8% suffered moderate to severe injuries. Regulations: will meet permitted activity regulations as it provides 97.2% safe fish passage so consent will likely not be needed (unless footprint of structure is changed).	**Implement**

Bedford fish friendly submersible SAF 70.05.12	Tested by WRC: No Likely mortality: Low Research: To be undertaken by WRC in 2025.	**Trial**
Bosman Vision MC pump	Tested by WRC: No Likely mortality: Low Research: Overseas studies – range from 2% to 5% mortality for different fish species. Improved fish passage compared to traditional axial pumps but still inflicts mortality and injury.	**Trial**
Bedford fish friendly submersible SAF 45.05.06	Tested by WRC: Yes Likely mortality: Low, but high injury Research: WRC study – 6% tuna mortality, 50% moderate-severe injuries. Comments: Improved survival rate compared to traditional axial pumps but still inflicts some mortality and high injury. Regulations: Fish friendlier pumps that do not provide close to 100% safe fish passage will likely require consent, in which conditions will be specified.	**Not recommended**
Traditional Archimedes screw pump	Tested by WRC: No Likely mortality: Low Research: Overseas studies – range from 3% to 37% mortality rate for different fish species. Improved fish passage compared to traditional axial pumps but still inflicts mortality and injury. Comments: Traditional Archimedes screw pumps generally have no place in our schemes moving forward. There may however be instances where non-fish friendly pumps are the preferred option, for example in small catchments where the watercourse goes dry for half the year and smaller tractor type pumps are in place. Larger fish friendly pumps may not be viable for such catchments.	**Not recommended**
MacEwans axial PPF or traditional axial pumps	Tested by WRC: Yes Likely mortality: High Research: WRC study – 100% mortality for tuna over 600mm, 64% mortality overall. Comments: Traditional axial pumps generally have no place in our schemes moving forward. There may however be instances where non-fish friendly pumps are the preferred option, for example in small catchments where the watercourse goes dry for half the year and smaller tractor type pumps are in place. Larger fish friendly pumps would not be viable for such catchments.	**Not recommended**
Monitoring tool		
Passive acoustic	Tested by WRC: Yes Research: WRC study – impellor strikes on tuna can be detected. Can be used to increase knowledge of a pump station mortality and injury rates. Further investigations are required to refine the tool as it currently has to be calibrated for each pump and site. Investment better used in other areas.	**Not recommended**

PART D: PRIORITISATION & DECISION MAKING

Te Whakaarotau me te Whakatau

10 Prioritisation matrix

The Waikato region has over 120 pump stations and remedial works can be costly. It is not feasible to upgrade all these assets at once and given some of these assets have decades left on their life, it may be some time before such upgrades can occur. It is therefore necessary to prioritise catchments for remediation and mitigation. There are a range of factors that might influence how pump stations are prioritised including both ecological and cultural considerations. Key factors to consider include:

- Cultural values
- Fish records (species and abundance present)
- Documentation of any past fish mortality
- Catchment size
- Presence of wetlands and lakes
- Asset information i.e. type and number of pumps, and presence of gravity bypass channel
- Other barriers within the catchment

Other considerations include watercourse classification, pump hours, catchment gradient, landcover and flood frequency.

To prioritise pumped catchments, a database with the above information was firstly created. The range of information collated provided transparency across all pumped catchments and gave a good starting point to determine the values of most importance to fish passage at pump stations. The information was then cross checked with the prioritisation criteria in Table 5.1 of the New Zealand Fish Passage Guidelines. A draft list of values was workshopped and confirmed with knowledge holders in the respective catchments (see Sections 10.1 and 10.2).

Fish records were obtained from WRC databases, informal records (from landowners and iwi) and the New Zealand Freshwater Fish Database (NZFFD). Records were generally sparce and only available for around half of the pumped catchments. Fish records are a key factor, and the technology is now available to more readily collect this information via eDNA sampling. eDNA is a relatively new tool that is being used more and more in Aotearoa instead of or in combination with traditional approaches. eDNA has been identified as a valuable tool in the implementation of eel management plans overseas, identifying the geographic distribution of eels and where to focus resources (Griffiths et al 2023). It is recommended that eDNA sampling be undertaken in the Lower Waikato and Hauraki catchments where fish records are not present.

Documentation of fish mortality has been inconsistent in the past and not always recorded when witnessed. Staff are now more aware of fish passage and subsequently reporting mortality events more frequently. It is important to continue encouraging staff to report mortality events. It is noted that not all mortality events are a direct result of pump operation, with some events likely the result of poor water quality.

Cultural values and Te ao Māori are important considerations when prioritising pumped catchments. Te ao Māori, the Māori worldview, recognises the interconnectedness between all living and non-living elements. Whakapapa is central to all living things. To understand whakapapa is to understand that all living things are connected.

The Māori worldview can be reflected in the story of creation:

Te Kore - the energy, potential, the void.
Te Po - the form, the dark, the dark night.
Te Wehenga o Ranginui raua ko Papatuānuku - the separation of Sky Father from Earth Mother.
Te Ao Marama - light and reality, and life borne; with the heavens adorned and the landscape covered, native species then took their place and flourished. Only then were humans given the breath of life.

The inextricable kinship between people and the natural world creates an obligation for us to nurture the environment, so it in turn can nurture us.

The prioritisation matrix work began with lower Waikato and then moved to Hauraki, both processes are explained in the following sections.

10.1 Lower Waikato

A hui was held with knowledge holders (including Waikato-Tainui representatives, consultants and WRC staff) for the lower Waikato scheme area in December 2019. Ecological and cultural values confirmed by knowledge holders for inclusion in the matrix are listed in Table 9.

