Native Fish Migration through Land Drainage and Flood Control Infrastructure

An Assessment of Effects and Review of Management Methods

June, 2017

BBO Ref: 140640 - 09

Prepared by:  ……………………………

Richard Duirs
Senior Environmental Planner
Bloxam Burnett & Olliver

Date 2 June, 2017

Peer review by:  ……………………….

Jacques Boubee
Freshwater Ecologist
Vaipuhi Freshwater Consulting Ltd

Date 2 June, 2017

Approved for release by:  ……………………….

John Olliver
Managing Director
Bloxam Burnett & Olliver

Date: 2 June, 2017

Bloxam Burnett & Olliver Ltd
PO Box 9041
Level 5, 18 London Street
Hamilton

Phone: 07 838 0144
Fax: 07 839 0431
Email: rduirs@bbo.co.nz

Disclaimer

This report has been prepared for research purposes and as a reference document and as such does not constitute the policy of any specific organisation or institution.

The author requests that if excerpts or inferences are drawn from this document for further use by individuals or organisations, due care should be taken to ensure that the appropriate context has been preserved, and is accurately reflected and referenced in any subsequent spoken or written communication.

While the author has exercised all reasonable skill and care in controlling the contents of this report, the author and their employer accepts no liability in contract, tort or otherwise, for any loss, damage, injury or expense (whether direct, indirect or consequential) arising out of the provision of this information or its use by you or any other party.

Acknowledgements

The project team would like to acknowledge the River Managers Forum for supporting the initiative, in providing information and contributing funding to complete this study. In particular, the following member organisations of the River Managers Forum are acknowledged for their support:

Waikato Regional Council
Horizons Regional Council
Hawkes Bay Regional Council
Greater Wellington Regional Council
Environment Canterbury
Bay of Plenty Regional Council
Otago Regional Council
Northland Regional Council
Auckland Council
Marlborough District Council

The following parties are also acknowledged for their advice and support which has assisted in the preparation of this report:

Michael Lake – Waikato Regional Council
Bruno David – Waikato Regional Council
Guy Russell – Waikato Regional Council
Ghassan Basheer – Waikato Regional Council
Kenny Growden - Waikato Regional Council
Natasha Grainger – Department of Conservation
Sjaan Bowie – Department of Conservation
Nicola Baker – Ph.D. student at Leeds University, United Kingdom.

All parties within the various Councils, government organisations and businesses that took the time to provide information for this project are acknowledged and thanked for their inputs.

Table of Contents

Abstract

Land drainage and flood control schemes in New Zealand have resulted in adverse effects upon native fish including direct mortality on downstream migrants as they pass through flood pumps and impediments to both upstream and downstream fish passage.

There is currently limited information available to quantify these adverse effects however consultation with drainage scheme operators has identified two recent, significant fish kill incidents at pump stations and further anecdotal evidence of more intermittent mortality effects. Furthermore, based upon the typical configuration and components of land drainage sites within New Zealand, it is considered reasonable to assume that these adverse effects are relatively common and are resulting in both direct mortality and significant reductions in habitat utilisation by native fish.

To date there appears to have been limited efforts made by land drainage and flood scheme managers in New Zealand to address these adverse effects although more of these parties are now beginning to acknowledge the issue and are considering implementation of remedial measures.

Internationally, a 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, including land drainage activities. Development of legislation requiring provision of fish passage through drainage assets is now considered standard practice in several countries.

Within the New Zealand legislative setting, while the relevant provisions of some national conservation statutes have not been applied, the sustainable management provisions of the Resource Management Act and relevant provisions of the Waikato Regional Policy Statement and Regional Plans indicate a requirement to ensure that fish passage is provided through instream structures where it would otherwise exist. Furthermore, the recent development and implementation of a number of iwi based legislation and management plan documents, indicate a directive for an increase in environmental enhancement initiatives through future resource management decision making. Implementation of these statutory measures will likely lead to increased pressure for the provision of best practice fish passage measures through catchments where it would otherwise occur and is currently restricted.

This study has identified and assessed a range of remedial options to address fish passage effects at land drainage sites. These have included:

- Barrier screens;
- Behavioural deterrents;
- Fish friendly pumps;
- Bypass routes;
- Fish friendly flapgates;
- Fish passes; and
- Trap and transfer operations.

There is unfortunately relatively limited conclusive information available in regard to the effectiveness of some these measures, particularly within the New Zealand setting. In most cases, the ability to implement appropriate, practical fish passage measures will be site specific and it is likely that a combination of measures will be required at some sites to provide for upstream and downstream passage through drainage scheme assets. It is recommended that drainage scheme operators should undertake a review of their operations with the support of an ecologist to identify priority catchments and to implement best practice fish passage measures to provide for upstream and downstream migration through their assets.

The implementation of these recommendations has the potential to present significant additional costs and increased maintenance requirements upon drainage and flood schemes. However, it is considered that the adverse effects of these activities upon 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. An innovative approach is required from scheme managers to begin to implement remedial measures and to adapt them to New Zealand conditions. Furthermore, a collaborative approach between scheme managers, regulators, stakeholders and industry is recommended to ensure sharing of information and that fish passage outcomes are optimised.

1 Introduction/Background

The development of New Zealand's agricultural industry over the past 200 years has been based upon the large scale conversion of natural areas including native forest and low lying floodplain and wetland habitats, to open pasture environments suitable for stock grazing and intensive agricultural management. Where these conversion works have occurred through modification of low lying floodplain and wetland environments they have often required the construction of land drainage systems and flood control schemes, hereafter collectively referred to as 'schemes'. The primary objective of these schemes has been to manage both groundwater and surface water hydrology within the developed catchments to maintain ground conditions to enable productive farming. Often these catchments are reliant on intensive management of their hydraulic connections to ensure that suitable moisture levels are maintained through the drier summer months while preventing elevated water levels during winter or during any significant flood events.

Additionally, flood control schemes have also been established throughout New Zealand to provide a level of protection for communities from extreme flood events which pose a threat to property, infrastructure and peoples safety.

These schemes within New Zealand are by their nature and design, typically configured to form a hydraulic disconnection between catchment areas to prevent elevated water levels from a dominant catchment overwhelming smaller tributary catchments. Stopbanks are typically established adjacent to river channels to form a physical barrier to flood water ingress into tributary catchments to prevent or reduce inundation of land. Hydraulic interactions between the catchments are then managed through the installation of specific scheme infrastructure including flood pumps and flap gate controlled culverts (floodgates) to maintain water levels within the flood scheme area at desired levels.

At the time these schemes were developed, little consideration was given to the potential impacts of these systems upon native aquatic ecology. Many of New Zealand's native fish are migratory, requiring hydraulic connection to the ocean to complete their lifecycle. Consequently, the installation of physical barriers between catchments (including but not limited to the scheme infrastructure) has created direct impacts upon both upstream and downstream fish migration and lateral use of inundated floodplain areas for feeding. In particular, the flood protection infrastructure which is the focus of this study is identified as presenting the following risks to native fish migration:

- Direct mortality of fish during their downstream migration from controlled tributary catchments via entrainment within flood pumps which provide the dominant outlet to the downstream environment;

- Direct impediment to upstream and downstream fish migration into controlled tributary catchments through the physical barriers presented by stopbanks and floodgates restricting swimming or climbing access into these catchments;

- Delay in both upstream and downstream fish migrations and additional predation pressures; and

- Adverse water quality and habitat impacts associated with managed catchment hydrology and channel morphology.

While these effects upon native fish would have been occurring within flood scheme areas for a number of decades, impacts on fish have largely been overlooked in favour of flood management practices to facilitate farming and protect upstream property. However, with heightened public awareness and increasing legislative pressure regarding conservation of native species, along with recently recorded significant fish kill incidents, there is an identified need to better understand the interactions between scheme infrastructure and native fish populations to inform future management decisions. Hence the Waikato Regional Councils (WRC) Integrated Catchment Management Directorate (ICM) in collaboration with other regional council participants in the New Zealand Rivers Managers Forum, has commissioned this study with the focus of addressing the following key points:

- Better understand the effects of scheme infrastructure upon native fish migration at a regional, national and international level;

- Identify the legislative requirements relating to the effects of land drainage/flood scheme infrastructure on native fish migration;

- Identify and assess available options for managing the effects of land drainage/flood scheme infrastructure upon native fish migration; and

- Provide recommendations to guide future decision making for managing the effects of flood scheme infrastructure upon native fish migration.

It should be noted that land drainage/flood scheme operations are not the only activities contributing to adverse fish migration effects within the New Zealand setting. The impacts of road culverts, water supply dams, weirs, hydro schemes and other instream structures have been well documented. Furthermore, it is acknowledged that it is not only the direct effects of flood scheme infrastructure which are adversely impacting native fish. Water quality effects and habitat loss and degradation associated with drainage scheme operation and maintenance activities are also considered likely to be contributing to adverse effects upon native fish populations. However, for the purposes of this project the key items subject to consideration and assessment within the scope of this study have been limited to the direct mortality and impediment effects associated with land drainage/flood scheme infrastructure as outlined above.

2 Flood Scheme Effects on Fish Migration

The impact of flood scheme infrastructure on fish can broadly be categorised into those effects occurring upon downstream migrants and those effects occurring upon upstream migrants. The research undertaken for this project has identified limited, robust information in regard to these effects. As a result, the approach has been to undertake consultation with a range of stakeholders to gather any relevant information to better characterise the nature and scale of this issue.

This has included consultation with Waikato Regional Council (WRC) flood scheme operations staff to document their observations and knowledge of flood asset interactions with native fish populations, including specific details of a recent significant fish kill incident at one of the WRC flood pump stations.

The investigations have extended further afield including consultation with other Regional Councils throughout New Zealand, consultation with Department of Conservation staff and circulation of consultation documentation to the New Zealand Fish Passage Advisory Group and the Institute of Professional Engineers NZ (IPENZ) Rivers Group requesting any relevant feedback/information in relation to these issues. In addition, a review of available international literature and data has been undertaken to better understand and characterise the effects of flood scheme infrastructure upon fish migration within the international setting.

Freshwater eels are the largest and most common migratory native fish species present within land drainage/flood scheme catchments today. They are also the species for which observations have been made and information collected both within New Zealand and overseas. In this respect, this project has adopted a strong focus upon effects of land drainage systems upon eels. However, the effects of scheme infrastructure upon fish migration described in this report would likely extend to include the majority of the diadromous native species as well as a number of introduced migratory species.

It is also important to acknowledge that in considering the current New Zealand land drainage/flood protection setting for assessing fish passage effects, this setting comprises a heavily modified environment from the pre-development baseline. This natural, baseline environment comprised catchments where connectivity was unimpeded and significant areas of stream channel and wetland habitat would have been available to support large productive fish populations. It is likely that during the initial implementation phase of land drainage/flood protection systems in New Zealand, a sharp decline in available habitat and subsequently native fish populations, would have occurred resulting in the reduced levels we see today within these catchments. Hence, where current information or observations may suggest limited impacts of drainage scheme infrastructure upon fish populations, it needs to be acknowledged that, in effect, these are the tolerant biological remnants persisting within heavily modified 'existing environments' which are likely to be very different to those that historically/naturally occurred.

2.1 Downstream Migration – Fish Mortality Effects

As described, many of New Zealand's native fish are diadromous meaning they migrate between freshwater and saltwater during some part of their lifecycle often in relation to spawning. This can vary with some species living in freshwater but migrating to spawn at sea (catadromous e.g. eels) while others spend some of their lives at sea then migrate upstream from the sea to spawn in freshwater (anadromous e.g. lamprey). Other species spend part of their lives at sea but the marine phase is not directly related to spawning but rather related to a juvenile maturation phase (amphidromous e.g. most whitebait species) (McDowall 2007).

Of the catadromous species, the most commonly found species within scheme areas in New Zealand are the shortfin (*Anguilla australis*) and longfin eel (*A. dieffenbachii*). The ability of these species to negotiate channel barriers and to travel overland for short distances during upstream migrations has allowed them to access scheme catchments where other native species have been blocked. Also, the ability of eels to tolerate the heavily modified, low quality habitats typical of scheme areas has allowed them to persist and, in the case of shortfin eels, thrive within many of these environments. The eels spend the majority of their life cycles within these freshwater environments, however upon reaching breeding size these long lived (up to 40+ years), semelparous (single spawning) organisms migrate to tropical oceanic areas to spawn and then die. Downstream migration typically occurs over the late summer and autumn months and is triggered by larger rain events which result in increased flows through these catchments. Outside of these spawning migrations it is thought that eels may also migrate laterally and longitudinally to access better habitat or feeding grounds (e.g. Chisnall 1987).

As eels migrate downstream within controlled flood scheme areas, they inevitably encounter the flood scheme infrastructure used to manage catchment outflows which may comprise high volume flood pumps. In some cases, it is quite conceivable that migrant adult eels may have accessed these catchments as elvers prior to the construction of flood control schemes. As the eel migrations typically align with large scale catchment rainfall events there is a high chance that the flood pumps will be in operation during these periods of downstream migration as they convey flows through the flood control stopbanks to the downstream watercourse.

The majority of flood pumps utilised within New Zealand drainage schemes comprise axial flow impeller/propeller driven systems with the impeller blades and their supports housed within a closed pipe system to convey floodwaters either horizontally or vertically to the downstream environment (Figure 1).

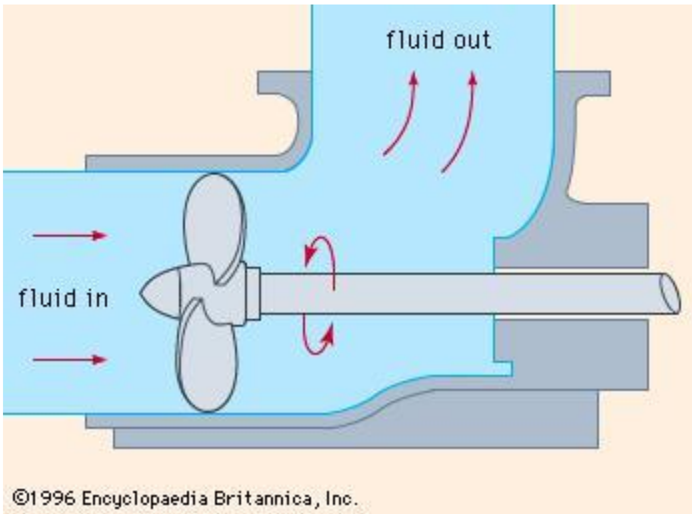


Figure 1. Typical axial flow impeller/propeller driven pump system. (image - www.britanica.com).

As migrating eels will typically follow the passage of flow through the catchment, they become entrained within the flows being sucked through the pumps and on passing through the high velocity, spinning impeller blades and static bearing supports are considered to have minimal chance of survival. These impacts create the potential for mortality of large numbers of migrating eels with evidence showing medium to large size eels being severed into multiple parts as they pass through the pumps. While there is very limited information regarding the effects of flood pumps within a New Zealand setting, it is assumed that the rate of mortality occurring at any flood pump site is a combination of multiple factors including:

- Upstream habitat quality and eel populations;
- Pump type/size
- Eel size i.e. some smaller eels may be able to pass through larger pumps;
- Alternative catchment outlet options e.g. flap-gated culverts;
- Pump debris screens.

The autumn downstream migration period is considered to present the key risk period for eel mortality through pump stations. However, Allan (2010) observed that operation of flood pumps can also occur outside this period and can still coincide with eel foraging activity after heavy rainfall. Consequently, eel mortality at pump stations can occur not only during the autumn migration period but also in summer when eel feeding activity is greatest. Photographic evidence of the effects of flood pump infrastructure on fish at two New Zealand sites is provided in Appendix A.

It is acknowledged that many of the flood pumps throughout New Zealand do incorporate design features which may assist in reducing fish mortality effects within flood pumps including the installation of debris screens across pump inlets and the presence of an alternative low flow outlet (often a flap-gated culvert) at some sites. However, while these measures may provide some benefits they are by no means considered 100% effective and still maintain significant risks for fish at flood pump sites.

Consultation undertaken with regional council operational staff for this project has identified limited information in regard to any observations or records of fish mortality occurring as a result of scheme infrastructure. Although it must be acknowledged that monitoring of these effects is not typically undertaken by staff during pumping activities and would typically be restricted by the limited time that staff are at the site, elevated water levels during pump operations (submerged pump outlets) and the rapid dispersal of any mutilated eel body parts below the pump during these events.

In addition to the direct mortality effects of these systems, eel fisherman in the Waikato, Hauraki and Whakatane regions have also for many years been concerned by the impact of flood pumps on migrant eels and subsequent eel recruitment, which has a potential to impact their commercial fishing operations (Eel Enhancement Company Ltd pers. Comm. with J. Boubée). In the Hikurangi flood scheme area in Northland, there is also a shared concern amongst tangata whenua and commercial fishers that hundreds of kilograms of both migrants and feeding eel are being killed during flood events. These concerns highlight the potential additional social, cultural and economic impacts which may be occurring as a result of these activities.

While no records, observations or data have been identified in relation to flood pump impacts upon other native fish species, it is considered likely that some adverse mortality/injury effects will be occurring as these species pass through the pump impellers during migration periods. Although, these effects may be occurring at a reduced level compared to eels based upon these species typically smaller body sizes (and hence reduced potential for blade impacts) along with their reduced ability to navigate channel barriers allowing them to access these catchments or to tolerate reduced habitat conditions within these catchments.

2.2 Upstream Migration – Catchment Barriers

The diadromous nature of the majority of New Zealand's native fish means that their life cycles are reliant upon maintenance of upstream migration access through catchments to reach appropriate freshwater habitat either as juveniles entering these habitats to mature (catadromous/amphidromous species) or adults entering these habitats to spawn (anadromous species). The construction of flood protection infrastructure to physically separate catchments from their downstream environments presents a barrier to upstream fish migration into these habitats hence directly restricting utilisation of available habitat within these catchments.

For some drainage scheme catchments within the Waikato Region, the scheme infrastructure provides a direct disconnect between the scheme area and the downstream environment with no provision for upstream access into the catchments and with outflows from the scheme areas limited to controlled pumping only. Hence, most migrating fish are likely to be entirely excluded from these catchments with no physical ability to access these catchments even when pumping of catchment outflows is occurring. However, it needs to be acknowledged that some fully pumped catchments in the Waikato are still known to support eel populations that include several year classes which suggests that there is some access for these species into the catchment although possibly mediated by human translocations or their ability to navigate overland during major rain events.