Table 9: Values for inclusion in the Lower Waikato and Hauraki prioritisation matrices

Value	Explanation and source of information
Fish mortality	Key cultural value. Records from WRC staff
Abundance of tuna	NZFFD and other formal records, or informal records (e.g. kōrero with tangata whenua)
Diversity of fish species	NZFFD and WRC records
Size of pumped catchment (upstream)	Upstream of the pump station. GIS analysis.
Size of lakes and/or wetlands within the upstream catchment	Combined aerial extent of lakes and wetlands. GIS analysis.
Flooding frequency	Based on 1% of AEP modelling for the Waikato region
Overlaps with Waikato and Waipa River Restoration Strategy (WWRRS) biodiversity priority areas	Identified for restoration focus as a priority in the WWRRS
Fisheries exclusion areas	Waikato-Tainui bylaw listed areas or protected DOC estate
Mahinga kai	Historic and current records
Outfall type	To be used as a proxy for where no fish records/data exists e.g. a pumped catchment with a gravity outlet has a higher likelihood of having native freshwater fish present compared with one without a gravity outlet as there is periodic upstream and downstream passage through the floodgate. Also used as a proxy for likely legislative compliance, presence of a floodgate will allow for up and downstream passage at various times
Pumped catchment slope/gradient	Range of elevation within the catchment as an indication of habitat types and diversity

A subsequent whakawhitinga korero was held with Waikato-Tainui which confirmed that the key cultural value is the health and wellbeing of tuna; this also includes the protection of tuna and prevention of mortality due to pump operations. This value is reflected by using fish mortality as a core cultural indicator value. Participants at the hui agreed that pumped catchments where pump-related mortality has been recorded should be given priority over other pumped catchments where there are no records of pump-related mortality.

An assessment of data availability ruled out mahinga kai and flood frequency as potential values due to the lack of consistent, reliable data. Also it is important to note that pumped catchments are still of cultural significance regardless of whether cultural harvest is practised today.

Access to sites and silting of pumped catchments now make it difficult for iwi to continue their cultural practises.

The final list of values is presented in Table 11. A scoring criteria of 1 to 4 was developed for each value. Adjustments to the scoring criteria were made in consultation with Waikato-Tainui.

Further detailed information on prioritisation methodology can be found in Williams et al 2021.

Field validation

The scoring criteria from Table 11 was applied to all 57 lower Waikato pumped catchments. The scores were summed to give an overall score for each catchment. The catchments were then ranked from highest to lowest.

Due to critical data gaps with respect to fish community composition and abundance for certain catchments, field validation surveys were undertaken during the summer of 2020 on the top and bottom 10% of scoring sites (12 sites in total). In addition, two further sites were surveyed (Muir's Pump Station and Island Block North Pump Station) that had records of fish mortality but no information on fish data. These sites were surveyed during the summer of 2021.

At each of the 14 sites, fish netting surveys and habitat assessments were undertaken, along with eDNA sampling at sites where standard survey methodologies could not be employed. Based on the field results, the scores were updated for 10 out of the 14 sites.

Further information on the field validation surveys can be found in Williams 2020.

Final matrix

The final prioritisation matrix for the lower Waikato can be found in Appendix B. Overall scores range from 5 to 28. All pumped catchment scores were placed into a percentile range to create four categories (Table 10).

Table 10: Ecological and cultural value scoring categories for lower Waikato pumped catchments

Category (priority)	Category scoring range	Number of lower Waikato pumped catchments
High (75-100% of sites)	17+	12
Medium - High (50 - 75% of sites)	12-16	16
Medium (25 -50% of sites)	8-11	15
Low (0 - 25% of sites)	0-7	14

As the health and wellbeing of tuna was highlighted as the most important value to Waikato Tainui, all sites that have documented mortality are highlighted red in Appendix B, equating to 23 or 40% of sites in total (at the date of this document). Of the sites with documented mortality, 7 of these sites are within the 'High' priority category and therefore ranked higher, so will be prioritised ahead of others.

Note: The matrix is a living document and will updated when new information is received. Always refer to the living document for the most up-to-date version.

Table 11: Scoring criteria for ecological and cultural values for the Lower Waikato and Hauraki pumped catchments

Ecological or Cultural Value	Scoring Criteria				
	0	1	2	3	4
Fish mortality record(s)	No record of mortality		Record of mortality		Records of significant mortality (multiple events over last 10 years, or large-scale mortality >10 deaths per event)
Catchment size (ha)		Less than 250ha	250 to 1,000 ha		Greater than 1,000 ha
Size of lakes and wetlands within the catchment (ha)	No lake or wetland area present	0.1 to 1 ha	1 to 10 ha	10 to 20 ha	Greater than 20 ha
Fish records	No native fish reported	Only shortfin tuna have been reported. Note unidentified tuna species records are assumed to be shortfin tuna.	Longfin tuna have been reported; OR shortfin plus one or more native species.	Longfin tuna species and at least one other native fish species have been reported; OR shortfin plus one or more At Risk or Threatened species.	Longfin tuna species and 1 additional or more At Risk or Threatened species have been reported.
Abundance of tuna	No tuna found/ no fish record		Some tuna, 50 or less		Abundant tuna, greater than 50
Overlaps with WWRRS[20] fish and/or biodiversity priority area	No overlap	Overlap			
Overlaps with Waikato-Tainui seasonal closure bylaw or PCL[21]	Not within bylaw watercourses or PCL				Within bylaw watercourse or PCL
Outfall type - proxy for fish records	Pump only (no passage)		Pump and gravity outlet (periodic passage)		
Outfall type - proxy for legislative compliance			Pump and gravity outlet (partial compliance)		Pump only (not compliant)

[20] Waikato and Waipa Rivers Restoration Strategy
[21] Public Conservation Land gazetted under the Conservation Act 1987

10.2 Hauraki

A hui was held with knowledge stakeholders (including iwi, consultants and WRC staff) for the Hauraki scheme in September 2020, and participants were asked to explore cultural values and how they can be used to inform pump prioritisation.

Upon discussions with local iwi and hapū, it was apparent that further dedicated time needs to be set aside to unanimously agree on cultural priorities. The outcome of the first hui was to engage a cultural writer to prepare a cultural values assessment (CVA). Two iwi cultural writers were identified, with one contracted to undertake the work but unfortunately the work was not delivered. Waikato Regional Council then sought the assistance from an internal staff member to lead the cultural values work.

A draft cultural values report was prepared (Tawa 2023), which was agreed upon at a hui in September 2023 with iwi and hapu, and WRC representatives. The values used for the lower Waikato scheme were also applied to the Hauraki scheme (Table 9). These represent ecological values for the Hauraki scheme. From a cultural perspective, no one catchment is more significant than another.