Other scheme controlled catchments have partial connection to the downstream environment through installation of low flow systems between the catchments. Typically, these systems comprise culverts fitted with a flap gate on the outlet (floodgates) to allow catchment outflows to occur during either low flow or low tide conditions within the receiving environment but which are shut off by hydraulic pressure during periods of elevated water levels (flooding/high tide) within the receiving environment. Hence fish have partial upstream access to these catchments during low flow/low tide periods when catchment outflows are occurring and flap gates remain open however are prevented from accessing these catchments during high tide or high flow periods.

Flap gate controlled catchment outlets located within tidal environments are considered to provide a particular impediment to migratory fish given their proximity to coastal waters (from which fish are migrating) and the relatively high proportion of time that they are closed (every high tide).

At least one drainage scheme area has been identified within the Waikato Region where a connecting, valve controlled culvert is in place between the catchments comprising the Motukaraka Drainage Scheme Area within the Maramarua River catchment. This culvert allows flows from the dominant downstream catchment (Maramarua River) to backflow into the lower lying scheme area during the summer low flow periods to maintain summer groundwater levels and support farm irrigation activities within this catchment. However, for the majority of the year the valve remains closed thus restricting any potential for fish migration into the scheme catchment. There is no specific information available regarding the ability of this culvert to provide migratory fish passage into this catchment during summer periods when it remains open and it would be assumed that as the flows are essentially occurring up-catchment into the low-lying flood scheme area via a small culvert (300m diameter) they would be unlikely to attract large numbers of fish. However, a recent large scale fish kill incident occurring at this flood scheme has suggested a healthy eel population within the scheme area and hence migration into the catchment may be occurring through this culvert. Although there is also anecdotal evidence that large numbers of eels may have been transferred into this catchment by eel fishermen (J. Boubée pers. comm.) and that large numbers of eels have navigated over the stopbank and into the catchment during large scale storm events (M. Lake pers. comm.).

2.3 The Motukaraka Flood Scheme Incident

The Motukaraka Flood Scheme is located within the lower Waikato River catchment and comprises approximately 1538ha of low lying former wetland and also drains runoff from approximately 2105ha of surrounding hill country. The scheme area is used predominantly for dairy grazing. The catchment was historically dominated by wetland habitats with the Kopuera Stream winding through the low-lying wetland basin. However, the Kopuera Stream has been straightened and an extensive land drainage network installed to suppress groundwater levels. The flood scheme infrastructure includes a large stopbank which separates the scheme area from the adjacent Maramarua River channel to prevent backwater flooding effects. Outflows are entirely controlled by a large scale flood pump operation located at the catchment outlet to the Maramarua River which comprises three impeller type axial pumps and a single large Archimedes screw pump. The Motukaraka Archimedes pump is shown in Figure 2 below.

Figure 2. Motukaraka Archimedes Screw Pump (photo – R. Duirs, BBO).

Pump operations are typically limited to the wetter months only with no pumping generally occurring during the summer months. As described above, there is a 300mm valve controlled culvert in place which allows backflow of water from the Maramarua River into the scheme area over the dry summer months to maintain catchment water levels however this system remains closed for much of the year to prevent adverse flooding effects within the modified, farmed catchment. The Motukaraka flood scheme is operated by the WRC ICM.

The large-scale Archimedes screw pump was installed for the express purpose of providing large volume outflows from the drainage scheme area to the downstream environment during storm events. The installation of the Archimedes pump included no consideration for provision of fish passage, however through subsequent resource consent application processes to authorise the scheme operation, the Archimedes pump was identified as a fish friendly pump and the key method for conveyance of migratory eels downstream during migration periods. Subsequently, conditions were imposed upon the resource consents requiring that the Archimedes pump operates 'prior to and during any time that the axial pumps are operated'.

Damage to the Archimedes pump gearbox sustained over the winter, 2014 period dictated the need for repair works during the summer months which required the temporary disestablishment of the pump. Key items determined prior to undertaking the repair works included:

- The pump would only be disestablished following late summer rains to allow peak eel migration to occur; and

- The pump would be run for as long as possible over/following two rainstorm events prior to disestablishment to allow downstream migration and clear any eels upstream of the pump.

These items were adhered to and the pump was disestablished on 14 April, 2015 with an anticipated shutdown period of 1 week. However, a significant, unanticipated large rain event occurred on 18 April, 2015 which is thought to have triggered further downstream migration of eels from the drainage scheme catchment. Subsequently, the flow levels within the scheme area triggered the automated function of the axial pumps with large numbers eels passing through the pumps resulting in their mortality and discharge of their mutilated bodies into the downstream Maramarua River channel. Photos of dead fish within the river channel below the pump taken a number of days after the incident are outlined within Figures 3 and 4 below and are included within the **Photo Records** in **Appendix A**.

Figures 3 and 4: Dead eels below the Motukaraka axial pump outlet. Note - photos taken a number of days after the eel kill incident. (Photos – M. Lake, WRC)

The fish kill was reported to the WRC by a member of the public with reports of hundreds of dead eels within the downstream river channel. Immediately upon becoming aware of the fish kill incident, ICM implemented measures in accordance with the consent requirements to prevent/minimise any further fish mortality effects including reinstatement of the Archimedes pump and installation of an electrified screen in front of the axial pump intakes to deter fish. A 'Letter of Direction' was issued to ICM by the WRC Resource Use Directorate (RUD) seeking clarification of the reasons the incident occurred and the immediate measures being implemented to prevent further fish mortality effects. The incident was also subject to a formal investigation by RUD to determine whether further enforcement action would be undertaken in the form of abatement/infringement notices in accordance with sections 322/343 of the Resource Management Act 1991 or a formal prosecution. Following this investigation, it was determined that further enforcement action would not be taken however RUD outlined a number of recommendations to ICM in relation to the future operation of the pump station in relation to improved environmental compliance.

While the potential impacts of flood scheme operations on migratory fish populations have generally been known to occur, it was the significant scale of the fish kill incident at this site and the subsequent compliance processes which have formed a key trigger in the implementation of this project.

2.4 Waikato Regional Council Operations

2.4.1 Summary of Waikato Regional Council Infrastructure/Operations

WRC ICM is currently in the process of developing an inventory of their drainage infrastructure with respect to fish passage issues. The intention is that this inventory will help to identify and quantify the types of infrastructure and the specific risks they present to migratory fish to assist with future decision making around upgrading of this infrastructure. The specific information which is being recorded for the assets associated with each land drainage scheme/catchment area includes:

- Catchment characteristics/flow regime;
- Type/number of infrastructure (pumps/floodgate culverts etc);
- Any catchment barriers to fish passage;
- Any known fish mortality issues;

- Past/planned modifications.

Based upon discussions with ICM staff the following key summary points are made in regard to the WRC drainage scheme infrastructure:

- The flood scheme network includes 118 pump stations;

- Only two of these pump stations (Motukaraka and Mangatawhiri Compartment 3) include Archimedes Screw Pumps which may be providing lower risk downstream fish passage for migrating fish. It is understood that these two pumps are the only screw pumps in place for council operated land drainage purposes in New Zealand;

- The remainder of the pump stations comprise axial flow impeller type pumps which are likely to present a high risk of mortality for migrating fish;

- The majority of the pump stations within the Hauraki zone (Hauraki Plains) include provision of a flap gate culvert as an alternative catchment outlet/inlet for migratory fish – based upon catchment gradients, tidal influence and daily fluctuating water levels within the main watercourses;

- The majority of the pump stations within the Lower Waikato zone exclude any alternative catchment outlet/inlet other than the flood pump.

2.4.2 Waikato Regional Council ICM Operational Staff Consultation

Consultation has been undertaken with WRC ICM scheme operational staff on the basis that they comprise the personnel most familiar with the day to day operations of the land drainage/flood scheme infrastructure and are the most likely to be present to observe any fish migration impacts during flood control asset operations. Consultation has been undertaken in the form of two workshops held with operational staff at the Gordonton works depot (Lower Waikato scheme staff) and the Paeroa works depot (Hauraki scheme staff). Operational staff were asked a number of questions regarding any observations of scheme infrastructure interactions with native fish populations followed by open discussion regarding this issue including any steps currently being taken to manage any effects of the drainage schemes on native fish.

Appendix B includes the recorded minutes from each of these workshops with the key outcomes of these discussions summarised as follows:

- The Motukaraka incident is considered to be a one off incident with no other observed or known significant fish kill incidents associated with ICM pump stations;

- Based upon staff observations fish kill incidents within flood pumps are considered to be minor and are not frequent;

- From time to time noises and power fluctuations are noted at the pumps during operation which are assumed to be individual eels passing through the pumps although this could be other pest species (koi carp/cat fish) or even weed/debris;

- Individual dead eels have been observed coming out of the pumps and the pumps have needed to be reversed to remove dead eels caught in the impellers but this is an infrequent occurrence;

- Staff acknowledge that they are only at the pumps for a small portion of the time the pumps are operating and rarely at night when eel migrate. They also do not actively look for dead fish at the outlet and pump outlets are often submerged below flood waters and hence observations are limited;

- All pumps typically include a debris screen with 50mm bar spacing which may limit larger eel entrainment to some degree;

- The majority of pumps within the Hauraki zone include a floodgate culvert separate to the pump which would assist fish migration and minimise entrainment through pumps;

- Lower Waikato Zone staff have never observed any eels passing over the two Archimedes screw pumps. While considered 'fish friendly', these pumps are still likely to present some risk of fish mortality given a high potential for fish to get caught between the sharp steel edges of the screw and the surrounding concrete trough housing;

- Eel fishermen are catching large numbers of eels within the affected catchments. Staff identified potential opportunities to work with eel fishermen to fish eels from the scheme watercourses or for ICM to purchase eel quota as mitigation for any effects of pump stations exists.

2.4.3 ICM/NIWA Floodgate Culvert Study

As described, a large number of ICM scheme sites include the provision of floodgates which still maintains some catchment connectivity, by providing a separate catchment inlet/outlet option for migratory fish. Based upon the restrictive nature of this infrastructure, ICM in conjunction with the National Institute of Water and Atmospheric Research (NIWA) has previously undertaken a case study into the effects of a floodgate upon fish communities through habitat modification and fish passage (Franklin & Hodges 2012). The study site comprised the Kurere Stream which drains a catchment within the Coromandel Ranges into the Waihou River with a six barrel floodgate outlet located within the stream channel directly upstream of its confluence with the Waihou. The study hypothesised that the floodgates would exclude/restrict the presence of native migratory fish within the catchment above the gates and would also impact the physico-chemical conditions of the aquatic habitat above the gates.

Fish surveys above the gates confirmed the presence of populations of migratory fish including eels, banded kokopu, common bullies and inanga which indicated that these gates are not a complete barrier to fish passage. This was thought to be due to the ability of fish to pass through the gates upstream during low tide when the gates are opened by catchment flow. In addition, a small gap (3cm) was identified between each gate and the concrete headwall structure which may allow some fish to pass during certain conditions. However, it was concluded that for much of the tidal cycle, fish passage would be restricted due to gate closure which was supported by observations of inanga aggregating downstream of the closed gates at high tide. Consequently, it was concluded that the abundance of native migratory fish upstream of the gates would likely be lower than if the gates were not present.

The study also concluded that the floodgates are a significant modifier of upstream instream habitat through reduced water quality in relation to control sites both upstream and downstream of the 2km study reach directly above the gates. The study included a trial opening of the gates to determine any water quality impacts which identified that partial opening of the gates for extended periods could provide immediate improvements to the aquatic habitat.

This study did not attempt to quantify the numbers of fish able to pass through the flap gate barriers however a further study undertaken in the Motueka River catchment of the South Island utilised sonar to monitor/quantify native fish movements between gated and ungated culverts (Doehring et al. 2011). In this study, the sonar allowed observations/recordings of juvenile galaxid movements over 24 hours through the gated and un-gated culverts. More than twice as many fish were recorded passing the un-gated culvert than the gated culvert. Movement through the culverts occurred during the day and night and was highest at the un-gated culvert just before high tide. By contrast, movement past the gated culvert was highest during low tide, when the gate was open.

2.4.4 WRC ICM Orchard Road Pump Station Study

Concurrent to this project, ICM have recently initiated a study at their Orchard Rd pump station in Te Kauwhata to further investigate the impact of traditional style axial flood pumps on migrant eels.

Resident migrant and non-migrant shortfin eels were captured upstream of the pumping station and implanted with Passive Integrated Transponder tags (PIT). Additionally, and to ensure a robust sample size to test the degree of mortality, live migrant eels were also introduced above the pump. A series of wide mouthed sock nets were fitted to the downstream flap gate to completely capture and filter all material discharged by the two conventional axial pumps that currently operate at this site.

The following information and observations were noted and recorded following a significant rainfall event during the 2017 migration season:

- Survival of eels collected below the pump station over a 24hr period was very low, particularly for large individuals;

- Individual eels exhibited a range of body trauma post pumping which included segmentation, stripping, and vertebral and cranial damage;

- A distinct sound could be heard at the pump when eels went through with corresponding confirmation that an eel went through by observing fragments in the surge chamber seconds after the sound occurred – this could be investigated further using acoustic monitoring as a means to quantify mortality at other pumping stations.

Photo images of the mutilated eel bodies collected below the pumps along with x-ray images outlining internal damage to in-tact individuals collected during this trial are included within Appendix A.

More monitoring is planned as part of the installation of a fish friendly pump station at this site in late 2017.

2.5 Other Council Operations

Numerous other councils outside of the Waikato Region are known to operate land drainage/flood control schemes which present the same risks to migratory native fish as described above. Hence consultation for this project has extended to seek inputs from other Regional Council scheme operators throughout New Zealand. This has occurred through an email mail out to council representatives on the New Zealand River Managers Forum which is made up predominantly of Regional Council land drainage/catchment management staff. Key questions asked related to any known land drainage infrastructure/migratory fish interactions within their areas and any efforts being made to address these effects.

Responses received from these parties have been limited with those responses which identified any issues or management strategies summarised as follows:

2.5.1 Whangarei District Council

Correspondence forwarded to Northland Regional Council was diverted to Whangarei District Council (WDC) as the operator of the main land drainage scheme within Northland comprising the large scale Hikurangi Flood Scheme. A response received from WDC describes the Hikurangi Scheme as comprising 5600 ha of flood prone land protected by seven pump stations containing 20 pumps comprising old torpedo style Pleugar pumps and vertical lift pumps, none of which are considered to be fish friendly.

Available information on the effects of this scheme on migratory fish has identified past anecdotal evidence of eel kill within the pumps and restricted upstream migration into the scheme area with trap and transfer trials undertaken within the 1990s and in 2013/14.

The information received from WDC for this project also identified a recent large scale fish kill incident which occurred within the scheme area in February, 2016. The information described that following a large scale rainfall event in the catchment which triggered pump operations, large numbers of dead, severed eels were identified directly below the pumps at four of the seven pump stations within the scheme area. Due to the large numbers and type of injuries occurring on the eels (i.e. bodies severed into multiple parts) and given that large numbers would also likely have been washed downstream, an estimate of dead eel numbers was not undertaken. Photos of dead fish within the river channel below the pump stations after the incident are shown in Figures 5 and 6 and are included within the **Photo Records** in **Appendix A**.


Figures 5 and 6: Dead eels downstream of a pump station on the Hikurangi Flood Scheme (photos – Whangarei District Council and J. Boubée, NIWA)

WDC have outlined that in accordance with conditions of the resource consents authorising the scheme activities, the Northland Regional Council were notified of the fish kill incident. No compliance action was undertaken in response to the incident. Nonetheless, it is outlined that following this incident, WDC are in the process of implementing some measures within this scheme with the aim of reducing the mortality of fish through the pumps and to improve upstream migration potential into the scheme area including:

- Trialling an electric screen on one flood pump station in 2016;
- Installation of mussel spat ropes to assist upstream migration.

Comments received outline that upgrade of the existing pumps to a fish friendly design is considered to be the only realistic option to prevent large scale fish mortality incidents reoccurring in future. However, these measures are considered to be too expensive and outside the current affordability of the scheme. It is also noted that some elver trap and transfer operations (seeding) are in place within the catchment however these are separate to Council operations.

2.5.2 Hawkes Bay Regional Council

A response received from Hawkes Bay Regional Council (HBRC) confirms a flood scheme network comprising 20 pump stations servicing 7,500ha with none of these pumps described as comprising fish friendly pumps.

No flood pump/fish mortality incidents have been recorded however potential upstream fish migration issues were described as being identified during a recent survey undertaken by HBRC in collaboration with the Department of Conservation. The survey assessed the impact of flood pump controlled catchments on inanga migration within the Napier watershed and included depletion trapping through a number of catchments to identify the presence/numbers of inanga in an unimpeded catchment versus an adjacent flood pump controlled catchments. Trapping within the unimpeded catchment (Taipo Stream) identified large numbers of inanga compared to no inanga being present within controlled catchments despite suitable upstream habitat.

The response received outlines other efforts being made to address fish migration issues including:

- Installation of fish friendly flap gates;
- A project to develop a floating fish ramp for perched culverts and other vertical fall issues; and
- Discussing potential options for flood pumps.

2.5.3 Bay of Plenty Regional Council

A response received from the Bay of Plenty Regional Council (BPRC) confirmed that they operate approximately 50 separate pump stations within their region predominantly servicing drainage scheme areas located within low lying coastal plains where gravity drainage is compromised by tidal fluctuations.

No specific fish kill incidents have been recorded but comments received indicate cases of eels becoming entangled within flood pumps requiring the need for reversing of the pump or in rare cases, lifting of the pump.

The BPRC is currently developing/implementing a programme for improvement of fish passage through their land drainage network which includes the following measures:

- Pump stations are typically fitted with a small transformer to impart an electrical charge through debris screens to deter fish from entering the pump stations. No research has been undertaken to assess the effectiveness of these measures;
- Some trap and transfer operations (netting) are undertaken to move eels around flood scheme infrastructure;
- Fish friendly flap gates are being implemented/trialled within the land drainage scheme. This has included investigations to prioritise where these measures will be of greatest benefit and has trialled different fish friendly flap gate design options. These have included specific design adaptions developed by council incorporating spacer boards around the perimeter of the gate to maintain a certain level of flows through the gate in all conditions to allow juvenile fish entry into the catchments under flood conditions.

Other key relevant items flagged by BPRC staff include:

- The importance of concentrating any efforts on catchments where good fish habitat potential exists particularly given low water quality issues (specifically reduced oxygen levels) within drainage scheme watercourses;
- Maintenance requirements for any measures can be significant and should not be underestimated. Flap gate attachments or opening of flap gates to improve fish passage increasing potential debris capture and localised suction effects increasing blockages and potential failure of the systems.