Further detailed information on prioritisation methodology can be found in Williams and Tawa 2023.

Field validation

The scoring criteria from Table 11 was applied to all 41 Hauraki pumped catchments. The scores were summed to give an overall score for each catchment. The scores ranged from 6 to 20. The catchments were then ranked from highest to lowest.

Due to critical data gaps with respect to fish community composition and abundance for certain catchments, field validation surveys were undertaken during the summer of 2020/2021 on the top and bottom 10% of scoring sites (eight sites in total).

At each of the 8 sites, fish netting surveys and habitat assessments were undertaken, along with eDNA sampling at sites where standard survey methodologies could not be employed. Based on the field results, the scores were updated for 7 out of the 8 surveyed sites.

Further information on the field validation surveys can be found in Williams 2021b.

Final matrix

The final prioritisation matrix for the Hauraki can be found in Appendix C. All sites that have documented mortality are highlighted red, equating to 7 or 17% of sites in total. Of the sites with documented mortality, 6 of these sites are within the “High” priority category and therefore ranked higher, so will be prioritised ahead of others.

All pumped catchment scores were placed into a percentile range to create four categories (Table 12).

Table 12: Ecological value scoring categories for Hauraki pumped catchments

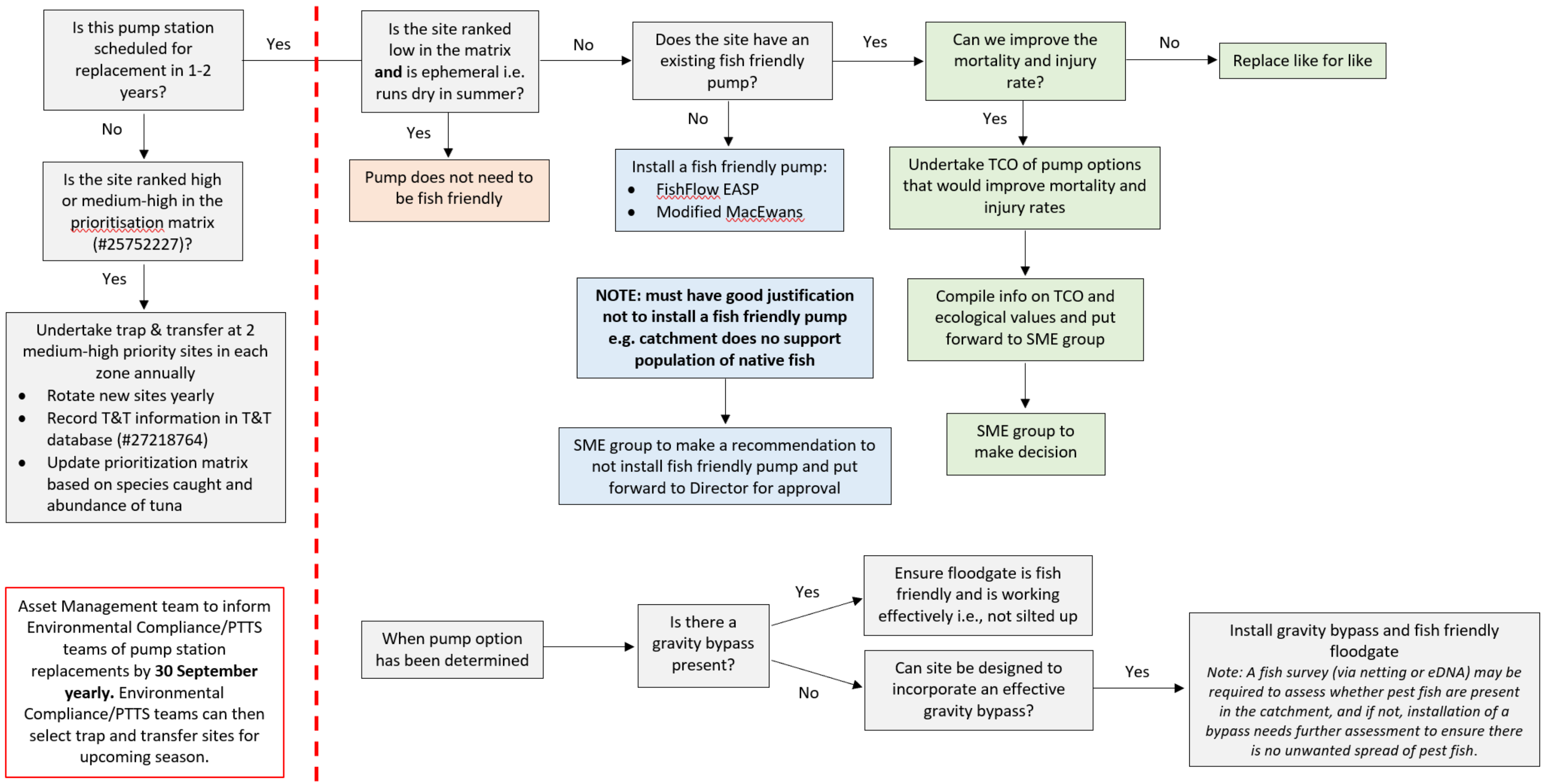
Category (priority)	Category scoring range	Number of Hauraki pumped catchments
High (75-100% of sites)	13+	9
Medium - High (50-75% of sites)	9-12	10
Medium (25-50% of sites)	7-8	10
Low (0-25% of sites)	0-6	12

Note: The matrix is a living document and will be updated when new information is received. Always refer to the living document for the most up-to-date version.

11 Decision flow chart

A decision flow chart was developed as part of PTTS to guide decision making around fish friendly pumps and mitigation tools (Figure 30). The tool should become an integral part of the asset management process and used with every new pump replacement project. The chart guides the user through a range of questions, including whether the site is scheduled for replacement and is it ranked low, before stepping into fish friendly pump options. When the pump option has been determined, a gravity bypass channel should then be considered.

There are a number of considerations that should be assessed alongside the flow chart, including the long-term sustainability of the pump station and whether it can be replaced with an open channel. The long-term sustainability of flood protection schemes is an important consideration given the range of environmental impacts the schemes pose on aquatic life, as well as hydrological disconnections, peat subsidence and water quality effects. In addition to environmental impacts, economic impacts of increasing asset costs and associated scheme rates are extremely important factors to take into consideration over the long term.



Assumptions:
- This flow chart only includes proven fish friendly pump options: FishFlow EASP and modified MacEwans pump.

Considerations:
- Can we replace the pump station with an open water channel?
- Are floodgates working effectively?
- Are there other barriers in the catchment that could be remediated to provide complete upstream and downstream passage?

Acronyms:
- EASP = Encased Archimedes screw pump
- PTTS = Pathways to the Sea
- T&T = Trap and transfer
- TCO = Total cost of ownership
- SAF = Submersible axial flow pump
- SME = Subject matter expert (group to consist of BATS Manager, Zone Manager, ecologist, Asset Management, works supervisor)

Figure 30: Decision flow chart for pump replacements

PART E: IMPLEMENTATION PLAN

Mahere Whakatinanatanga

The goal of this Strategy is to:

Improve safe downstream fish passage at Waikato Regional Council managed pump stations

This section describes the actions recommended to achieve this goal.

12 Implementation actions

Based on the research in Part C, a number of actions are recommended (Table 13). These actions can be grouped into the following focus areas:

Focus area 1: Implement mitigation tools to reduce the mortality rate as an interim measure
Focus area 2: Install fish friendly pumps as the ultimate long-term solution
Focus area 3: Test other options to add to the toolbox
Focus area 4: Add to our knowledge base and keep information up to date
Focus area 5: Work with our iwi partners and keep stakeholders informed

Some of the actions will be ongoing while others are researched focused and will be implemented over a short period of time. Funding will be required for some of the actions, via the mechanisms described in Section 14.

As a general principle going forward, any untested options, particularly new pumps will need to have their efficacy tested before they can be added to the toolbox of approved options and included in the decision flow chart.

Table 13: Actions recommended based on the research undertaken as part of PTTS

Action	Description	Who & When
FOCUS AREA 1 - Implement mitigation tools to reduce the mortality rate as an interim measure		
Implement trap and transfer	• Build into capital programme development • Implement at priority sites, based on decision flow chart and prioritisation matrix • Engage iwi partners, where possible, to undertake the work and select sites	Target migrant tuna during January-May 2 sites per zone per year Environmental Compliance, Zone Managers, Iwi
Install gravity bypass outlet	• Build into capital programme development and asset renewals programme • Install gravity bypass outlet during pump replacements • Investigate retrofitting floodgates with fish friendly designs at existing gravity bypass outlets with careful consideration to the risk of upstream flooding • Assess catchment for pest species presence, to ensure pest species are not spread	Ongoing, during pump replacements Environmental Compliance, Zone Managers, Asset Management, Operations

Change operational management	• Scope and trial changes to operational management of pump stations to reduce tuna mortality and injury. For example, keep floodgates open for longer periods of time	Scope and trial in 2025 Environmental Compliance, Operations
FOCUS AREA 2 - Install fish friendly pumps as the ultimate long-term solution		
Install Encased Archimedes screw pump	• Build into capital programme development and asset renewals programme • Install at sites where the footprint allows • Implementation based on decision flow chart and prioritisation matrix	Ongoing, during pump replacements Environmental Compliance, Zone Managers and Asset Management
Install Modified MacEwans pump	• Build into capital programme development and asset renewals programme • Install at suitable sites • Implementation based on decision flow chart and prioritisation matrix • Liaise with MacEwans on the development of a larger sized modified MacEwans pump	Ongoing, during pump replacements Environmental Compliance, Zone Managers and Asset Management
FOCUS AREA 3 - Test other options to add to the toolbox		
Trial Bedford fish friendly submersible pump	• Trail SAF 70.05.12 at Paeroa Main Drain pump station for fish friendliness • Use the same methodology as used for the modified MacEwans and Encased Archimedes screw pumps • Add to the toolbox if successful	Test during 2025 tuna migration season Environmental Compliance, Iwi
Trial fish friendly floodgates	• Incorporate the findings of the Aka Aka project into this Strategy • Scope other fish friendly floodgate technology	Scope in 2025 Environmental Compliance, Asset Management
Trail Bosman Visions fish friendly pump	• Scope the Bosman Visions MC fish friendly pump to see if it would be suitable for Waikato pump stations	Scope in 2025 Environmental Compliance, Asset Management
Investigate upstream passage	• Investigate options and solutions for the safe upstream passage of fish at WRC pump stations.	Scope in 2025 Environmental Compliance, Asset Management, Iwi, Operations
FOCUS AREA 4 - Add to our knowledge base and keep information up to date		
Undertake eDNA sampling	• Undertake eDNA sampling at pumped catchments with little/no fish records • Add new information to the database and prioritisation matrices	Initiate in 2025; ongoing until all pumped catchments have been sampled Environmental Compliance, Asset Management
Test sensor fish through new pumps	• Use a sensor fish to test through new fish friendly pump options	When new pumps are tested Environmental Compliance

Document fish mortality	• Encourage staff to report and document fish mortality sightings at pump stations	Ongoing Environmental Compliance, Operations, Asset Management
Keep prioritisation matrices and databases up to date	• Add new information to the database such as fish mortality and fish sampling (e.g. eDNA and fish netting) records • Update the prioritisation matrices when new information becomes available	Ongoing Environmental Compliance
Keep decision flow chart up to date	• Update and add to the decision flow chart when new tools or pumps have been successfully trialled	Ongoing Environmental Compliance
FOCUS AREA 4 – Work with our iwi partners and keep stakeholders informed		
Work with our iwi partners	• Continue to work with our iwi partners • Keep iwi up to date with implementation progress with regular hui	Ongoing Environmental Compliance, Zone Managers
Keep stakeholders informed	• Keep stakeholders up to date with implementation progress	Ongoing Environmental Compliance, Zone Managers

13 Implementation mechanisms

There are several regional plans and strategies that influence flood and drainage management decisions. Investment decisions that WRC makes today can have long term ramifications - including committing WRC and communities to inter-generational investments.

This strategy cannot be implemented on its own. It must inform and be implemented through a cascade of other Council approved plans and strategies, with associated funding requirements (Figure 31). The strategy must also be built into everyday programmes and thinking such as the Capital Programme. Communication with key internal stakeholders is key to raise awareness of the strategy and importance of fish passage.