2.5.4 Selwyn District Council

Canterbury Regional Council confirmed that they do not have responsibility for any land drainage/flood scheme infrastructure however they referred to a project being undertaken by the Selwyn District Council (SDC) on a flood scheme within the Lake Ellesmere (Waihora) catchment which included a specific project to manage eel populations within the scheme area. Hence information was sought from SDC to clarify the fish migration issues/management methods associated with this project.

A response was received from SDC which confirmed the project as relating to a land drainage scheme which drains a low lying agricultural catchment to the north of Lake Ellesmere. Catchment outflows to the lake controlled by a stopbank, a pump station and a floodgate culvert. The drains within the scheme area were identified as habitat for large populations of eels which are able to access the catchment from the lake via the floodgate culvert (when open) and via flood flows which overtop the stopbank during extreme events. Furthermore, the eels are known to migrate downstream from the scheme drains into Lake Ellesmere via the scheme outlet which includes a flood pump which presents a risk of eel entrainment and mortality within the pump station. While no specific eel kills have been documented, the resource consents authorising these activities have imposed a number of requirements to minimise the potential for these potential effects that include:

- Installation of a fish exclusion device to prevent fish from entering the pump. As a minimum SDC is required to install a new grill/screen with 20 – 25mm spacing's;
- Repair a leaking seal on the flap gate to minimise the potential for fish to enter the drainage scheme area;
- Development and implementation of a fish relocation and monitoring program including eel/fish salvage for two nights each year for the first 5 years of the consent.

The fish relocation programme was described as being required to remove as many eels as possible from the scheme area to minimise potential mortality effects when the pumps come into operation during migration periods. To date this programme has been implemented once with the eel relocation being undertaken in conjunction with a drain cleaning operation within the lower reaches of the scheme area. During the operation a team of staff and volunteers netted eels as they emerged from the excavated drain cleanings which were placed upon the banks of the channel. The eels were then transferred directly into the adjacent Halswell River channel with over 1000 eels transferred during this operation.

2.5.5 Greater Wellington Regional Council

A response received from the Greater Wellington Regional Council (GWRC) identified that they operate a number of drainage schemes within the Wairarapa including a significant scheme within the Lake Wairarapa catchment as well as some smaller schemes within the Kapiti Coast area.

The Lake Wairarapa scheme is described as including a large barrage structure on the lake outlet to regulate catchment flows between Lake Wairarapa and the downstream Ruamahanga River. When the barrage gates are closed they present a direct impediment to upstream/downstream fish passage between these catchments. The effects of these gates upon fish migration have been the subject of a number of previous studies undertaken by GWRC with the most recent study (Glova & Jellyman 2003) indicating trends of increased upstream fish movement into the lake when the barrage gates are opened. This study made a number of recommendations in regard to allowance for maintaining the gates open for specified duration over the key upstream and downstream fish migration periods.

The GWRC response outlined that the resource consents authorising the barrage structure incorporate specific conditions requiring opening of at least two of the lateral gates for one hour at low tide during the downstream migration period and for one hour at high tide during the upstream migration period to enable fish migration through the structure.

The response outlined that a more recent survey undertaken within drains around Lake Wairarapa appeared to identify that migration into pumped drainage scheme areas within the lake catchment was impeded with lower numbers of shortfin eels recorded within the controlled drains. However, the controlled drains were also found to hold moderate numbers of the threatened brown mudfish which may be due to reduced numbers of migratory eels (a key predator of mudfish) accessing the catchment and hence some positive effects may be occurring due to these impediments.

The response also referred to one fish friendly flap gate installation at a drainage scheme within the Kapiti Coast area.

2.5.6 Horizons Regional Council

A response received from Horizons Regional Council outlined that they currently manage 22 land drainage pump stations and that typically these pump stations incorporate a gravity flow floodgated outlet culvert. Where floodgate culverts have come up for replacement, Horizons has assessed the benefits of replacing the old structures with fish friendly gates and have installed several of these gates over the past 2 years.

Horizons has focussed on using two types of fish friendly floodgates within their schemes. The first comprises a gate with an extending counterweight arm on the front of the gate which assists in holding the gate open for an extended period of tide over the rising tide or flood level to increase the period available for fish access. The second comprises the installation of springs on the culvert rim area to hold the floodgate partially open under the majority of flow conditions with the gate only compressing the springs shut during significant high flow/tidal conditions.

Horizons drainage staff have noted issues with the counterweight arm system including the arm being easily damaged by debris and also catching debris and thus maintaining the gate open for longer than desired resulting in increased upstream flood levels. The spring gate system has been noted as working well on a number of smaller culverts with no notable issues and with fish seen passing through the gate when it would usually be closed.

Staff have outlined a number of key factors when considering the installation of these fish friendly floodgate measures including:

- Upstream impacts of maintaining the gates open for extended periods. Inevitably this will increase water levels upstream resulting in potential flooding effects;
- Increased debris capture if the gate is maintained partially opened under flood conditions;
- Consideration of side hung timber or plastic gates which will typically be open for longer than typical top hung steel gates which require greater head pressure to open the gate;
- Whether upstream habitat warrants the installation of a fish friendly gate.

Horizons drainage staff have outlined that fish mortality through flood pumps is not known to be an issue other than staff reporting the sound of eels occasionally being wrapped around the pump shaft. Most pump stations are equipped with debris screens with 50mm bar spacings.

2.6 Other Consultation

Consultation with other parties has been initiated via an email out to relevant Department of Conservation staff, the Fish Passage Advisory Group and the Institute of Professional Engineers NZ (IPENZ) Rivers Group. No specific or documented information has been provided in responses from these parties although a number of parties have outlined anecdotal evidence of fish passage issues associated with land drainage/flood control scheme infrastructure around New Zealand.

2.7 International Literature Review

The range of freshwater Anguillid (eel) species extends throughout much of the world including many countries where extensive managed land drainage systems are in place and hence the effects of these systems upon eel migration are not unique to New Zealand. The following sections provide a summary of the state of the eel fishery within a number of countries where the effects of land drainage activities (amongst other factors) have been identified as adversely affecting eel populations. The general policy approach being undertaken in response to this issue at an international level is also described. Furthermore, the results of a number of studies undertaken to directly assess the effects of typical flood pump operations upon migrating fish are summarised.

2.7.1 State of the Fishery and Policy Approach

Worldwide stocks of Anguillid eels are in decline (Haro et al. 2000; Richkus & Whalen 2000; EIFAC/ICES 2001). The reasons for the decline are unknown, but likely comprise a combination of factors including oceanic influences, pollution, over-fishing, predation and disease, but also direct (e.g. flood pump and hydro turbine mortality) and indirect (loss or changes in habitats) impacts caused by development/drainage projects.

The reduction in eel stocks has resulted in the European Eel being listed on Annex II of CITES (Convention on International Trade in Endangered Species). Based on the annual recommendations of the Scientific Review Group comprising experts from EU countries, international trade of European eel into and out of the EU has also been prohibited. Similarly, freshwater eels in Canada and Japan have been red listed (under CITES) while in the USA robust management actions to improve passage and limit the exploitation of glass eel and silver eel have either been applied or are under consideration.

The international decline in eel abundance was brought to the attention of policy maker by a series of journal articles at the International Eel Symposium, 2003 which formed the basis of the 2003 Quebec Declaration of Concern. A summary of the international decline in eel populations as presented at the symposium is outlined in Figure 7.

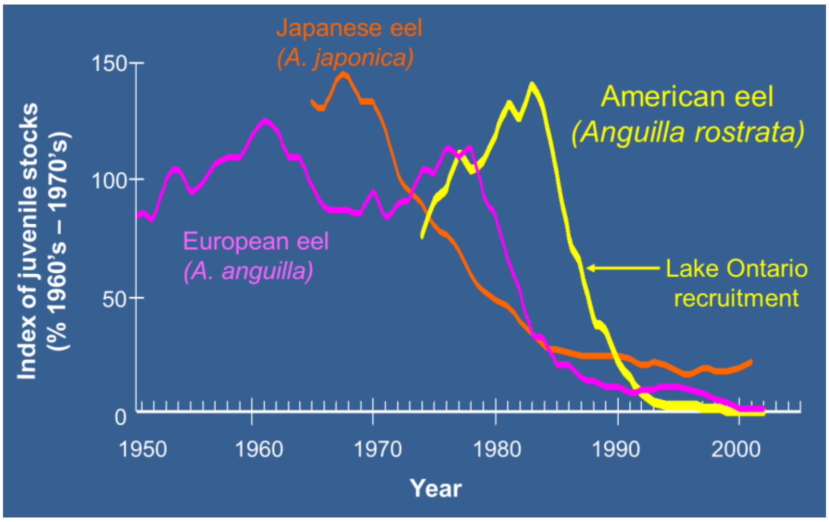


Figure 7: Index of eel recruitment across the northern hemisphere. (From International Eel Symposium, Quebec City AFS Annual Meeting, August 2003)

This declaration signed by internationally renowned scientists eventually triggered responses across the world, including New Zealand where the longfin population is considered to be in decline (Goodman et al. 2013). The European Council when reviewing the available information concluded*:*

"The latest scientific advice from the International Council for the Exploration of the Sea (ICES) concerning European eel is that the stock is outside safe biological limits and that current fisheries are not sustainable. ICES recommend that a recovery plan be developed for the whole stock of European eel as a matter of urgency and that exploitation and other human activities affecting the fishery or the stock be reduced as much as possible".

The result was the passing of EU regulation 1100/2007 that requires each country to put in place an Eel Management Plan that aims to return escapement of adult (silver) eel to 40% of pristine escapement levels in the long term. The content of these Eel Management Plans varied significantly between the various countries dependent upon the state and value of the eel fishery within the country, however some of the key management requirements implemented through Eel Management Plans within key EU countries is summarised as follows:

United Kingdom

- Development/implementation of regulations requiring provision of an eel pass on any instream structure where eel migration may be compromised;
- Screening of intakes and outfalls to protect eels;
- Stocking of waterways with European eel;
- Monitoring of eel and elver populations;
- Development of manuals and guidelines to inform the implementation of this legislation.

Ireland

- Cessation of the commercial eel fishery and closure of the market (the fishery had essentially collapsed anyway);
- Mitigation of the impact of hydropower, including a comprehensive trap and transport plan to be funded by the Electricity Supply Board (i.e. using ex commercial fishers);
- Ensure the upstream migration of juvenile eel at anthropogenic barriers;
- Improvement of water quality;
- Comprehensive eel monitoring program targeting glass eels/elvers, yellow eels and migrant eels so as to assess the effectiveness of the plan.

Netherlands

The Netherlands is relatively unique in that it maintains a long established eel fishery involving between 500,000 and 700,000 individuals. Based upon its low lying geography, the country also has around 4,600 pump stations and numerous other migration barriers.
The main aspect of the official Dutch eel fishery plan were:

- Administration of the country's four main river basins as one unit;
- Reduction of eel mortality at pumping stations and other water works;
- Reduction of eel mortality at hydro-electric stations;
- Establishment of fishery-free zones in areas that are important for eel migration;
- Release of eel caught at sea to inland waters by anglers;
- Ban on recreational fishing in coastal areas using professional gear (essentially a ban on use of fyke nets and long-lines by recreational fishers);
- Transportation and release of silver eel at sea in combination with an annual closure of the fishery from 1 September to 1 December – the downstream migration period;
- Restocking of glass eel and pre-grown eels from aquaculture;
- Research into the artificial propagation of eel;
- Control and enforcement;
- Monitoring and modification of the plan based on the findings.

With regards to the pumping station upgrades, €200 million has been allocated with half of the 1880 major barriers projected to be retrofitted or removed by 2015 and the remainder by 2027.

The outcome of the measures taken across Europe have been unexpectedly rapid and since 2011 there have been signs that the somewhat limited actions already taken had succeeded in halting if not reversing the decades long trends of decline in eel recruitment (Decker & Casselman 2014).

2.7.2 Technical Studies

Limited information has been found in relation to the ability of traditional impeller/propeller type flood pumps (as used throughout New Zealand) to pass live eels. The results of two studies identified are summarised as follows.

Buysse et al. (2014)

This study assessed the mortality rate of eels in a small (0.8 m^3/s,) and large (1.6 m^3/s, 0.8 m diam. casing, 0.41 m diam. core revolving at 420 rpm) four blade propeller type pumps. The head at the pumps monitored was only 0.2 m. During the study the large pump passed 39 eel, mostly females (length range 400-810 mm). Only one of these eels (560 mm) passed the pump alive and without visible injuries with all the others sustaining lethal injuries (cuts) or were dead.

Baker (2016)

This study assessed the survival rate of eels passing through a number of different pump types/sizes within the Anglia region in the UK. The results of the study are summarised in Table 1 below.

Type of pump	Diameter (m)	No. of blades	Speed (rpm)	Capacity (m^3/s)	Avg. eel size and range (mm)	No of eel tested and survival
Vertical mixed flow impeller	2.65	3	127	20.00	521 (340-765)	35 (100%
Vertical mixed flow impeller	2.23	3	100-107	9.43	565 (310-882)	58 (100%)
Horizontal axial flow	1.30	4	200	3.80	561 (400-777)	63 (93.7%)
Vertical axial flow	0.80	4	400	1.90	532 (380-830)	17 (41.2%)
Vertical 'fish friendly'	0.60	2	872	1.15	Approx. as above	60 (91.7%)

Table 1: Results of eel mortality test undertaken at five type of pump station in the Anglia region, UK. Survival rate shown is instantaneous and does not account for latent mortality. (From N. Baker, Hull University, pers. comm.)

The first four pumps listed in Table 1 are representative of standard impeller/propeller type pumps typically utilised on flood schemes in New Zealand. However it is notable that the first three pumps comprise large diameter pumps which operate at slower speeds and with wider blade openings which would account for the high survival rates recorded for eels passing through these pumps (94 – 100%).

The fourth pump (vertical axial flow) comprises a small-medium diameter, higher speed pump that presents a reduced opportunity for eels to pass through the pump without being impacted by the impeller blades and this would account for the significantly reduced survival rates for eels passing through this pump (41.2%).

By comparison, the only fish friendly pump tested, comprising an even smaller diameter, higher speed pump (a Bedford Fish Friendly Pump) than the vertical axial flow pump indicates a high level of survival for fish passing through this pump (91.7%).

ICM staff have outlined that flood pumps utilised within the Waikato Region range in diameter from 0.15 m – 1.2 m with average pump diameters in the range of 0.75 m – 0.9 m. On the basis of the above information it is therefore reasonable to assume that the small/medium diameter, axial/impeller type pumps utilised in the Waikato Region would likely be resulting in the mortality of a large proportion of the eels that pass through them. A further notable aspect of the above study is that the sizes of the European Eels recorded for that study are relatively small in comparison to typical sizes of the native eels found in New Zealand – particularly the more significant and threatened longfin. The larger eel sizes found within New Zealand are likely to be more at risk of high mortality/injury when passing through pumps due to the increased likelihood of impact with the impeller blades, however, this postulation has not been tested.

2.8 Effects Summary

Land drainage/flood control scheme infrastructure is known to be having adverse effects upon the upstream and downstream migration of native fish within New Zealand with two large scale eel kill incidents recorded within recent times as a direct result of land drainage activities.

Consultation with drainage scheme operational staff in the Waikato and throughout New Zealand has indicated that reported large scale fish kill incidents are not a common occurrence although there is anecdotal evidence that intermittent mortality of individuals is occurring as they pass through pump stations. The limitations of operational staff in identifying any effects and the lack of any conclusive data in regard to these issues however should be acknowledged. Furthermore, it must be acknowledged that the current land drainage setting presents significantly reduced habitat values and likely reduced fish populations to the predevelopment/baseline environmental setting and hence limited information or observations should to some degree be anticipated. Preliminary results from the current WRC ICM Orchard Road Pump Station study have indicated significant levels of mortality for migrant eels passing through this axial flow pump.

Scheme infrastructure directly compromises the upstream migration of native fish to aquatic habitat within scheme catchments however fish access is likely to be better where flap gate culverts maintain partial/restricted connectivity into these catchments (compared to pump only connections).

Table 2 below, summarises the likely effects of the typical outfall types found and drainage scheme infrastructure sites within New Zealand and the associated fish passage impacts

Outlet Type	Upstream Passage	Downstream Passage
Floodgate only	Passage blocked during flood/high tide periods; Passage may be restricted during other times; **Moderate level of passage available. Mortality unlikely.**	Passage blocked during flood/high tide periods; Passage may be restricted during other times; **Moderate level of passage available. Mortality unlikely**
Floodgate and pump combo	Passage blocked during flood/high tide periods; Passage may be restricted during other times; **Moderate level of passage available. Mortality unlikely**	Passage blocked during flood/high tide periods; Passage likely during other flow conditions **Moderate level of passage available. Mortality likely under some conditions**
Pump only	Passage restricted during all conditions – reliant on fish being able to navigate through the pump structure or over the stopbank **Very poor level of fish passage. Mortality unlikely.**	Only available through pump operation with a high risk of mortality for fish passing through the pump; **Very poor level of fish passage. High probability of mortality.**

Table 2: Summary of Fish Passage Effects by Scheme Outlet Type.

Currently, there is little being done throughout New Zealand to enhance fish passage through drainage scheme infrastructure. Efforts appear to be limited to installation of a small number of fish friendly flood gates and some trap and transfer operations occurring within some regions. While two Archimedes Screw Pumps are in place in the Waikato, the reason for the installation of these pumps was not to facilitate fish passage and there is currently no evidence to confirm their effectiveness in moving fish safely downstream.

Evidence from a number of more heavily developed and populated countries identifies a significant decline in eel populations in recent times as a result of multiple factors including habitat loss and migration impediments. This decline has resulted in the development and implementation of intensive policy and regulations to reinstate eel stocks including requirements for implementation of fish friendly drainage infrastructure. While there is limited information available to confirm the impacts of drainage infrastructure upon eel migration, the results of two foreign studies have confirmed high rates of eel mortality when the eels pass through small/medium diameter impellor/propeller style pumps which are typical of those utilised in New Zealand.