Figure 31: Regional plans and strategies relevant to flood and drainage management. The PTTS strategy must inform and be included in these strategies/plans

Implementation will be an ongoing process and as new LTPs, Infrastructure Strategies, RAMPs and ZMPs are developed and reviewed, the PTTS strategy and implementation actions will need to be included.

The RAMP Operation Manual is a key implementation document for this Strategy. It describes the asset renewals programme and where the PTTS Strategy and fish passage are considered as part of this process. The asset renewals programme forecasts 3-5 years out and focuses on major stop bank, pump station and floodgate rebuild (refurbish) and replacements. The programme aims to deliver the agreed level of performance from the asset base while maximising their economic life. Priorities are reviewed annually based on new condition and performance information collected throughout the year, and unexpected failures or risk/issues in the dynamics of the flood protection scheme.

For now, pump replacements with fish friendly versions are triggered by operational needs rather than ecological impacts. There may, however, be opportunities in the future to secure funding for replacements purely on ecological grounds. The project management process to undertake pump replacements is shown in Figure 32. Fish passage and this strategy should be considered in the 'initiation' phase of the process.

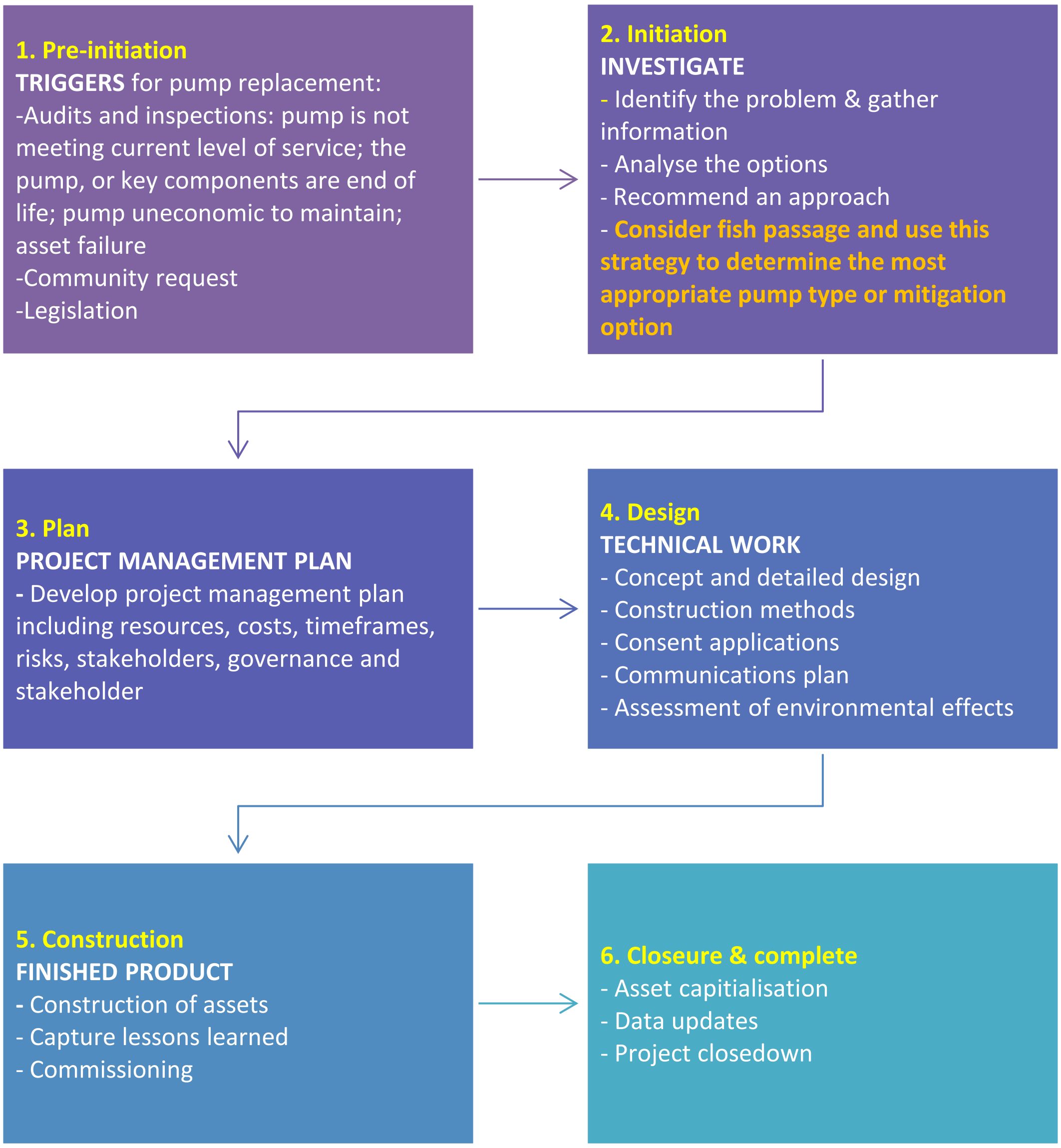


Figure 32: Waikato Regional Council's project management process for asset renewals, highlighting where fish passage and the PTTS Strategy should be considered

14 Funding and costs

The actions identified in this Strategy will generally need to be funded by Council, with funds secured via the LTP. The Council collects rates (general and targeted) for flood protection, river management and catchment management works based on the areas of benefit and activities that contribute to the programmes being managed.

There are a number of other funding sources that could be available to deliver fish passage works for example Waikato Catchment Ecological Enhancement Trust (WCEET) and Waikato Regional Authority (WRA). Funding was received from WCEET, WRA, Ministry for Primary Industries and the New Zealand Lottery Grants Board for the research and development undertaken for PTTS.

In some instances, there could be opportunities for central government funding for example the Covid-19 Response and Recovery Fund (Kānoa Regional Economic Development and Investment). This fund partially paid for the installation of the enclosed Archimedes screw pump at Mangawhero pump station.

The costs associated with the tools recommended in Section 14 can be very site specific and particularly for pumps, require detailed scoping according to the site. Tables 14 and 15 provide indicative costs of the mitigation tools and new pumping systems recommended in this strategy. Note: these are high-level cost estimates only, as per the date indicated.

Table 14: Indicative costs of tools recommended by this strategy

Tool	Cost	Details
Trap and transfer	$5,000 per site	Based on setting nets over two nights
eDNA sampling	$1,200 per site	Based on six replicates and analysis for fish species only
Funnel net (to test fish friendliness of new pumping systems)	$5,000-6,000 each	A custom net needs to be made and fitted to the outlet of the pump being tested. Cost will vary depending on the manufacturer and site dimensions. Cost here is based on the nets made for Mangawhero, Huntly Golf Course and Paeroa Main Drain pump stations.

Table 15: Indicative costs of new pumping systems recommended by this strategy

Pump	Details	Cost
Pump only (based on 1 cumec and < 4m head)		
Modified MacEwans pump	**Supplier:** MacEwans Pumping Systems (NZ) **Pump size**: PPF 24/30	**Cost of pump:** $470,000 (as per May-24)
Encased Archimedes screw pump	**Supplier:** FishFlow Innovations (Netherlands)	**Cost of pump:** $527,000 (as per Aug-24)
Full pump station replacement		
Encased Archimedes screw pump	**Based on:** Mangawhero pump station replacement; greenfield build **Supplier**: FishFlow Innovations (Netherlands) **Pump size**: single screw, 1.6m diameter, 8m length, 0.52 cumecs	**Capitalised cost**: $2,000,000
	Based on: Churchill East pump station replacement; retrofitted to an existing concrete structure **Supplier**: FishFlow Innovations (Netherlands) **Pump size**: two screws, 3m diameter, 10m length, 2.25 cumecs	**Total cost of project:** $6,000,000 (forecast as per July-24)

Notes:
'Cost of pump' includes cost to purchase the pump from the supplier and is exclusive of shipping and on-site pump installation costs which can be significant.
'Total cost of project' includes design, consents, materials, pump, electrical and construction.

When scoping long-term assets, it is important to calculate the 'total cost of ownership' (TCO). The TCO is a holistic way to view the costs of an asset over its entire lifetime. It includes the long-term costs and expenses such as maintenance incurred during the asset's lifetime. An example of TCO is provided in the case study below.

Case study: TCO of open versus encased Archimedes screw pump at Motukaraka pump station

The Motukaraka pump station currently consists of one traditional Archimedes screw pump, two Harland Johnson pumps and one MacEwans PPF 24/30 axial pump. Due to land subsidence, the screw pump is no longer meeting the required level of service and a replacement pump is being investigated. Two replacement pumps were investigated, including an open Archimedes screw pump and an encased Archimedes screw pump. Although encased Archimedes screw pumps are proven fish friendly, there was interest from the landowners to retain a similar 'open' style as the existing pump had performed well. Plus, there was a perception that there would be a cost disadvantage switching to an encased fish friendly design.

The costs to purchase replacement pumps are as follows (as per December 2023; does not include shipping):
- Open Archimedes screw pump from Landustrie in the Netherlands: **$1,600,000**
- Encased Archimedes screw pump from FishFlow in the Netherlands: **$2,600,000**

The upfront cost of an open Archimedes screw pump is more cost effective but when considering the total life of the asset, the **encased Archimedes comes out on top and is many millions less**. This is why it is important to calculate the TCO.

The TCO is based on the total lifespan of a pump (80 years for Achimedes screw pumps) and includes capital costs, interest, electricity, maintenance, overhauls, and VSD and screen replacements for the life of the pump.

The lower TCO for the encased pump is attributed to its high efficiency (99% compared to 66% for the open pump), lower electricity costs, and lower maintenance and overhaul costs.

It is always recommended to calculate the TCO when scoping replacement pumps.

15 Summary

Waikato Regional Council has embarked on a significant programme of work over the past five years to improve the safe downstream passage of fish at pump stations. The work wouldn't have been possible without our iwi, funding, consultants and industry partners who have supported financially, and/or via time and knowledge. The programme has been successful and has contributed significant information, knowledge and research to downstream fish passage in Aotearoa. Over twenty technical reports have been produced through the programme. This information aids in decision making within a Aotearoa context, providing significant guidance, both internally for WRC and also externally for other regional councils, territorial authorities, stakeholders and industry.

The devasting impacts of traditional pump stations is now well known, particularly on larger species of fish like freshwater tuna. Freshwater tuna are a taonga species and it is important to understand their inherit right to safe passage and a healthy habitat, when managing drainage and flood control schemes.

The PTTS programme considered a number of mitigation tools and new pumping systems. The trials clearly demonstrated the effectiveness of the encased Archimedes screw pump and modified MacEwans pump at safely passing fish. These pumps outperformed the other pumps tested and are recommended for any pump replacements. There is a realisation that pump replacement is costly and it will take some time to replace all pumps in the Waikato region. In the interim, measures such as trap and transfer and operational changes can be employed, and further research undertaken.