Overall, while the project investigations have identified limited data to quantify the effects of land drainage/flood control systems on native fish migration, based upon the information obtained it is considered reasonable to assume that these systems are resulting in adverse effects upon native fish migration. At both a regional and a national level, these effects alone may not be contributing to a significant decrease in native fish populations, however when combined with the numerous other activities contributing to adverse effects on fish migration and aquatic habitat (e.g. other instream structures, habitat loss, degraded water quality, pest species competition, channel 'management'), these activities are considered to be contributing to significant, cumulative adverse effects on the ability of native fish to complete their life cycles and utilise all available habitat.

3 Legislative Context

There are a number of legislative and statutory documents in place in New Zealand which include both high level and more specific provisions in relation to the potential impacts of land drainage/flood scheme infrastructure upon native fish migration. In addition, there is legislation which is specific to management of land drainage and flooding which must be balanced against fish passage requirements within environmental decision making. The key documents and their relevant provisions along with their current application to resource management decision making are outlined within the following sections.

3.1 Freshwater Fisheries Regulations 1983

The Freshwater Fisheries Regulations 1983 (FFR) contains provisions relating to management of both native and exotic sport freshwater fish in New Zealand. It is the key piece of national legislation reviewed which contains specific references and requirements regarding the provision of fish passage and native fish mortality effects. The following sections outline and assess the relevant provisions of the FFR in relation to the fish migration effects of land drainage scheme infrastructure and discusses the current application of this legislation in relation to these issues.

3.1.1 Relevant Provisions

PART 6 – FISH PASSAGE

Section 41 – Scope

Specifies that the following fish passage requirements apply to every dam or diversion structure in any river, stream or water other than:

d) any structure authorised by a Regional Water Board not requiring a water right that in no way impedes the passage of fish.

This section confirms that these provisions are applicable to the majority of flood scheme infrastructure sites as they do impede the passage of fish.

Section 43 – Dam and Diversion Structures

Specifies that the Director General of the Department of Conservation may require any proposed dam or diversion structure to include a fish pass facility – other than any structure subject to a water right issued under the provisions of the Water and Soil Conservation Act 1967 prior to 1 January 1984.

Requires that any person proposing to build such a dam or diversion structure, shall notify the Director-General and forward a submission seeking the Director-General's approval or dispensation from the requirements of these regulations.

Some of the drainage scheme assets within the Waikato Region may have been subject to a water right issued under the provisions of the Water and Soil Conservation Act 1967 prior to 1 January 1984 and hence would be exempt from these provisions. However other assets are known to be authorised via general authorisations or resource consents issued under the Resource Management Act 1991 (RMA) and hence would be subject to these provisions.

This section of the FFR implies a specific permit application process whereby any party proposing to build a dam or diversion structure requires specific approval or dispensation from the DoC to authorise the structure under this legislation.

Sections 44 – 50 – Requirements for Fish Facilities

Where the Director General of the Department of Conservation determines that a fish pass facility is required, he shall specify what is required (in terms of design).

The manager of every structure shall manage/maintain the structure to facilitate fish passage at all times.

PART 10 – INDIGENOUS FISH

Section 70 – No Killing of Indigenous Fish

Specifies that no person shall in any water <u>intentionally</u> kill or destroy indigenous fish.

The mortality effects of flood pumps on eels are known and hence the ongoing operation of this infrastructure may be seen as the intentional killing of indigenous fish thus constituting a breach of Section 70 above.

Section 71 - Taking of indigenous fish

Specifies that the requirements of Section 70 above do not restrict the taking of whitebait, or eels, or other indigenous fish for the purposes of scientific research or for purposes of human consumption, or as affecting the operation of any other regulations which restrict the taking of any indigenous fish.

The exemptions provided by Section 71 do not outline any specific exemptions which would be applicable to allowing killing of indigenous fish in association with land drainage/flood control scheme operations.

3.1.2 Application of the Freshwater Fisheries Regulations 1983

The FFR is administered within New Zealand by the Department of Conservation (DoC). Consultation has been undertaken with key DoC staff in relation to how and when the regulations are currently being applied to get a better understanding of its potential implications for land drainage schemes and their interactions with native fish. A summary of the outcomes of this consultation is outlined as follows:

- To date DoC generally hasn't implemented its regulatory powers under Section 6 of the FFR with respect to authorising barriers to fish passage and re-instatement of passage to barriers constructed since 1984. The exception is a few large scale projects where permits have been sought to authorise fish passes or exemptions from the regulations – due largely to their high profile and closer scrutiny of legislative requirements;

- For the majority of projects to date, fish passage requirements are typically addressed by Regional Councils through resource consent processes only;

- The Wellington Conservancy of DoC has previously established a Memorandum of Understanding with the GWRC to take responsibility for their statutory fish passage responsibilities under the FFR. However the legality of this agreement has been questioned as there is no specific allowances provided within the FFR to transfer these powers to another agency;

- DoC is in the process of trying to better manage their responsibilities under the FFR including establishment of improved procedures for dealing with any permit applications that are received by DoC. In the future there is potential that DoC will review the regulations to ensure they are more relevant to current practice/processes and including consideration of the separate line of assessment of fish migration effects provided for by Regional Plan regulations under the RMA. This may also result in DoC becoming more proactive in enforcing the requirements of the FFR;

- Considering s70(1) of the FFR – if flood pumps are known to be killing native fish and continue to operate, this could be seen as an offence under these provisions i.e. it is intentional. However there are no known cases of enforcement/prosecution having been undertaken under these provisions for these types of activities to date.

In summary, the FFR outline requirements and procedures to maintain fish passage through structures within a watercourse. Some potential exclusions are noted which may be relevant to historic land drainage structures dependent upon previous authorisations. The FFR is administered by DoC however there has been limited application of the requirements of the legislation to date with DoC relying more heavily on Regional Council resource consent processes to address fish passage issues.

3.2 Conservation Act 1987

The Conservation Act 1987 comprises a higher level statute developed to promote the conservation of New Zealand’s natural and historic resources. The Conservation Act established and outlines the roles of the DoC in achieving these conservation objectives.

The Conservation Act does not contain any specific requirements requiring the provision of fish passage for native fish species. However, reference to provision of fish passage is noted within Section 48A of the Act as follows:

Section 48A - Special regulations relating to freshwater fisheries

(1) Without limiting section 48, the Governor-General may from time to time, by Order in Council, make regulations for all or any of 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.

Discussions with DoC staff have outlined that they are not aware of the provisions of this section of the Conservation Act ever being enacted to require fish passage through any specific structures.

3.3 Resource Management Act 1991

The Resource Management Act 1991 (RMA) forms the main statute guiding natural resource management decision making within New Zealand. The RMA establishes the requirement for the preparation of Regional Policy Statements and Regional Plans by regional authorities along with the specific requirements and procedures associated with application, assessment and decision making for resource consents.

The RMA provisions in relation to natural resource management are high level and do not contain any specific requirements relating to fish migration/fish passage. Nonetheless, the following guiding provisions of the RMA are considered relevant to activities which have the potential to impact fish migration/fish passage and would require consideration when these activities are being assessed through a resource consent process.

PART 2 – PURPOSE AND PRINCIPLES

Section 5 – Purpose

To promote the sustainable management of natural and physical resources which includes:

- *safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and*

- *avoiding, remedying, or mitigating any adverse effects of activities on the environment.*

Section 6 - Matters of national importance

(c) the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna.

Section 7 - Other matters

(d) intrinsic values of ecosystems.

PART 3 - DUTIES AND RESTRICTIONS UNDER THIS ACT

Section 13 - Restriction on certain uses of beds of lakes and rivers

Specifies that no person may undertake an activity within the bed of a lake or river unless expressly allowed by a national environmental standard, a rule in a regional plan or a resource consent. These activities include:

- Any structure within the bed of a lake or river ; and
- Any activity to damage, destroy, disturb, or remove the habitats of animals in, on, or under the bed of a lake or river.

Part 5 - Standards, policy statements, and plans

Sections 61/66 – Matters to be considered by regional councils (policy statements/plans

Requires regional councils in preparation of regional policy statements and plans to have regard to:

- *regulations relating to ensuring sustainability, or the conservation, management, or sustainability of fisheries resources;*

While the above RMA provisions are high level, the overall ‘sustainable management’ principles of this legislation imply that where activities are undertaken which utilise/impact natural resources, they incorporate measures to avoid, remedy or mitigate the effects of the activities upon the environment.

Considering land drainage/flood control activities, it is reasonable to assume that this would extend to measures to maintain passage for migratory fish where it would otherwise occur.

3.4 Land Drainage Act 1908

The Land Drainage Act 1908 (LDA) provisions do not appear to outline any specific overarching purpose or objective of this legislation in relation to land drainage. Rather, the provisions of this Act establish the powers to establish drainage districts and associated drainage boards and the powers of these boards to construct and maintain drains and watercourses. Within the Waikato Region, the provisions of the LDA are predominantly coordinated and implemented by the WRC ICM.

Section 17 of the LDA outlines the various powers of a board to construct and maintain drains and includes the following allowances:

(a) cleanse, repair, or otherwise maintain in a due state of efficiency any existing watercourse or outfall for water, either within or beyond the district, or any existing bank or defence against water;

(b) deepen, widen, straighten, divert, or otherwise improve any existing watercourse or outfall for water, either within or beyond the district, or remove obstructions to watercourses or outfalls for water, or raise, widen, or otherwise alter any existing defence against water;

(c) make any new watercourse or new outfall for water, or erect any new defence against water, or erect any machinery, or do any other act required for the drainage of the district;

(k) fill up or obstruct any drain.

The LDA does not contain any specific provisions relating to environmental management and in particular, fish migration through land drainage infrastructure established by drainage boards under the powers within this Act. Nonetheless, it is noted that Section 2A outlines the relationship of this Act to the RMA as follows:

Section 2A - Relationship to Resource Management Act 1991

Nothing in this Act shall derogate from the Resource Management Act 1991.

In this respect, all functions and powers established through this Act to allow implementation of land drainage activities are subject to the environmental management provisions of the RMA and the subsidiary statutory documents and processes established through the RMA including regional policy statements, regional plans and resource consents.

3.5 Soil Conservation & Rivers Control Act 1941

The key objectives of the Soil Conservation and Rivers Control Act 1941 (SCRCA) are outlined within Section 10 of the Act as follows:

(a) the promotion of soil conservation;

(b) the prevention and mitigation of soil erosion;

(c) *the prevention of damage by floods;*

(d) *the utilisation of lands in such a manner as will tend towards the attainment of the said objects.*

The provisions of this Act establish the powers to establish catchment districts and associated catchment boards and the powers of these boards whom are vested with the responsibility to implement the above catchment management objectives. The above objectives clearly state responsibilities of the catchment boards in relation to prevention of damage by floods which in some catchments include the implementation and management of flood scheme infrastructure (e.g. stopbanks, flood pumps etc.)

Within the Waikato Region, the provisions of the SCRCA are predominantly coordinated and implemented by the WRC ICM.

Section 126 of the SCRCA outlines the general functions and powers of Catchment Boards and reiterates the key function to:

'to minimise and prevent damage within its district by floods and erosion'

Clause 2 of this section further details the functions of Catchment Boards and outlines that all boards shall:

'…have power to construct, reconstruct, alter, repair, and maintain all such works… necessary or expedient for:

(a) *controlling or regulating the flow of water towards and into watercourses;*

(b) *controlling or regulating the flow of water in and from watercourses;*

(c) *preventing or lessening any likelihood of the overflow or breaking of the banks of any watercourse….*

Again, the LDA does not contain any specific provisions relating to environmental management and in particular fish migration within catchment management districts. Nonetheless, it is again noted that Section 10A outlines the relationship of this Act to the RMA as follows:

Section 10A - Relationship to Resource Management Act 1991

Nothing in this Act shall derogate from …. the Resource Management Act 1991.

Hence, all functions and powers established through this Act to allow achievement of the above catchment management objectives are again subject to the environmental management provisions of the RMA and the subsidiary statutory documents and processes established through the RMA including regional policy statements, regional plans and resource consents.

3.6 Waikato Regional Policy Statement

The key purpose of the regional policy statement is to assist and guide regional and local councils in carrying out their functions to achieve the sustainable management purposes of the RMA. In this respect, a regional policy statement provides an overview of the resource management issues of the region and outlines the ways in which integrated management of the region's natural and physical resources will be achieved.

The Waikato Regional Council has been in the process of developing a new regional policy statement (RPS) relatively recently with the new RPS made operative in April 2016.

The RPS contains a range of high level objectives and policies to guide resource management decision making within the Waikato Region. A number of objectives and policies are identified which either directly or indirectly relate to the provision of fish passage through watercourses which are identified as follows. Specific provisions which are considered to be of direct relevance to maintenance of fish passage are identified through underlining.

Objective 3.3 - Health and wellbeing of the Waikato River

The health and wellbeing of the Waikato River is restored and protected and Te Ture Whaimana o Te Awa o Waikato (the Vision and Strategy for the Waikato River) is achieved.

The RPS includes multiple references to the Vision and Strategy for the Waikato River and the Vision and Strategy document forms part of the PRPS and must be given effect through the plans administered by regional and territorial authorities along the river. The relevant provisions of the Vision and Strategy in relation to fish migration effects within the Waikato River catchment are discussed further in section 3.9 below.

Objective 3.13 - Mauri and values of fresh water bodies

Maintain or enhance the mauri and identified values of fresh water bodies including by:

b) safeguarding ecosystem processes and indigenous species habitats;

c) safeguarding and improving the life supporting capacity of freshwater bodies where they have been degraded as a result of human activities, with demonstrable progress made by 2030;

Objective 3.18 - Ecological integrity and indigenous biodiversity

The full range of ecosystem types, their extent and the indigenous biodiversity that those ecosystems can support exist in a healthy and functional state.

Policy 8.3 - All fresh water bodies

Manage the effects of activities to maintain or enhance the identified values of fresh water bodies and coastal water including by:

c) providing for migratory patterns of indigenous freshwater species up and down rivers and streams and to the coastal marine area where practicable;

Policy 11.1 Maintain or enhance indigenous biodiversity

Promote positive indigenous biodiversity outcomes to maintain the full range of ecosystem types and maintain or enhance their spatial extent as necessary to achieve healthy ecological functioning of ecosystems, with a particular focus on:

a) working towards achieving no net loss of indigenous biodiversity at a regional scale;

b) the continued functioning of ecological processes;

c) the re-creation and restoration of habitats and <u>connectivity between habitats</u>;…

d) supporting (buffering and/or linking) ecosystems, habitats and areas identified as significant indigenous vegetation and significant habitats of indigenous fauna; c) providing ecosystem services; d) the health and wellbeing of the Waikato River and its catchment;

11.1.2 Adverse effects on indigenous biodiversity

Regional and district plans shall recognise that adverse effects on indigenous biodiversity within terrestrial, freshwater and coastal environments are cumulative and may include:

a) fragmentation and isolation of indigenous ecosystems and habitats;

b) reduction in the extent and quality of indigenous ecosystems and habitats;

c) loss of corridors or connections linking indigenous ecosystems and habitat fragments or between ecosystems and habitats;

d) loss or disruption to migratory pathways in water, land or air;

e) effects of changes to hydrological flows, water levels, and water quality on ecosystems;

h) loss, damage or disruption to ecological processes, functions and ecological integrity;

j) effects which contribute to a cumulative loss or degradation of indigenous habitats and ecosystems;

l) loss of habitat that supports or provides a key life-cycle function for indigenous species listed as 'Threatened' or 'At Risk' in the New Zealand Threat Classification System lists.

11.1.3A Recognition of activities having minor adverse effects on indigenous biodiversity Regional and district plans should include permitted activities where they will have minor adverse effects in relation to the maintenance or protection of indigenous biodiversity. They may include:

a) the maintenance, operation and upgrading of lawfully established infrastructure, regionally significant infrastructure and lawfully established activities using natural and physical resources of regional or national importance;

b) existing lawfully established uses of land where the effects of such land use remain the same or similar in character, intensity and scale;

The above provisions of the RPS directly identify the potential impacts of activities upon the migratory pathways of indigenous fish and promote measures to provide for migratory patterns of indigenous fish up and down rivers and streams where practicable.

Objective 3.13 is notable and relevant as it sets a target of maintaining or enhancing the values of freshwater bodies through safeguarding and improving the life supporting capacity of freshwater bodies where they have been degraded as a result of human activities, with demonstrable progress by 2030.

The identified ongoing impacts of existing land drainage/flood scheme infrastructure upon native fish migration would likely be seen as being directly contrary to these provisions of the PRPS.

It is noted that Policy 11.1.3A does recognise activities having minor adverse effects on indigenous biodiversity and recommends the provision of permitted activity allowances for these activities which may include the maintenance and operation of lawfully established infrastructure. In this respect it is considered unlikely that the mortality effects and direct migratory impediments created by land drainage/flood scheme infrastructure in the Waikato Region would comprise minor effects without specific provisions to maximise fish passage to the greatest extent practicable through these structures.

Overall, the continued operation of land drainage/flood scheme infrastructure which present a direct impediment or risk to native fish migration would be inconsistent with these provisions of the RPS. Consistency with these provisions would appear to require ICM to make specific efforts within their land drainage network to implement measures to maximise the potential for native fish to pass through scheme infrastructure to access and utilise as much of their native habitat range as possible without restriction or risk of mortality.

3.7 Waikato Regional Plan

The Waikato Regional Plan (WRP) aims to implement the provisions of the RPS through development of more specific objectives and policies along with rules and standards in relation to the use, development and protection of the Waikato Regions natural resources. It is these provisions which currently dictate the specific environmental design standards and statutory status of land drainage/flood control infrastructure within the Waikato Region.

Discussions with ICM staff have outlined that of the 118 flood pump operations managed by ICM, the only site which is currently subject to specific resource consent authorisations under the WRP is the previously described Motukaraka site. This is on the basis that all of the other sites are authorised as 'existing lawfully established activities' which can operate within the relevant WRP permitted activity provisions. The means of lawful establishment of these activities is identified as previous authorisation either via a 'water right' or a 'general authorisation' issued under the provisions of the former Water and Soil Conservation Act 1967 (now superseded by the RMA).

The relevant provisions of the WRP in relation to these assets are considered to be those relating to discharges to water, damming and diversion of water and river and lake bed structures. The sections of the WRP relating to these activities contain a number of key references and requirements in relation to provision of fish passage in association with activities within waterbodies. These provisions, including the specific permitted activity rules and their associated resource management implications, are identified and discussed as follows.

SECTION 3.5 – DISCHARGES

3.5.10 Implementation Methods - Drainage Water Discharges
3.5.10.1 Permitted Activity Rule – Take, Diversion and Discharge of Water Pumped from Drainage and Flood Control Schemes

The take, diversion and discharge of pumped water to water from drainage districts and river control schemes lawfully established or authorised before the date of notification of this Plan (28 September 1998) is a permitted activity subject to the following conditions…………..

This rule specifically permits the movement of pumped water from lawfully established land drainage and flood control schemes subject to adherence to a list of performance conditions. The conditions have been reviewed and contain no specific standards in relation to provision of fish passage in association with these activities and it is considered likely that all other performance conditions would be able to be met by the ICM pump station sites. Hence the take, diversion and discharge activities occurring at the ICM pump station sites are permitted by the WRP without any specific requirement for fish passage.

SECTION 3.6 – DAMMING AND DIVERTING

Objective 3.6.2

Damming and/or diverting of water undertaken in a manner that:

c) Does not obstruct fish passage where it would otherwise occur in the absence of unnatural barriers, so that trout or indigenous fish can complete their lifecycle.

Policy 3.6.3 (2) - Damming and Diverting of Water in Perennial Water Bodies

Manage the damming and diverting of water in perennial water bodies in a manner that ensures:

c) That the activity will not obstruct fish passage of trout and/or indigenous fish to complete their lifecycle where it would otherwise occur in the absence of unnatural barriers.

Rule 3.6.4.6 - Permitted Activity – Existing Lawfully established Stopbanks

*The damming or diversion of water by way of a stopbank, where the activity was lawfully established or authorised before the date of notification of this Plan, is a **permitted activity** subject to the following conditions:*

f) The structure shall provide for the safe passage of fish both upstream and downstream.

The key land drainage/flood control structures associated with the damming and diverting of water comprise the stopbank structures constructed to hydraulically separate catchments during flood events but which can also prevent/restrict fish passage due to the physical barriers they present to both upstream and downstream migration.

The above provisions outline a directive that both proposed and existing stopbank structures should provide for fish passage. In this respect, any existing ICM stopbank infrastructure which do not provide a means for fish migration between catchment areas are likely to be considered contrary to these provisions and would not be able to adhere to the permitted activity provisions outlined within this rule and hence should be subject to resource consent authorisation.

4.4 - RIVER AND LAKE BED STRUCTURES

4.2.2 Objective

The use, erection, reconstruction, placement, alteration, extension, removal or demolition of structures in, on, under or over the beds of rivers and lakes managed in a manner that:

c) does not obstruct fish passage for trout and indigenous fish to complete their life cycle.

Policy 4.2.3(1) - Enable Low Impact Structures

Enable through permitted activity rules the use, erection, reconstruction, placement, alteration, extension, removal or demolition of structures, in, on, under or over the beds of rivers or lakes which:

c) do not obstruct fish passage for trout and indigenous fish.

Rule 4.2.5.1 - Permitted Activity – Existing Lawfully Established Structures

*Unless controlled by Rules 3.6.4.5…the use or alteration (including operation, repair, upgrading and maintenance activities encompassed by section 13(1)(a)) of any existing lawfully established structure authorised before the date of notification (28 September 1998) of this Plan… are **permitted activities** subject to the following conditions:*

d) The structure shall comply with any conditions that are part of a resource consent granted for the structure before the date of notification (28 September 1998) of this Plan, other than conditions relating to review or expiry;

j) For culverts in water bodies classified as Trout Fisheries or Indigenous Fisheries:
i. the structure shall not impede fish passage where it would otherwise occur, or
ii. a mechanism, structure or procedure shall be provided, that allows for fish passage where it would otherwise occur.

In considering ICMs land drainage/flood control infrastructure against these provisions, it is the flood pumps and/or any associated flood control culvert structures installed between the catchment areas to which these provisions apply.

The above objective and policy provisions indicate a directive that these structures should provide for fish passage and hence any structures which impede or pose a threat to fish migration would be inconsistent with these provisions. However, it is noted that Rule 4.2.5.1 outlined above provides for these structures as permitted activities on the basis that they comply with any resource consents granted for the structures prior to notification of the WRP (condition d). Furthermore, the only specific requirement for fish passage through these structures, is where the subject structure comprises a culvert and is located within a watercourse with a fishery classification as identified under the WRP.

As previously described, the only ICM flood control structure subject to resource consent authorisation comprises the Motukaraka flood scheme infrastructure which was approved prior to the specified date of notification of the WRP.

Considering condition (j) of this rule, an assessment of the water management classifications applicable to ICM floodgates has not been undertaken. However, it is considered likely that at least some of these culverts would be located within watercourses to which a fishery classification applies and hence if these structures do not include specific allowance for fish passage, they would not be able to adhere to these permitted activity provisions. Furthermore, it is a likely assumption of this rule that the WRP fishery classification maps provide a robust method for identifying all catchments where good populations of native fish are present. However, experience with these maps has identified that many catchments without an indigenous fishery classification still hold good populations of indigenous species. Hence, this rule is considered to be somewhat flawed in achieving the overarching fish passage objectives of the WRP.

In summarising the key provisions of the WRP in relation to the fish passage requirements of ICMs land drainage/flood control infrastructure the following key points are noted:

- Like the RPS, the guiding objectives and policies of the WRP all appear to indicate a directive that the various activities associated with land drainage/flood scheme operations should include allowance for fish passage whether or not the activity is existing or lawfully established;

- The rules relating to the take, diversion and discharge of water through flood pumps permits these activities without any specific fish passage requirements;

- There is an inconsistency between the rules relating to the various structures (stopbanks/pumps/floodgates) associated with ICMs drainage/flood control activities. Specifically, the damming/diversion rules relevant to existing stopbank structures only permit these structures where they incorporate fish passage provision. Whereas, the riverbed structure rules relevant to flood pump and flood control culvert structures only requires provision of fish passage on culvert structures located within fishery classification watercourses. Outside of these watercourses flood pumps and flood control culverts are able to occur without fish passage provision as a permitted activity.

Overall, while inconsistencies are noted between these relevant provisions, it is assumed (based particularly on the objective and policy provisions of both the RPS and WRP) that the intent of these rules is to ensure that fish passage is maintained where it would otherwise exist whether it be on either existing, lawfully established or upon new activities/structures.

3.8 Waikato-Tainui Raupatu (Waikato River) Settlement Claims Act 2010

The Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010 was enacted in May 2010 with the purpose of implementing co-management agreement of the Waikato River. The overarching purpose of the Act is to restore and protect the health and wellbeing of the Waikato River for future generations. Through this legislation it is intended to implement the “Vision and Strategy” (the V & S) for the River and consequently aims to meet the objectives of Waikato Tainui for the Waikato River. As previously described, the V & S is also incorporated within the PRPS and must be given consideration to in resource management decision making for activities which affect the Waikato River and its catchment.

The V & S provisions are relevant to ICM land drainage/flood control infrastructure located within the Waikato River catchment only. The key vision for the Waikato River as outlined within this document is:

‘For a future where a healthy Waikato River sustains abundant life and prosperous communities’

The V & S goes on to outline a number of key objectives and strategies for implementing this vision. The objectives and strategies are high level and do not contain any specific references to either fish passage or land drainage/flood control activities. Nonetheless, objectives and strategies are identified which are of relevance to these activities and their effects as follows:

Objectives

a. The restoration and protection of the health and wellbeing of the Waikato River

g. The recognition and avoidance of adverse cumulative effects, and potential cumulative effects, of activities undertaken both on the Waikato River and within its catchments on the health and wellbeing of the Waikato River;

i. The protection and enhancement of significant sites, fisheries, flora and fauna.

Strategies

1. Ensure that the highest level of recognition is given to the restoration and protection of the Waikato River;

5. Develop and share local, national and international expertise, including indigenous expertise, on rivers and activities within their catchments that may be applied to the restoration and protection of the health and wellbeing of the Waikato River;

9. Encourage and foster a ‘whole of river’ approach to the restoration and protection of the Waikato River, including the development, recognition and promotion of best practice methods for restoring and protecting the health and wellbeing of the Waikato River;

While these provisions are high level in nature, they are considered to indicate a general management approach being sought by the V & S through the restoration and protection of the river and its catchment. In this respect, the continued operation of land drainage/flood control operations which create direct effects upon the ability of native fish to complete their life cycles through either direct mortality or migratory impediments is unlikely to be consistent with the objectives and strategies sought through the V & S to achieve the overarching vision for the river and its catchment.

3.9 Iwi Management Plans

Iwi Management Plans have been developed by a number of iwi within the Waikato Region to address matters of significance within their respective rohe in terms of specific cultural and environmental values associated with resource management decision making.

These plans are required to be taken into account by Councils in the management of the region's natural resources, providing a formal way for iwi interests to be incorporated into the council's decision making.

Considering the location of the WRCs land drainage/flood control schemes within the region, there are two iwi management plans which are considered to be of relevance to the activities comprising the Waikato-Tainui Environmental Plan and the Hauraki Iwi Environmental Plan. The relevant provisions of these plans in relation to the effects of land drainage/flood control infrastructure on native fish migration are identified and discussed as follows:

3.9.1 Waikato-Tainui Environmental Plan

The area to which the Waikato Tainui Environmental Plan (WTEP) relates comprises the Waikato Tainui rohe which encompasses the central and western parts of the Waikato Region including the central and lower reaches of the Waikato River and its catchment.

The WTEP is a comprehensive document with an overarching vision of returning the Waikato Tainui rohe to the modern day equivalent environmental state that it was in pre 1900 as described within the words of the second maori king Taawhiao. In this respect, the provisions of the WTEP promote the restoration, enhancement and protection of the area’s natural resources.

Section 22 of the WTEP relates to fisheries and identifies the native fisheries of the Waikato as a taonga (a treasure) on the basis that they sustain Waikato Tainui both physically as a food source, and spiritually as they play a significant role within many traditional stories and waiata. This section outlines a significant list of objectives and policies in relation to fisheries management again with a focus on implementation of management methods and procedures which enhance the Waikato fishery in line with the overall purpose of the WTEP. Policy 22.3.13 of the WTEP contains specific provisions in relation to fish passage as follows:

Policy 22.3.1.3 *To be aware and respond to other factors that potentially impact on fisheries or fisheries management.*

Methods

(a) In undertaking or planning activities that potentially impact on fisheries or fisheries management, demonstrate, in consultation with Waikato-Tainui, how the activity does or will manage effects on:

(iv) Fish passage and migration;

3.9.2 Hauraki Iwi Environmental Plan

The area to which the Hauraki Iwi Environmental Plan (HIEP) relates comprises the Hauraki iwi rohe encompassing the entire Firth of Thames/Hauraki Gulf catchment which within the Waikato Region includes the Hauraki Plains/Western Coromandel catchment areas.

The vision of the HIEP in relation to freshwater outlines an aim that by 2050, most of the waterways within rural and urban areas have been restored to their indigenous state and are home to increasing populations of fish.

The HIEP identifies the importance of native fish, particularly eels and whitebait species, as a historic, important food source for the Hauraki whanui with these species being particularly abundant within the Waihou and Piako catchments. Land drainage and flood protection activities along with commercial fishing are identified within the HIEP as having an adverse impact upon populations of these species with the Hauraki rohe.

The HIEP outlines a number of specific objectives, outcomes and actions in relation to enhancing the fishery in-line with the vision of the plan as follows:

Objectives

d) To restore and increase inanga spawning in Hauraki Rivers;

f) To determine and achieve an acceptable 50% recovery rate for tuna and whitebait fisheries;

g) Develop a programme to monitor recovery of the tuna and whitebait fisheries;

Outcomes

a) Enhancement of the freshwater fisheries habitat;

f) Increased populations of fisheries, birds and plant resources.

Actions

a) Develop catchment based strategies for the recovery of tuna and inanga whitebait fisheries.

The identified provisions of the two relevant iwi management plans described above both highlight the importance of the native fishery to local tangata whenua and promote the development and implementation of measures to restore and enhance the native fishery within their rohes. The continued operation of land drainage/flood protection activities within the Waikato/Hauraki catchment areas has been identified as presenting a potential for direct mortality of native fish or impediment to fish passage which may restrict the ability of these species to access habitat for completion of their life cycles. Hence the continued operation of these activities in this manner, would not be consistent with the identified provisions and overarching principles of these documents.

With an increasing emphasis on iwi involvement and consideration of iwi based legislation and management documents such as these within resource management decision making, it is unlikely that any future consent processes for ICM scheme infrastructure which compromises fish passage would be considered acceptable to local iwi under these documents. Adherence to the visions and principles outlined within these documents would require development and implementation of best practice fish passage measures to enable passage in-line with the aquatic habitat/fishery enhancement principles promoted through these documents.

3.10 Treaty of Waitangi

There have been long standing grievances from many iwi groups throughout New Zealand over breaches of their rights and entitlements established through the Treaty of Waitangi. The Waitangi Tribunal has been established to investigate and make recommendations on claims brought by iwi relating to actions or omissions of the Crown which may be in breach of the promises made in the treaty of Waitangi.

As part of the Te Paparahi o Te Raki District Inquiry (Wai 1040), a claim on behalf of the Ngati Hau Trust Board and Ngati Hau Hapu o Ngapuhi (Wai 246) is currently in front of the Waitangi Tribunal. In their submission to the tribunal Ngati Hau have stated that Northlands Hikurangi swamp, which is encompassed within the Hikurangi Flood Scheme area, is no longer the food basket it once was and the scheme pump stations, seven in total, continue to cut and kill thousands of tuna (eel) with every flood. This has been described as occurring since the scheme was built in the 1970s and little if anything is considered to have been done to remedy or alleviate the situation. Ngati Hau have described that they are no longer able to manaaki (care for/feed) their manuhiri (guests/visitors) fittingly due to all of the detrimental impacts imposed upon their waterways without any understandings or appropriate care of the food basket that the Hikurangi Swamp provided prior to its destruction. The claimants consider that such actions show complete disregard for the principle of the Treaty of Waitangi and Ngati Hau asserts that the Crown has failed in its obligation to protect the tuna fisheries and other treasures of the Hikurangi Swamp.

This current case has highlighted the awareness and concerns of at least one iwi group in regard to the impacts of flood scheme infrastructure upon native fish populations as well as the wider ecological values within flood scheme catchments. While the outcome of this case is yet to be determined it presents a potential precedent for other flood scheme areas throughout New Zealand.

3.11 Legislative Summary

Conservation legislation including the FFR and Conservation Act are identified as the only national legislation documents containing specific provisions which enable DoC to require fish passage through instream structures and to prevent the intentional killing of native fish. However, to date these provisions have been largely overlooked and have not been applied by DoC.

Instead, consideration of fish passage requirements has predominantly been applied and implemented on a site specific basis through resource consent processes under the RMA. Provision of fish passage for native fish where it has previously existed, would appear to be a requirement for any instream activities or structures to ensure adherence to the sustainable management principles of the RMA.

The LDA and SCRCA comprise the key legislative documents associated with establishment of drainage and catchment boards and management of land and watercourses to prevent adverse flooding effects. However, both of these acts include a specification that these activities shall not derogate from the overriding sustainable management principles of the RMA and its subsidiary regional policy statement and regional plan documents.

At a regional level, both the RPS and the WRP include objectives and policies which aim to ensure that fish passage is either maintained or enhanced through watercourses where it would otherwise exist. These directives would appear to apply to existing, authorised structures such as ICMs land drainage/flood control infrastructure on the basis that direct mortality or migratory impediment effects are unlikely to being considered minor adverse effects associated with these activities. While some inconsistencies/uncertainties are identified between the permitted activity allowances for the various activities relating to ICM scheme infrastructure under the WRP, the intent of these rules is assumed to be that fish passage is maintained where it would otherwise exist whether it be on either existing, lawfully established or upon new activities/structures.

The enactment of the Waikato-Tainui Raupatu (Waikato River) Settlement Claims Act 2010 and the increased recognition of iwi management plan documents within resource management decision making highlights a direction of increased ecosystem enhancement for activities which impact aquatic habitat and ecology. The continued operation of land drainage/flood protection activities which present a potential for direct mortality of native fish or impediment to fish passage where it would otherwise exist would not be consistent with the overarching vision and relevant provisions of these documents.

Overall, while the specific fish passage provisions of national conservation legislation documents are not being implemented for these activities, the RMA and its subsidiary regional planning documents within the Waikato outline a requirement to provide for fish passage through land drainage systems where it would otherwise exist. Furthermore, the new RPS in conjunction with recent iwi based legislation and management plan documents, indicate a directive for an increase in environmental enhancement initiatives (as opposed to the RMA's traditional 'avoid, remedy, mitigate approach) through future resource management decision making. This directive would likely include increased pressure for provision of best practice fish passage measures through catchments where it would otherwise occur and is currently restricted.

4 Remedial Options to Address Fish Migration Effects of Land Drainage & Flood Schemes

There are a wide range of factors which influence decision making around what remedial measures can be implemented at a site where fish passage is being impacted by scheme activities. These include the catchment characteristics (hydraulic, topographic and ecological), the type of scheme infrastructure present at the site and their configuration, efficiency/benefits of remedial works along with available funding, constructability and maintenance requirements.

Furthermore, there are a wide range of remedial options which may be available to assist with upgrading/enhancing fish passage through scheme infrastructure. These options can be broadly categorised into the following areas to address the various factors which may be impacting fish passage at a site:

- Deterrent measures to prevent fish from entering high impact, traditional pumps where they may be injured or killed;
- Alternative pumping systems identified as being 'fish friendly' which may provide much reduced injury/mortality as fish pass through;
- Alternative floodgate/tidegates which provide an extended period within fish are able to migrate into and out of the catchment;
- Fish passes which can provide an alternative route for fish to migrate into and out of the catchment separate to the restrictive drainage infrastructure.

While these options may provide opportunities for improved fish passage through the infrastructure, none provide completely unimpeded fish passage and some level of fish passage delay, restriction or risk is always likely to remain so long as the infrastructure is retained. Furthermore, in some situations, multiple measures may be required to provide fish passage (e.g. a deterrent measure to prevent fish entering a traditional, high impact pump along with an alternative catchment outlet system to allow fish to safely pass through the scheme infrastructure).

The following sections provide details of the potential remedial options which may be available for different types of drainage scheme sites along with an assessment of their appropriateness and effectiveness for the improvement of fish passage at these sites. Indicative cost estimates for some of the options discussed in the following sections can be found in Appendix D.