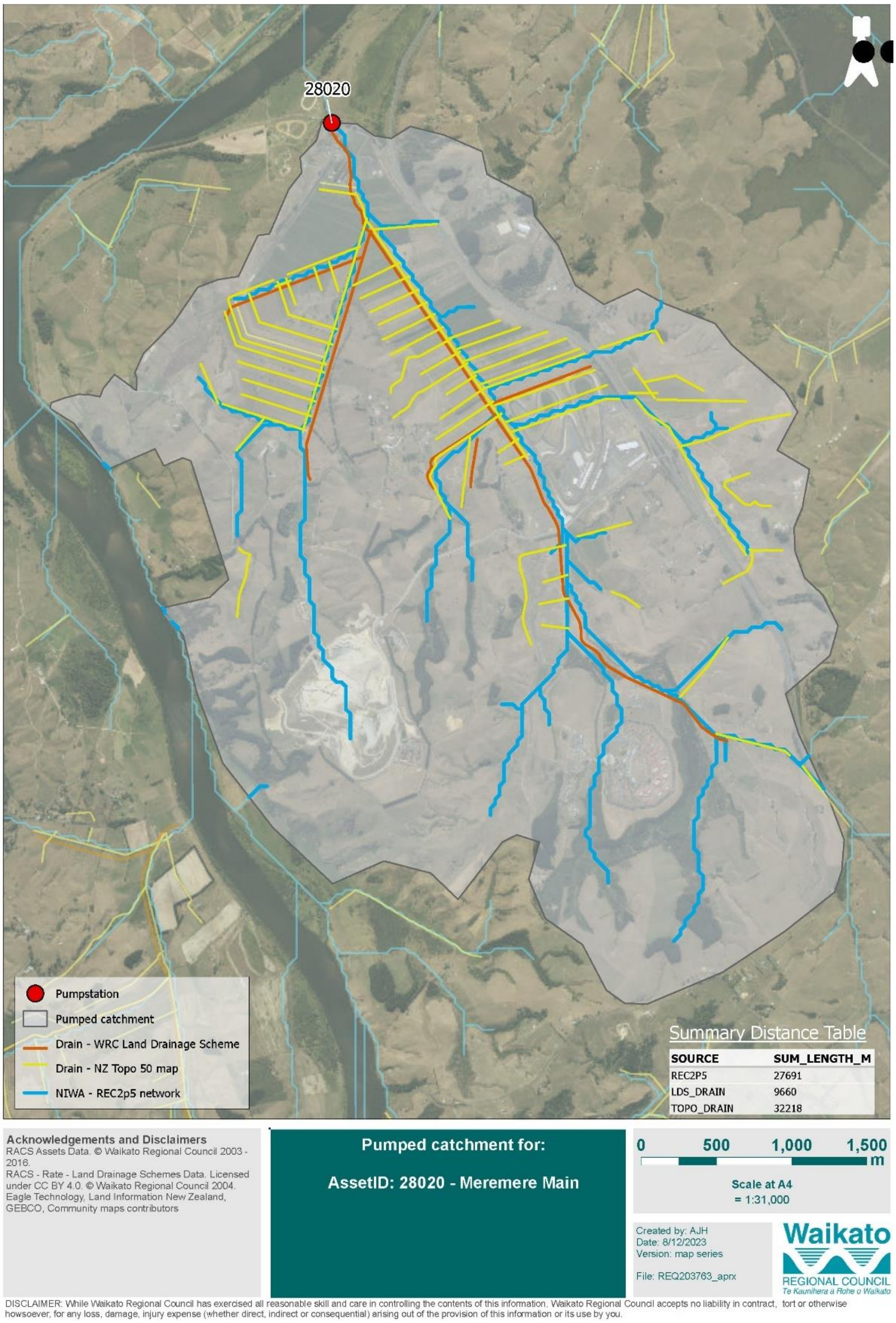
Gravity bypass outlets are currently the only option for upstream passage at pump stations and should be installed alongside fish friendly pumps (where viable). We now also have a greater understanding of tuna behaviour and should consider changes to the operational management of our pump stations to reduce the impacts on native fish.

Implementation and ongoing communication is key to the success of this Strategy. Fish passage and this Strategy must be built into everyday programmes and thinking. Communication with key internal stakeholders is vital to raise awareness of the strategy and shift thinking to balance environmental and operational needs.

We now have a path forward and WRC can slowly, pump by pump, create pumped catchments that are safe for native fish.

Appendices

A – Watercourses comprising Meremere Main catchment



B - Prioritisation matrix - Lower Waikato

Note: The matrix is a living document and will change when new information is received. Always refer to the discover document (#25752227) for the most up-to-date version.

Site	Catchment size (ha)	Fish records	Fish mortality documented	Combined size of lakes and wetlands (ha)	Abundance of tuna	Outfall type - proxy for no fish data	Outfall type - proxy of legislative compliance	Overlaps with WWRRS Fish and/or Biodiversity Priority area	Overlaps with Waikato-Tainui Seasonal Closure Bylaw	TOTAL SCORE
Motukaraka pump station	4	3	4	4	4	0	4	1	4	28
Whangamaire pump station	4	4	4	4	4	2	2	0	0	24
Bell Road pump station	2	4	0	2	4	2	2	1	4	21
Meremere East Main pump station	4	4	4	2	2	0	4	1	0	21
Eastern Drain pump station	4	4	2	3	2	2	2	1	0	20
Orton pump station	4	1	4	3	2	0	4	1	0	19
Mangatawhiri Compartment 4 Main pump station	4	4	2	2	2	2	2	0	0	18
Mangatawhiri Compartment 3 pump station	4	3	0	3	4	0	4	0	0	18
Swan Road pump station	2	1	0	2	4	0	4	1	4	18
Lake Hakanoa pump station / floodgate	2	3	0	4	4	2	2	0	0	17
Okowhao pump station	2	3	0	4	4	2	2	0	0	17
Orchard Road pump station	1	1	4	2	4	0	4	1	0	17
Blairs pump station	1	2	0	4	4	2	2	1	0	16
Waller Commins pump station / floodgate	1	1	0	1	4	0	4	1	4	16
Parish Polder pump station	1	3	0	0	2	0	4	1	4	15
Pattersons (Horohoro) pump station	4	1	2	1	2	0	4	1	0	15
Churchill East pump station (Holmes)	4	2	0	1	2	0	4	1	0	14
Mangawhero (Waikato) pump station	1	3	0	1	4	0	4	1	0	14
Masseys pump station (Franklin District Council: Finleyson)	2	1	2	2	2	2	2	1	0	14
Rangiriri North pump station	1	1	2	3	2	0	4	1	0	14
Island Block South pump station (main)	1	1	2	0	4	0	4	1	0	13
Mangatawhiri Compartment 5 (Miller Farlane) – pump station Submersible	1	3	0	2	2	0	4	1	0	13
Muirs pump station	1	1	2	1	4	0	4	0	0	13
Sandy Muirs pump station	1	3	0	0	4	2	2	1	0	13
Churchill Secondary pump station	2	1	2	0	3	0	4	0	0	12
Golf Course pump station	2	1	2	1	2	0	4	0	0	12
Island Block North pump station	1	1	2	1	2	0	4	1	0	12
Sharpes pump station (Franklin District Council: Harker)	1	3	2	1	0	0	4	1	0	12
Mangatawhiri Compartment 2 pump station	2	3	0	2	0	2	2	0	0	11
Higgins pump station	1	1	2	0	2	2	2	0	0	10
Huntly North pump station	2	0	0	4	0	2	2	0	0	10
Aireys pump station (Franklin Murphy)	1	0	2	1	0	2	2	1	0	9
Austins pump station	2	0	2	0	0	0	4	1	0	9
Churchill East Watts pump station	1	0	2	1	0	2	2	1	0	9
Saxton pump station	1	1	0	0	2	2	2	1	0	9
Tuakau pump station / floodgate	1	0	2	1	0	0	4	1	0	9
Furniss Downstream pump station	1	0	0	2	0	0	4	1	0	8