4.1 Catchment Prioritisation

As there is often limited funding available for fish passage remedial works on scheme infrastructure it is important to prioritise catchments where remedial works may occur. Decision making should include a detailed cost/benefit analysis of the remedial works necessary to achieve the level of benefit sought in term of fish passage and fish population improvements within the catchment. Key considerations when prioritising catchments/scheme areas for remedial works should include:

- What fish species are already present? Are any rare or endangered species? Is it pest fish free? If so is fish passage still desirable? (e.g. restrict eel passage to benefit mudfish populations);
- What the target fish population(s) is/are and reasons why;

- Consequence (biological, legislative etc.) Of providing or not providing fish passage;
- Documentation of any past fish passage issues or incidents;
- Presence or otherwise of a gravity outlet. This will help identify the level or impact as well the potential costs associated with any remediation;
- Habitat size (i.e. How much catchment is available upstream to support the targeted fish populations);
- Habitat quality (i.e. Does the upstream catchment provide good quality existing or potential habitat to support the targeted fish populations?;
- Upstream barriers – are there additional upstream barriers (natural or artificial) which may be restricting fish passage?;
- Catchment hydrology – are flows sufficient/appropriate to enable effective function of the proposed remediation measures?;
- Other environmental constraints/risks to effective operation e.g. siltation, pest fish/plant invasion.

The above list is by no means complete but highlights the broad range of considerations which may need to be addressed if remedial action is to be taken. It is also recommended that in all situations inputs from the following specialist areas be included in the decision making:

- A freshwater ecologist familiar with catchment ecology and fish passage requirements;
- A local scheme engineer familiar with catchment hydrology and typical operation of the scheme infrastructure;
- A hydraulic/civil/environmental engineer familiar with and experienced in both scheme infrastructure design and installation and fish passage requirements.

In addition, consideration should be given to involvement from local landowners, local iwi representatives and other stakeholder groups who may also be able to contribute valuable inputs in regards to catchment conditions and values.

4.2 Exclusion/Deterrent Measures for Downstream Migrants

Exclusion and deterrent measures typically comprise measures implemented within a watercourse to minimise the potential for fish to enter traditional style pump systems where they may be injured or killed. While fish may naturally avoid an operating pump because of noise, turbulence or vibration, the initial response eventually becomes suppressed through habituation and the desire to migrate resulting in fish moving into the pump systems. The aim therefore is to enhance avoidance responses to divert fish away from the pump intake and direct them to a safer outlet system. Measures utilised to achieve these responses may comprise physical barrier systems such as screens to exclude fish from entering a pump intake or behavioural deterrents which act upon the fish senses to deter them from an unsafe route and guide them to a safe outlet.

It is important to note that exclusion/deterrent measure will only form part of the fish passage solution for existing pump stations. The ability of fish to migrate downstream through the scheme infrastructure will be reliant upon an alternative outlet option such as a controlled culvert, bypass channel or fish friendly pump. These alternative outlet options are described in more detail in Section 4.4 of this report.

4.2.1 Bar Racks/Screens

Bar Racks typically comprise a screen formed from evenly spaced, vertical steel bars installed directly upstream of the flood scheme infrastructure. Bar racks may be installed either to exclude debris and fish from a pump intake, or to allow fish to pass through a screen so they can access a safe outlet (e.g. a culvert or fish friendly pump) while still restricting the entrance of debris that could block the system.

4.2.1.1 Fish Barrier Screens

In considering the use of bar rack screens as a means of impeding fish entry to pump stations, difficulties arise in developing structural barriers to downstream migrating eels by the fact that eels behave very differently from other species for which deterrent structures have been successfully employed to date. In contrast to other fish, eels tend to bump into structures through which flows are passing and try to force their way through them, rather than be guided by them (Richkus 2001).

As previously identified, all pump stations within the Waikato Region are already fitted with debris screens with steel bars at about 50mm spacings (Figure 8). These screens have been installed to prevent vegetation and other large debris from entering the pump and block or damage it. . However, 50mm spacings are considered to be too large to be effective in preventing most fish (notably eels) from entering the pumps and this has certainly been confirmed by the recent Motukaraka fish kill incident.

Figure 8: 50mm debris screen on Motukaraka scheme axial pump intake (photo – R. Duirs, BBO)

No specific information has been found in relation to the effectiveness of bar racks to prevent eels from entering land drainage/flood pump systems with available information being limited to larger hydro power scheme screening systems. The results of German studies by Berg (1995 cited by Thon, 1999) concluded that eels up to 70cm in length were able to pass through bar racks with 25mm spacing, and that eels of 55 to 60cm could pass through 20mm spaces. Based on these results, 20mm bar spacings were initially prescribed for intake screens at hydroelectric projects in Germany but as the water velocity at the bar rack was often over 1m/s, a high mortality of migrating eels due to impingement and partial passage through the screens was soon observed. Subsequent work notably by Adams and Schwevers (1997) led to present Europeans recommendation for bar spacing to be no more than 10-15 mm and approach velocities of less than 0.3 to 0.5m/s at small (<30m^3/s) power plants. For larger power schemes in Germany, predictive monitoring using an electronic early detection system for fish migration activities (MIGROMAT®), is routinely used to induce turbine shut down and spillways openings during recorded migration peaks.

Figure 9: **European eels (length 0.7 to 0.9m) passing through an intake screen grate with 20mm spacing and approach velocity of 0.9 to 1.0m/s (photo - U. Dumont)**

Records on bar rack width and eel size in New Zealand are sparse and are again limited to hydro power scheme intake structures. Boubée et al. (2001) measured the length and head width of eels collected at Aniwhenua Power station on the Rangitaiki River above the screened turbine intake (i.e. eels that have been blocked by the intake screens). The screens at this power station had a relatively narrow bar spacing at 30 mm.

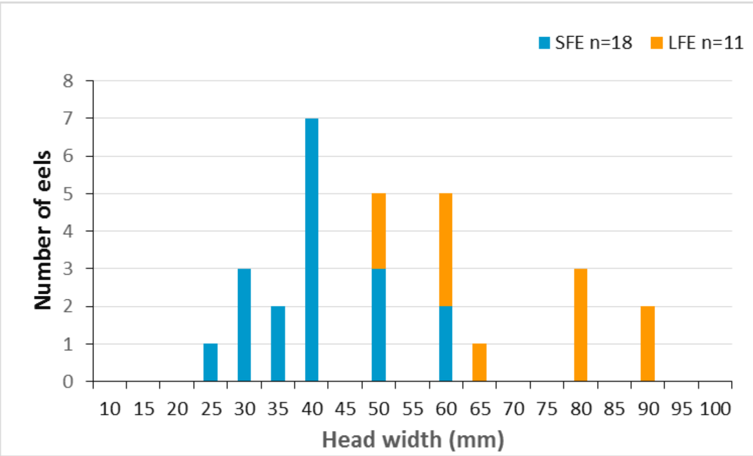


Figure 10: **Size distribution of migrant eels collected from Aniwhenua Power Station in the 1990s. A head width of 25 mm equates to an eel around 0.85 m in length (so a female). (graph from Boubée et al. 2001)**

The results of this study (Figure 10) indicate that the 30mm screen has been effective in preventing larger eels (25mm head width so longer than 0.85m) from entering the turbines. Although relatively small migrants were collected, the records gave no indication if the size distribution of the eel collected is representative of the migrant population. Given that the European studies have shown that a 0.70m eel could pass through a 25mm gap it is highly likely that a large proportion of "smaller" migrants (i.e. males) were able to pass through the 30 mm screens at Aniwhenua Power Station.

Studies at Mokauiti and Wairere Falls power stations where screens with 30 mm gap are also present, indicated that eels over 1 m long could pass through these relatively narrow intake screens (Boubée 2001). The likely cause for this is that over time, screens become damaged by debris and bars are often pushed apart by debris resulting in screen gaps wider than those nominally installed.

Data collected from the Rangitaiki River by Boubee (2001) were used to compare eel length against head diameter for a number of shortfin and longfin downstream migrant eels (Figure 11). This data shows that, at a minimum, migrant eels of up to one meter should be able to pass through a screen with 50 mm bar spacing. However, it is likely that downstream eels considerably longer than one meter would also be able to pass through a 50 mm screen given their ability to squeeze through gaps much smaller than their head widths

(Adams and Schwevers 1997). It should be noted that the size distribution of migrant eels collected by Boubee (2001) is likely to be quite different to that collected in the lower reaches of catchments where pump infrastructure is typically present. For example male shortfin migrant eels with head diameters of as small as 10 mm have been observed in the lower Waikato River catchment (J. Boubee pers. obs.)

This data indicates that screens with a 50 mm bar spacing are sub-optimal both in terms of their ability to exclude small migrant eels from unsafe outlet routes (e.g. traditional axial pumps) or their ability to allow very large eels to utilise safe outlet routes (e.g. fish friendly pumps and gravity outlets). Further work is needed to determine optimal screen designs including gaining a better understanding of the relationship between bar spacings and the size of eels that they will pass and also the proportion of migrant eels that will be excluded by a given bar spacing.

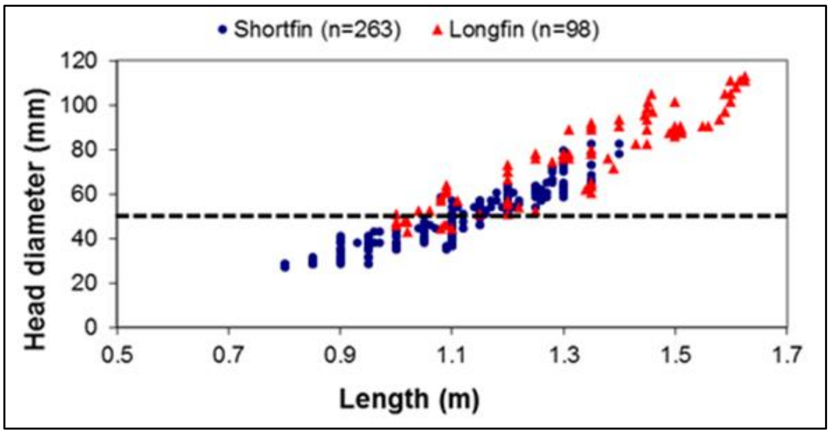


Figure 11: Eel length vs head width – Rangitaiki River (graph from Boubée et al. 2001)

Overall, based upon the currently available information, for a screen/bar rack to be effective in preventing downstream migrant eels from the entering pump intakes, it is considered that the European screening criteria of 10-15mm bar spacings would need to be adopted. While no specific information has been found in relation to screening of other native fish species, even smaller bar spacings would be required to exclude smaller native species from pump intakes.

It is acknowledged that this recommendation would inevitably result in functional and operational issues for flood pump operations through both reduced hydraulic efficiencies and increased maintenance requirements which are both items that need to be carefully considered prior to installing smaller grade screens.

Methods for managing potential debris blockages on smaller grade screens may include increased channel maintenance to remove prolific weed growth within drainage channels (Figure 12). While these activities are themselves acknowledged as creating their own potential environment effects (e.g. increase sediment resuspension, direct fish mortality, habitat disturbance), less invasive methods such as channel shading with riparian planting, herbicide spraying, lower impact weed removal machinery or use of grass carp are available to minimise weed loading at pump station sites. An example of this is the Envirolands weed removal barge which operates within the Waikato region to mechanically remove invasive aquatic weeds from lakes, rivers and drainage systems while minimising bed disturbance effects. (Figure 13). However, these activities will still need to be balanced with the aquatic habitat benefits provided by maintaining some plant cover and habitat variability within catchment watercourses, as complete removal of channel materials has the potential to be counterintuitive to enhancing native fish populations.

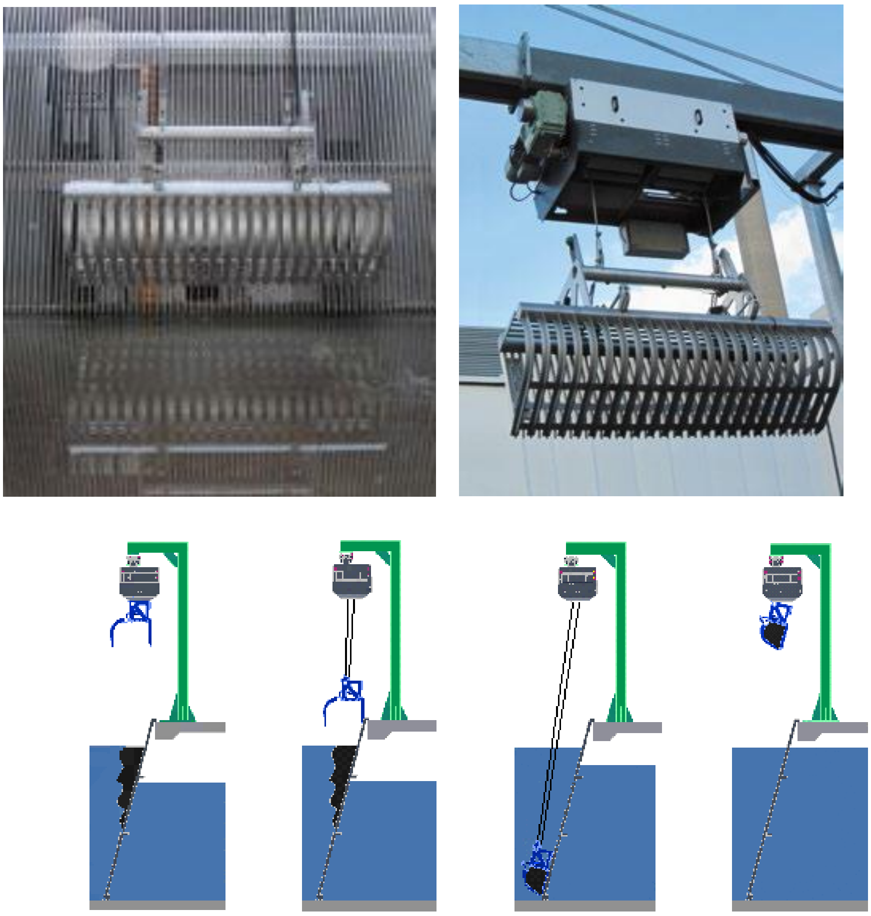
Figure 12: Prolific weed growth in drainage channel directly above pump station requiring mechanical removal (photo – WRC)

Figure 13: Envirolands Weed Removal Barge (photo provided by Envirolands).

Even with enhanced channel maintenance methods, reduced screen spacings are still likely require increased screen maintenance to routinely remove debris and blockages from the narrow bar racks. To date, screen maintenance on pump stations is normally undertaken manually, typically using hand held rakes or with excavators where larger debris loads are present. With an increased potential for debris blockage, the smaller grade screens will invariably necessitate the installation of automated screen cleaner devices.

Such screen cleaners are in common use at hydro power stations within New Zealand and vary in size and type. Where only trash is to be catered for, claw type screen cleaners are recommended (Figures 14-19). Where weed rafts are a problem, even with an automated screen cleaner installed, it may still be necessary to install diversion booms or bollards.

Figures: 14 – 16: (<u>Top</u>) Rotary screen cleaner Piripaua Power Station intake (Waikaremoana Power Scheme). (<u>Bottom</u>) Grab screen cleaner, Wairere Fall Power Station Mokau River. (Screen cleaner originally from Karapiro Dam) (photos J. Boubée, NIWA)



Figures 17-19: Geiger claw screen cleaner. (Top) close up of Claw bucket, (Bottom) operating cycle. (From http://www.water.bilfinger.com/)

The addition of an automated screen cleaner to any pump station where a small grade screen has been implemented will invariably present a significant cost to the scheme, however based upon available information this is the only available option for addressing increased debris capture at screens fine enough to exclude downstream migrant eels.

4.2.1.2 Fish Passing Debris Screens

In some instances, a screen may need to be installed at a drainage scheme outlet site to provide for safe downstream passage of fish while capturing debris which may pose a risk of blockage or damaging the system.

For these systems, a minimum bar spacing of 150 mm is recommended so as to maximise passage for the larger female longfin migrants along with all other native fish which may utilise the outlet. However maximum spacings should be carefully considered to ensure these are appropriate to control potential debris entry based upon catchment conditions (anticipated debris load and size), outlet size and the design of the pump. Where the catchment outlet comprises a fish friendly pump, it is noted that information obtained from one pump manufacturer (Bedford Pumps, UK) has indicated a maximum debris screen size of 125mm to capture debris of a size which may compromise the pump function. This screen size is considered to provide sufficient width to pass all but the very largest female longfin migrants and hence would allow for effective fish passage through the screen into the fish friendly pump. However, where smaller screen sizes are required to be installed to maintain the integrity of the pump a portion of the migrant population could be prevented from entering the fish friendly pump inlet system and without additional measures would not be able to complete their migration. Additional measures that could be contemplated in such cases could include the provision of an isolated opening towards the base of the screen to allow larger eels to pass through the screen.

Correspondence from another pump manufacturer (FishFlow Innovations, Netherlands) has indicated that given the ability of Archimedes pumps to pass relatively large pieces of debris, these pumps can often operate without the need for any debris screening although for smaller pumps a screen with 150 mm bar spacings would be recommended.

4.2.2 Rotary Screens

Rotary screens have been installed at a number of locations in New Zealand to prevent small fish from entering intakes (e.g. Huntly Power Station cooling water intake and on the Rotoaira Canal within the Tongariro Power scheme (Figures 20 and 21)).

Figures 20 & 21: The Wairehu drum screen (Tongariro Power scheme) and weed collection point where trapped migrant eels are collected. (Photos: C. Speedy, Genesis).

Whenever screens are included in the design of an intake some means of removing or bypassing fish (and debris) is always also required and in this respect, the screens at Huntly have been retrofitted to remove weed and fish automatically and transfer them downstream. The most widely used modification on conventional travelling screens or on rotating sweeping screen cleaners is the addition of fish collection buckets. Travelling screens modified in this manner are commonly termed 'Ristroph Screens' (EPRI 1986) and are popular due to their ability to be retrofitted to existing installations. The buckets are designed to retain water once they have cleared the water surface during the normal rotation of the travelling screens. The bucket holds the fish in water until the screen rises to a point where fish are spilled onto a sluice or trough for return either to the source water or downstream habitat (Figure 22).