Guests pump station	2	0	0	1	0	0	4	1	0	8
Harveys pump station	2	0	0	1	0	0	4	1	0	8
Hills pump station	2	0	0	2	0	0	4	0	0	8
Meremere West Henrys pump station	1	0	2	0	0	0	4	1	0	8
Vrsaljkos pump station / floodgate	1	1	0	0	2	2	2	0	0	8
Huntly South pump station / floodgate 1	1	0	2	1	0	2	2	0	0	8
Deroles pump station	2	0	0	1	0	2	2	0	0	7
Hoods Landing pump station	1	0	0	1	0	2	2	1	0	7
Huntly South pump station / floodgate 2	1	0	0	2	0	2	2	0	0	7
Johansens pump station (Franklin District Council Bonds)	1	0	0	1	0	0	4	1	0	7
Freshfield pump station	2	0	0	0	0	2	2	0	0	6
Halls pump station	1	0	0	1	0	2	2	0	0	6
Huntly South pump station / floodgate 3	1	0	0	1	0	2	2	0	0	6
Kimihia Internal pump station	1	0	0	1	0	0	4	0	0	6
Meremere West Peters pump station	1	0	0	0	0	0	4	1	0	6
Onewhero West Drainage pump station	1	0	0	0	0	2	2	1	0	6
Tabenels pump station	1	0	0	1	0	2	2	0	0	6
Furniss Upstream pump station	1	0	0	0	0	0	4	0	0	5
Kitcheners pump station	1	0	0	0	0	2	2	0	0	5
Manor Park pump station	1	0	0	0	0	0	4	0	0	5

Note: red text indicates documented fish mortality

C - Prioritisation matrix - Hauraki

Note: The matrix is a living document and will change when new information is received. Always refer to the discover document (#25752227) for the most up-to-date version.

Site	Catchment size (ha)	Fish records	Fish mortality documented	Combined size of lakes and wetlands (ha)	Abundance of tuna	Outfall type - proxy for no fish data	Outfall type - proxy of legislative compliance	Overlaps with WWRRS Fish and/or Biodiversity Priority area - scored	Overlaps with Waikato-Tainui Seasonal Closure Bylaw - scored	TOTAL SCORE
Mangawhero pump station (Piako)	4	3	0	4	4	2	2	0	0	19
Mill Road pump station	4	3	2	3	2	2	2	0	0	18
Pouarua pump station	4	3	2	1	4	2	2	0	0	18
Rawe Rawe pump station	2	3	4	1	4	2	2	0	0	18
Steiners pump station	2	3	4	1	2	2	2	0	0	16
Phillips Road/ Torehape/ Stitchburys pump station	4	3	0	0	4	2	2	0	0	15
Appletree pump station	4	1	4	1	0	2	2	0	0	14
Carters Block pump station	2	0	4	4	0	2	2	0	0	14
Waikaka South pump station / floodgate	4	4	0	1	0	2	2	0	0	13
Mangaiti pump station	2	3	0	1	2	2	2	0	0	12
Waikaka North pump station	1	3	0	0	4	2	2	0	0	12
Johnstones pump station	2	1	0	0	4	2	2	0	0	11
Kurere (Komata North) pump station	2	1	0	0	4	2	2	0	0	11
Pukahu/ Roger Harris (H Drain) pump station	4	2	0	1	0	2	2	0	0	11
Rangiora Road pump station	2	2	0	1	2	2	2	0	0	11
Julians (Island Block) pump station	1	1	0	0	4	2	2	0	0	10
No.10 (Kerepehi North)/ Reservoir Canal/ Kerepehi Extension pump station	4	0	0	2	0	2	2	0	0	10
Robinsons (Island Block) pump station	1	1	0	0	4	2	2	0	0	10
Awaiti South/ Tee Head pump station	2	1	0	2	0	0	4	0	0	9
Ahikope pump station	2	1	0	1	0	2	2	0	0	8
Alexanders pump station	4	0	0	0	0	2	2	0	0	8
Bancrofts pump station	2	0	0	2	0	0	4	0	0	8
Kaihere pump station	1	1	0	0	2	2	2	0	0	8
Ngarua Central pump station	2	0	0	2	0	2	2	0	0	8
Poulgrains/ Wani Road/ Handleys/ Awaiti West pump station	4	0	0	0	0	2	2	0	0	8
Rowes East pump station	1	1	2	0	0	2	2	0	0	8
Stocks pump station	4	0	0	0	0	2	2	0	0	8
Rangiora Road North pump station	1	0	0	0	2	2	2	0	0	7
Rolleston Street pump station / floodgate	1	0	0	0	2	2	2	0	0	7
Drents pump station	1	0	0	1	0	2	2	0	0	6
Fisher Road pump station	2	0	0	0	0	2	2	0	0	6
Ngatea Town pump station	1	0	0	1	0	2	2	0	0	6
North Road pump station	2	0	0	0	0	2	2	0	0	6
Opukeko pump station	1	0	0	1	0	2	2	0	0	6
Paeroa Main Drain pump station	2	0	0	0	0	2	2	0	0	6
Prices pump station	2	0	0	0	0	2	2	0	0	6
Arnets pump station	1	0	0	0	0	2	2	0	0	5

Heale Street pump station / floodgate	1	0	0	0	0	2	2	0	0	5
Hubbard Road pump station	1	0	0	0	0	2	2	0	0	5
Louch McDuff pump station	1	0	0	0	0	2	2	0	0	5
Paul Leonard pump station	1	0	0	0	0	2	2	0	0	5

Note: red text indicates documented fish mortality

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Policy Series 2023/18
ISSN 2230-4339 (Print)
ISSN 2230-4347 (Online)
November 2021 #7576

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