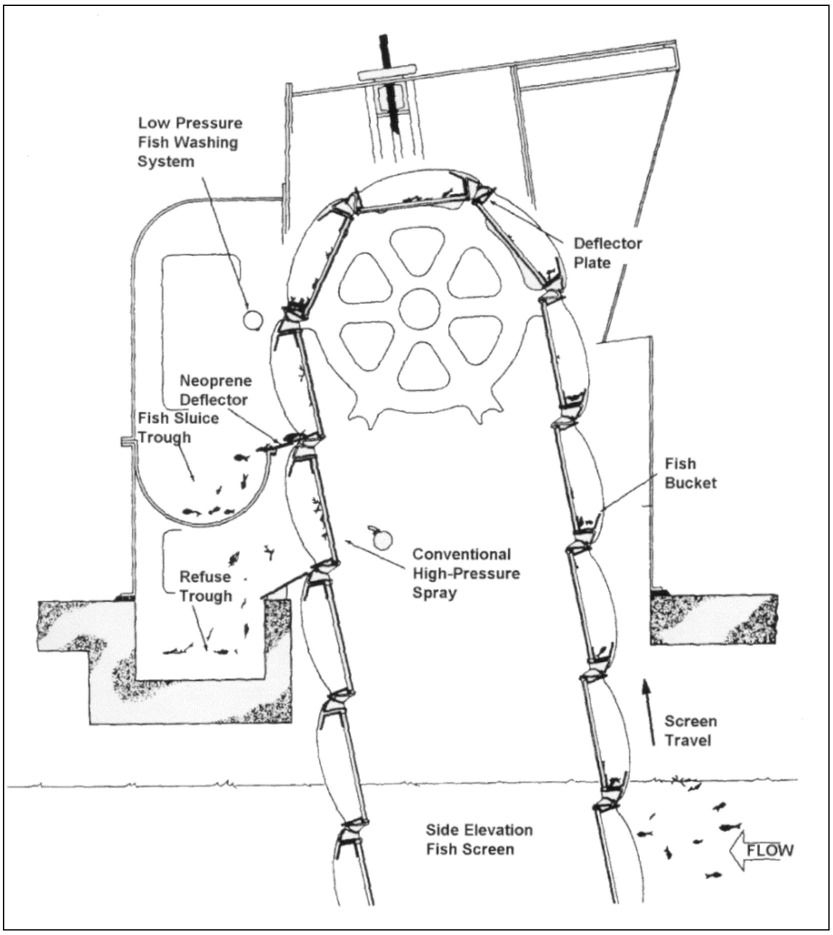


Figure 22. Section of a travelling Ristroph screen modified with fish buckets (From EPRI 1986). Note: The same concept has been used to modify travelling screen cleaners for traditional bar racks.

Rotary screens and rotating screen cleaners, while expensive to install, operate and maintain have proven to be effective on power scheme intake systems and could be used effectively at pumping stations to exclude eels and smaller native fish from pumps intakes while still providing a potential means of transferring them downstream and also managing catchment debris flows. However, the significant costs associated with these systems would need to be weighed up against other options to determine their feasibility for any site specific application.

One additional and important benefit of these automated or self-cleaning screen devices is the reduced health and safety risks for maintenance staff who have traditionally undertaken manual maintenance using rakes with at least one report of a staff member falling into the watercourse while undertaking this work.

In any case, the installation of an automated screen cleaning system or fish passing screen mechanism and its ongoing maintenance will again present a significant cost to the scheme. These costs will need to be closely assessed against potential alternative options such as the installation of a safe bypass system or fish friendly pumps to determine the best management option for the site.

4.2.3 Behavioural Deterrents

Behavioural deterrents comprise measures that are installed immediately upstream of an unsafe pump intake to impart an undesirable impulse upon a fish's senses to direct it away from an unsafe pump outlet and/or direct it toward a preferred, safe outlet system. There are a number of different behavioural deterrent options which have shown some positive results. Although successful application of these options is expected to be site specific none of these options are likely to achieve 100 percent effectiveness in deterring fish from unsafe pump outlets. Given the relatively complex nature of some of these measures they are also considered likely to present increased maintenance requirements and potential for failure. Furthermore, these measures will again always be reliant upon an alternative outlet option such as a controlled culvert, bypass channel or fish friendly pump.

4.2.3.1 Electric Screens

According to Turnpenny & O'Keffe (2005), electric screens were first developed in the 1950s by the MAFF Fisheries laboratory in the UK and several were installed but then removed over fears for their safety (see safety section below). Influencing upstream migrants with electricity is easier than influencing downstream migrants, as upstream migrants are actively choosing to move upstream and can therefore be actively discouraged from continuing on their route whereas downstream migrants move passively and may be less able to move away from the field. Nonetheless, eels, and especially large ones, are particularly sensitive to electrical fields (Richkus & Dixon 2003). Field and laboratory studies have indicated that electricity can be an effective deterrent (Hadderingh & Jansen 1990), although the results seem to be inconsistent. Gleeson (1997) designed an electrical guidance system at a small low-head dam and showed that an avoidance response occurred when the field was first charged or initially approached by an eel. However, field testing was not rigorous and therefore the success of the guidance technology in situ remains unproven.

A number of challenges need to be overcome when using electrical fields to protect fish at flood pumps. Unlike other behavioral deterrents, electricity has the potential to permanently damage and/or stun the fish upon contact. As a result, their mobility could be debilitated (Roth et al. 2004), thus culminating in the water flow drawing them further into the area they were expected to avoid. This is especially important at flood pump facilities as the intake will be in the direct path of their migration, and bypasses typically require fish to be able to actively move towards them. In flows that are within the swimming capacity of the target fish species, it may be possible to use an electrical field to deflect them towards a bypass if the fish has sufficient time to respond to the stimulus. This would mean that for flood pumps, the electrical field would have to be located some distance from the intake screen. There are also Health and Safety implications in the use of electrical fields notably when high amperage units are used and these should be carefully considered.

There are currently a number of commercially available electric screen systems available to manage fish movements within waterways. In the last two decades or so Smith-Root in the USA has developed a Graduated Field Fish Barrier (GFFB™). The system has been used to influence the direction of upstream migrants in a range of situations, such as deterring sea lampreys from accessing spawning sites (Pratt et al. 2009) and Asian Carp from advancing into Lake Michigan (Stokstad 2003). With the GFFB™ system, downstream migrating fish can be guided into a by-wash system by angling the array in relation to flow (Figure 23). This configuration could prove effective at a pump station site to guide fish towards a bypass system or a fish friendly pump.

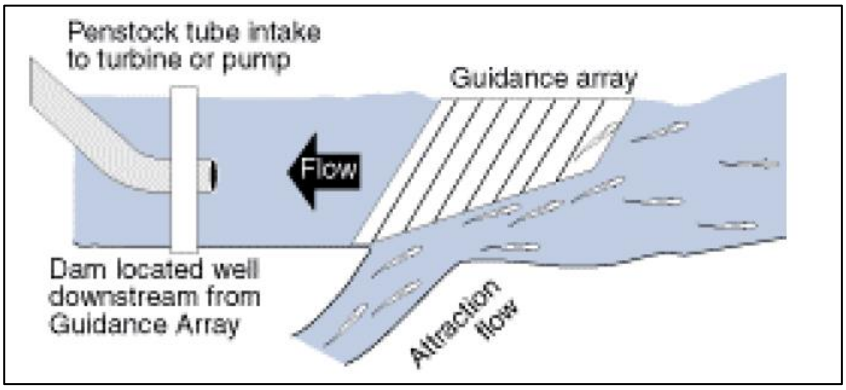
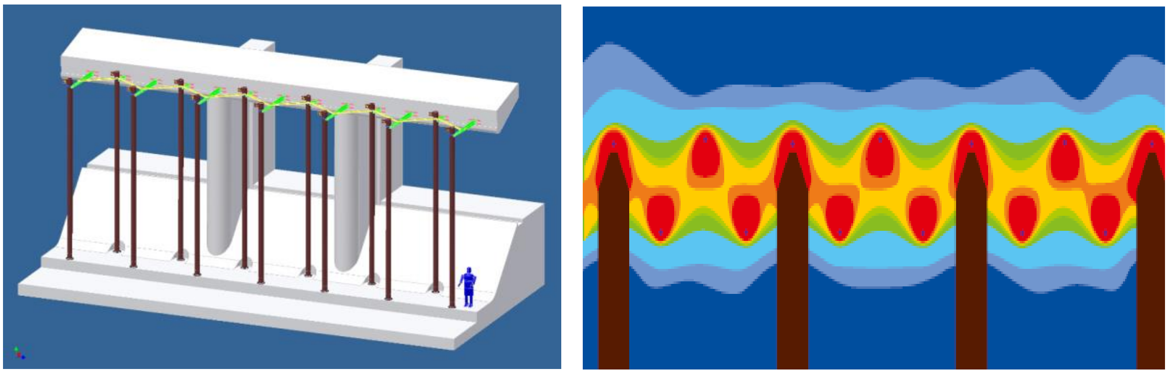


Figure 23: Diagram of the GFFB™ in use as a downstream guidance system (from www.smith –root.com in: Turnpenny & O'Keeffe 2005)

Bilfinger Water Technologies in Germany produces the GEIGER® Electric Fish Repelling System (Figures 23 & 24). The Company web site (http://www.water.bilfinger.com) states that the basic technology has been developed in cooperation with the German Federal Research Institute for Fisheries over 20 years ago. The Bilfinger system emits short polarity-changing sequences which prevent fish moving towards the anodes (galvanotaxis as used when electrofishing) and has been installed to protect water intakes at over 50 sites in Europe. Although no information on efficiency of the system is readily available the Bilfinger web sites claims that the efficiency of the system has been significantly improved by using special optimisation software which allows the system to be adapted for site conditions, target species and maintenance requirements.



Figures 24 & 25: Schematic of electric field created around probes of the GEIGER® Electric Fish Repelling System (from Bilfinger Water Technologies brochure)

Communication with Bilfinger Water Technologies indicated that it would be possible to install, a guidance system at the Motukaraka pump station to guide eels toward the Archimedes screw pump. The voltage across the series of electrodes would be around 600 V so, even though amperage is low, both people and stock would need to be kept well clear of the array. The company also offers a barrier of around 5 volts but this system is more expensive and relies on having alternative charged probes placed close together and an automated screen cleaning device installed. At time of writing no further detail of this system has been received. Either system is expected to work well on large eel but would not be 100% effective for downstream migrants. Both systems also require flows through the array to be below 0.3m/s so most likely could not be installed at pump stations where screens are currently installed i.e. directly in front of the pump bay.

There has been a number of attempts to use electric barriers in New Zealand which have typically been based upon applying a charge across the existing debris screen or using a simple wire barrier in front of the screens.

A 12 volt DC system was installed several decades ago at the Piripaua Power Station (Waikaremoana scheme) to deter eels from entering a cooling water intake located in the tailrace. A similar system was also in place on the original intake of the Wairere Falls Power Station and according to the then operators was highly successful although no data is available. The operators reported being alerted to system failure when the turbine would grind to a halt due to eel bodies wrapping themselves around the turbine blades.

As previously described, electric barrier systems have been implemented on all the pumping stations in the Bay of Plenty (Brian East, WEC and Coastline Electrical, Whakatane, pers. comm.). Although the pump operators report that since the implementation of the electric barrier they now rarely have to reverse pumps to remove eel bodies from the impeller there has been no robust monitoring of the system. The observed reduction in the incidence of eels affecting the pumps could equally have simply resulted from a decline in large eel numbers.

Nevertheless, based on the experience in the Bay of Plenty a 12V AC charge has been added across the Meremere East pump station screen within the last decade. At that location, instead of having one of the screens acting as an anode and the ground as a return, power was applied from one side of the screen array to the other with gaps between the screens panels presumably acting as insulation. Unfortunately, again the present pump operators have been unable to report if the system has been effective.

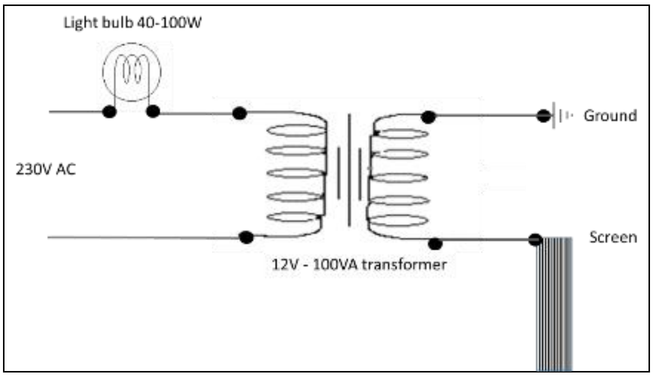


Figure 26: **Sketch of electric barrier system in use at pump stations in the Bay of Plenty. Varying the lamp size between 40 and 100 Watts will change the screen voltage with the ideal being in the range of 3-5 volts (Higher voltage will stun the eels and cause them to be drawn into the pumps.) At high barrier efficiency the lamp will hardly glow but if the screen becomes buried in silt the lamps will shine brightly but there may still be enough voltage to repulse the eels. (Derived from information provided by Brian East, WEC and Coastline Electrical, Whakatane.)**

Figures 27-29: **Photos of the electrical eel barrier installed at the Meremere pump station, Waikato. (Top left) view of pump station and screen. (Top right) Electrical connection on left of screen array which is duplicated on right. (Bottom left) Gap between the screen panels which insulated the left and right electrified screen panels (photos - J. Boubée, NIWA).**

At the time of writing, NIWA was investigating the potential for a low voltage pulsed electrical barrier to restrict migrant eel movement (the pulsing being used to give eel enhanced startling effects and also to decrease the chance of tetany). Initial studies were undertaken in an experimental flume using migrant shortfin eels. Results indicated that on nights when the barrier was energised, only 1% of active eels passed through the barrier. On nights when the barrier was not energised, 18% of active eels passed through. Despite approach velocities not being as high as could be expected in front of a drainage pump, the study indicates that electrical barriers can affect migrant eel behaviour.

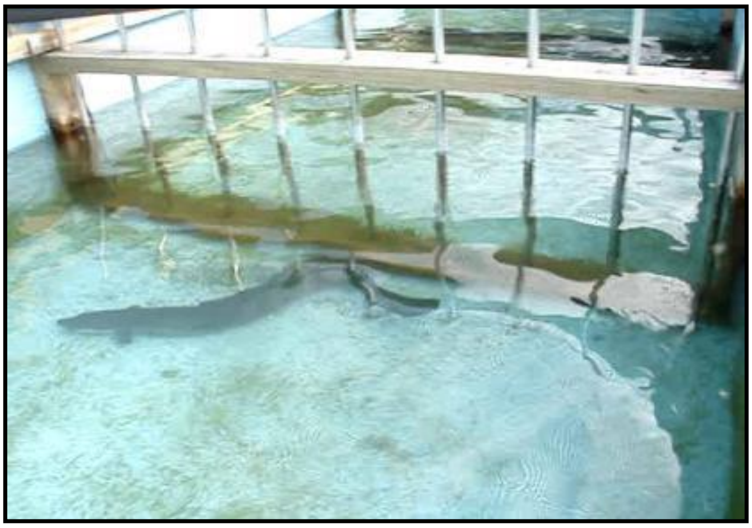


Figure 30: Eel being repelled by electric barrier in an experimental flume. (Photo: J. Boubée, NIWA)

Based on these results, field trials were implemented at the Wairua Hydro Scheme in Northland to test the effectiveness of the electric barriers in real life situations. Studies were impacted by external factors including opening of the spillway giving the tagged eels an alternative and preferred passage route, and the results were inconclusive. Further, where electrification of the debris screen was trialed, the operators have outlined that the system may have made the situation worse by possibly stunning the eels allowing them to either become trapped on the screen or pass through the screen and into the turbines. They outlined that measuring/monitoring of the strength of the electric field in the water and the polarity of the electric current were important factors dictating the success of these systems.

An electric barrier was also installed at the Mountain Rd flood pump on the Whangarei District Councils Hikurangi Flood Scheme in 2013 and was operated both that year and in 2014. Eels were tagged and monitored to identify their movements through the pump station. Although the pump station has a gravity flow tide gate culvert that operates outside of flood flows, no tagged eels were recorded as having successfully passed through the station in both 2013 or 2014 which was determined to be likely due to the charge on the screen being too high (i.e. fish were deterred from moving through either the safe culvert outlet or the pumps). In contrast in 2015 when the barrier was off, eels were recorded as passing through the station. Trials are currently in progress (Autumn 2016) with the barrier being turned on only when the pumps are operating to deter fish from entering the pumps (Figure 31).

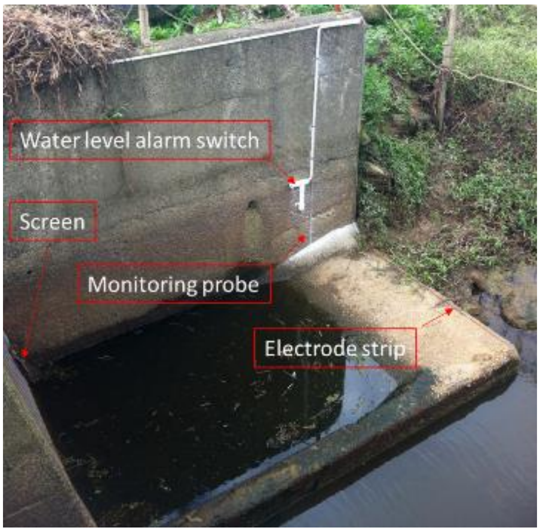


Figure 31: View of forebay - Mountain Rd pump station, Hikurangi, Northland at low flow. Voltage for the electric barrier is applied between the screen and the electrode strip that runs along the side and floor of the structure. Equipment that measure and logs the voltage between the earth strap and the monitoring probe is used to warn the operator of malfunction. At this site a water level switch has

also been added to warn the operator when a critical water levels which turn on the pumps and electric barrier are reached (photo J. Boubée, NIWA)

Finally, a similar pulsed electric barrier was installed at the Motukaraka pump station in Autumn, 2015 following the previously described eel kill incident to attempt to divert eels to the Achimedes pump system rather than through the axial pumps. No monitoring has been undertaken to confirm whether this system is effective.

Based on existing reports there appears to be merit in undertaking further investigation into the efficacy of electrical barriers to deter migrant eels. Future research must ensure that velocities within the zone in which the field is encountered remain below the velocity at which the fish can take avoidance action. The size and species of any test fish should also match that of the target species as it appears that eliciting a response in larger fish may require smaller voltage differentials compared to smaller fish (Mitchell & Boubée 1992). Some field testing should be anticipated to ensure that these design parameters are being met should these options be implemented.

One issue that has been raised by pump owners is the potential for the electric barrier to enhance corrosion of the screens. However, a system referred to as Impressed Current Cathodic Protection (ICCP) is routinely used to protect against corrosion of pipelines etc. (e.g. the pipeline that is used to load iron ore onto ships at Taharoa).

Based on our limited knowledge of ICCP it appears that applying a DC voltage on the screen as a fish deterrent also has the potential to reduce corrosion. However, wrongly applied, the opposite could occur and it is therefore strongly recommended that a corrosion expert should be consulted regarding the potential for corrosion that may result from installing an electrical fish deterrent system at any sites.

Although up to several hundred volts may be used in commercially available electric barrier/guidance system, they are designed to be non-lethal and use low frequency pulsed direct current (DC) which is recognised as being less harmful to human and fish. The purpose of the barrier is to change the behaviour of fish and not to cause galvanotaxis, tetany or anaesthesia. Typically pulse frequency and duration, as well as current are set well below the electrocution threshold for humans and hence are considered to present a low risk for electrocution. Despite these safety features both Smith Root and Bilfinger strongly recommend that the area be fenced off and well sign posted to limit public access. Health and safety requirements should be given careful consideration in any electrical screen application.

4.2.3.2 Light Barriers

It is well known that eels are nocturnal and generally inactive during daylight (Tesh 2003). The influence of light on downstream migration has been demonstrated by many authors (e.g. Lowe 1952; Hadderingh et al. 1992; Cullen & McCathry 2000). Light sources can be continuous or flashing (strobe). In theory light could be used to deflect eels from harmful and potentially lethal obstacles (e.g. flood pumps) during their downstream migration but are likely to be only effective in very clear water (Richkus 2001). Such a clear water prerequisite is unlikely at most land drainage sites within New Zealand making light an unlikely candidate as an effective behavioural avoidance system for these applications. Furthermore, the fact that lights are attractive to some fish species at low intensity but repelling at high intensity (i.e. at close proximity) renders the effect on target species and on the fish community as a whole (including the biota on which fish feed) highly uncertain (Johnson et al. 2005).

Nevertheless, the repellent effect of a continuous, submerged light screen at an illumination level of 3–5m Lux was used in an experimental situation to deflect 50–65% of migrant eels in one trial in Europe (Hadderingh et al. 1999). The same study also investigated whether the attraction stimulus from higher velocity flows (which are preferred by migrant eels, due to energy saving) was greater than the deflection stimulus by light. The results indicated that the deflection stimulus of light was stronger than the attraction of higher velocities, which is an important finding for applying this experimental data to field situations. To permit the eels to move against/out of the flow upon encountering the light screen and to orient themselves towards a bypass Hadderingh et al. 1999 suggested that it was important to keep the angle between the light screen and the flow as small as possible, recommending an angle of 25°.

There has been a number of studies completed in the last decade trying to exploit the avoidance of lights by migrant eels, the most extensive being in the St Laurence River which forms part of the border between the USA and Canada. In general, the responses of eels to light (both continuous and strobe) have tended to be inconsistent (EPRI 2008). Most significant is that the efficacy of light is strongly affected by water clarity, with turbid water being poorer at transmitting light. However there have also been suggestions that the response to strobe lighting might be improved for some species when used under conditions that enhance light scattering (EPRI 2008).

Within New Zealand, submerged lights were tested as a deterrent at Huntly Power Station but proved ineffective in part because of high maintenance cost (the cable kept getting fouled with weeds and the glass cover of the light themselves developed an envelope of algae within hours). The lights also proved to attract smelt and other fish species increasing their risk of being entrained or being predated by other fish (including eels). Currently surface lights are in use as a deterrent at the Piripaua Power Station intake on the Waikaremoana Power Scheme but although some avoidance response have been recorded, the system does not appear to provide 100% protection even in the very clear water present (Boubée et al. 2015).

The inconsistencies in experimental results suggest that light barriers are not generally suitable for use at pump stations where water tends to be turbid and tannin stained. Nevertheless, light barriers still may have some use in guiding eels toward a bypass or capture net to increase the efficiency of those devices. If light deterrence is being considered for a site, it is recommended that tests should be undertaken for at least one full migration season to ascertain whether water clarity remains at an acceptable level throughout the migration season, and also determine if the avoidance response on the target fish species remains consistent under all conditions. Effects on other fish species should also be considered.

Figure 32: Light barrier in use in the Netherlands. The lights can be lowered into the canal by reducing the tension on the support cable. (photo – J. Boubée, NIWA)

4.2.3.3 Sound Barriers

Acoustic barriers represent a potential opportunity for fish protection and guidance, as fish are known to use hearing to evaluate their surrounding environment (Fay & Popper 2000). Swimming fish naturally produce infrasound[1] and it is thought that infrasound may play an important part in predator-prey interactions (Sonny et al. 2006). The avoidance response noted with eels at some power station intakes (e.g. Watene et al. 2003)

[1] Infrasounds are acoustic signals characterised by frequencies below 20 Hz, too low for human hearing. Fish have been shown to have an acute sensitivity to infrasound (e.g., http://www.sciencedaily.com/releases/2007/05/070514154055.htm; Karlsen et al. 2004)

and with other fish at pumps in general (e.g. Week et al. 1989) may in part be the result of noise emanating from the intake.

The way in which fish respond to sound varies between species and therefore acoustic barriers may not be suitable in all circumstances. Similar to light and electric screens, acoustic barriers do not form absolute barriers to fish movement and will probably always need to be used with a secondary screen if fish are to be prevented from entering flood pumps. However, unlike screens, acoustic deterrents have comparatively minimal physical components and should in theory be less expensive and present less maintenance requirements than screens or even light barriers.

The design of sound based deterrent systems should ideally be based on the specific auditory responses of the target fish species. It is also vital to know the characteristics of any background noise at the site and to determine whether the infrastructure required to support an acoustic barrier at an appropriate distance from the intake can be engineered (silt, algae and water plants are known to absorb sound). Water velocities at the distance that the fish first encounters the acoustic barrier should be within the swimming ability of the fish, to permit the fish to change direction if required.

Infrasound has been used to divert migrant European eels successfully under field conditions (Sand et al. 2000). These authors observed a reduction of 43% in the number of eels entering parts of a river section that were subject to infrasound, whilst an increase of 44–52% was recorded in the adjacent areas that were not influenced by infrasound. However, other studies have produced variable results (EPRI 2008). An acoustic deterrent system using infrasound on the River Doel (Belgium) found that fish with a swim bladder (including eels) were more affected than those without or with small swim bladders but that there was still an overall fish impingement reduction of 59.6% (Maes et al. 2004). Infrasound modules are now commercially available but the information we have received indicate that these units are still subject to regular component failure (J. Boubée pers comm.).

Overall field experience has shown that operating sound deterrent systems on a continuous basis is expensive. Furthermore, in one trial, the device caused structural damage to a nearby building forcing the trial to be abandoned prematurely (J, Boubée, pers. obs.). Environmental conditions (both pump noise and ambient noise such as moving rocks and water turbulence) have also been shown to affect the efficacy of acoustic barriers. Future developments may see acoustic barriers being applied more successfully. However, based upon the limited currently available information and identified constraints in relation to drainage scheme deployment these measures are not considered appropriate for implementation without further field trial investigation.

Figure 33: Infrasound module (ProFish[2]). (photo – Profish)

[2] http://www.profish-technology.be/EN/societe.php

4.2.3.4 Water Jet/Bubble Curtains

Fish guidance systems that use water jets or bubble curtains have also been tested. Water jet/bubble curtains are created by pumping air through a diffuser to create a continuous curtain of bubbles (Figure 34).

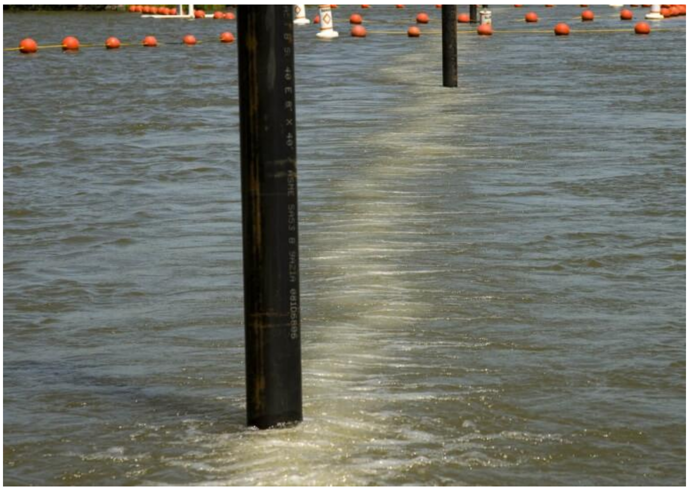


Figure 34: Bubble curtain in place to deter fish from a power plant water intake (from - www.ovivowater.com/).

Bubble curtains have been used alongside acoustic deterrents, for example in systems such as the Bio-Acoustic Fish Fence (BAFF) manufactured by Fish Guidance Systems3. In tests undertaken with Atlantic salmon smolts, Welton et al. (2002) reported that between 30–41% were deflected during daylight and 73–76% during darkness when a BAFF was used. The lower rate observed during daylight was thought to be due to the fish reacting to (and swimming through) spaces they visually identified within the bubble curtain. Background noise was low in this test environment, (which may not the case at pump installations). Furthermore, a study by Adam & Schwevers (1997) found that migrant eels readily habituated to the curtains and swam through them after an initial period of avoidance.

Use of the water jet/bubble curtains in the field has indicated that silting of the diffuser can cause a problem when the system is not in use, and it was suggested that continuous operation may be necessary in silty environments (Welton et al. 2002). Further, the integrity of the bubble curtain may not be maintained in higher velocity water, which reduces its applicability for use at high pumping rate intakes.

Overall, based on existing information, the use of water jets/bubble curtains at pumping stations is not considered practical and is not recommended for land drainage applications.

4.2.3.5 Surface Guide Walls

For fish that migrate in the surface layers, surface guide walls can be installed to guide them towards an alternative, safe catchment outlet. One example of a guide wall provided by Larinier & Travade (2002) extended vertically half way down the water column at an angle of 40º to the flow. The wall guided any fish in the top of the water column towards a bypass located on the true left of the river. A secondary bypass was also installed on the true left of the turbine screens to provide passage for any smolts that were unaffected by the guide wall. A total of 84% of smolts were deflected by the guide wall, with an additional 10% passing through the bypass. Surface guide walls may be useful for small fishes that drift passively downstream, as the walls guide them towards a bypass area. However, unless approach velocities can be kept very low, these fish run the risk of being entrained as they move unprotected past the end of the guidance wall.

[3] http://www.fish-guide.com/home.htm

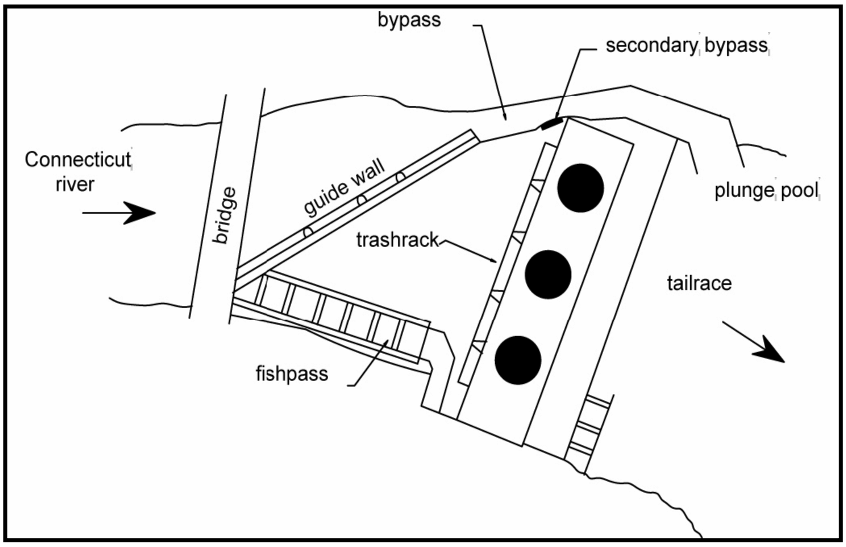


Figure 35: Guide wall at Bellows Falls power station (from Odeh & Orvis 1998).

Given that eels use the entire water column to migrate it is highly unlikely that a guide wall would be effective for eels and hence these systems would not be recommended for use in a New Zealand land drainage or flood scheme setting.

In summary, the information reviewed in relation to the various behavioral deterrent methods assessed has indicated mixed and inconclusive results in their efficacy with very limited information available regarding their use within a New Zealand setting. Furthermore, the effectiveness of these measures is likely to vary significantly between locations with numerous factors likely to effect their function and maintenance requirements. Nonetheless, it is recommended that the field trials instigated by NIWA into electrical barriers should be continued to determine whether these methods show any further potential within the New Zealand land drainage setting.

4.3 Fish Friendly Pumps

Table 1 of this report indicates that while large diameter traditional axial/impeller type pumps may be able to successfully pass eels unharmed, the small/medium diameter traditional style pumps as utilised in the Waikato Region (average pump diameters in the range of 0.75m – 0.9m), are likely to be resulting in the mortality of a large proportion of eels that pass through these systems. In addition to the pump diameter, blade shape, blade number and rotation speed are all considered to be factors that will influence the fish mortality/injury effects of the system. It should also be acknowledged that it is not only the pump itself which could be causing these effects. Anecdotal reports of fish mortality/injury occurring as fish are discharged from the pump through pipe outlet structures or onto concrete aprons at high velocity have been reported (Nicola Baker, Leeds University, pers. obs.). In effect when assessing pump impacts on fish, it is important to not only consider pump blade impacts, but the potential effects of the pump station as a whole.

A number of alternative pumping systems to the traditional axial flow/impeller driven pump systems commonly found on New Zealand schemes are now available. Some of these pumps provide a reduced risk for fish injury/mortality during operation and include a modified version of the Archimedes screw pump along with a number of alternative/modified impeller driven pumping systems which have been specifically designed to pass fish unharmed. Installation of a new pumping system designed to pass fish safely will involve a significant capital cost for a scheme and hence is only currently likely to occur where either existing pumps are due to be upgraded or where existing pumps are known or are likely to be causing major fish migration/mortality effects.

A key aspect of any pump design/installation is its ability to pass the sufficient catchment flows to achieve the design level of service. In this respect the capacity of any fish friendly pump design will require careful consideration to ensure that the design water level management pumping capacities can still be achieved while providing a ‘fish friendly’ catchment outlet system for migrants. Again, this may often determine the need for a fish friendly pump to be implemented in conjunction with other management systems including existing axial flow pumps to maintain the design level of service along with barrier/deterrent measures (e.g. narrow bar racks, electric barriers) to ensure that fish are diverted away from the axial pumps to the fish friendly pump outlet.

The following sections identify the main types of fish friendly pumps and assesses the appropriateness/effectiveness of each option for improving fish passage through land drainage infrastructure.

4.3.1 Archimedes Screw Pumps

Archimedes screw pumps have been in usage for centuries because of their ability to transfer large volumes of water over significant vertical distances. Capacity of screw pumps can vary from 10 to 11,500 l/s and can lift water from 0 to 25 m. Angle of the screw set up normally varies between 30° and 38°. Traditional screw pump design typically comprises either a coated steel or stainless steel screw fitted within either an open steel or concrete trough within which the screw rotates.

The design of the screw pump also allows for the passage of large debris through the pump with reports of even a dead cow being conveyed via a large screw pump within the Waikato. Consequently, the screw pumps are also considered able to pass fish with an assumed reduced risk of injury or mortality. However, some risk for injury or mortality of fish likely remains with Fishflow Innovations and others describing the premium cause for damage being that fish are hit by the leading edge of the screw and a secondary cause that fish get stuck between the screw and the trough within which the screw sits/rotates (e.g. http://fishflowinnovations.nl/en). Furthermore, it should be noted that the significant turbulence and noise created by the pump especially in its traditional open design is still likely to provide a deterrent to fish entering the pump and could result in significant delays in migration.

Buysse et al. (2014) assessed the mortality rate of eels of European Eel in Belgium passing through three traditional style screw pumps comprising one small (1.6 m^3/s, 25 rpm, 4.67 m long, outer diam. 2 m, core diam. 1.016, flight height 1.016 m) and two large (3.6 m^3/s, 21 rpm, 5.34 m long, outer diam. 3 m, core diam. 1.52 m, flight height 0.74 m) three flight Archimedes screw pumps with a designed gap between the base and the blades of 30mm. Maximum head was 0.57 m. The study was undertaken during the eel migration period with fyke nets attached at the pump station outlet to capture eels passed by the pumps (Figure 36). During the study the small pump passed 47 eels (length range 392-831 mm), and the large pumps 125 eels (370-936 mm). Most of the eels were females. Mortality rate was 17 % and 19 % respectively for the small and large pumps. Although these mortality rates at first glance are small, in systems where more than one pumping station is operating in series the cumulative effect could be significant and unsustainable.

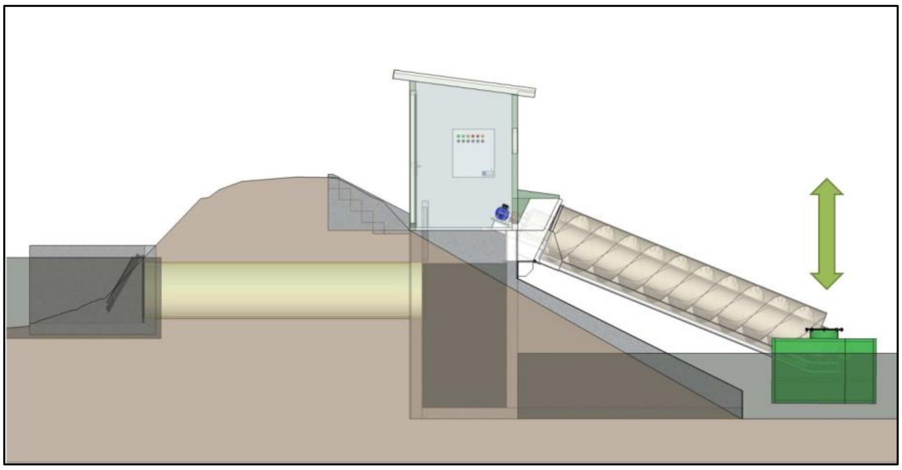
Figure 36: Fyke nets installed on the pump outlets to capture eels passed by the Archimedes screw pumps at the Buyse et al. 2014 study site. Note the pump set up appears to comprise five adjacent screw pumps (3 large/2 small) housed within the pump house pictured (photo – Google Earth).

Adaptation of traditional screw pump design undertaken in Europe to improve their fish friendliness, has included modification of the leading edge of the blades and housing the blades within a shell that rotates with the screw as shown in Figures 35 and 36. An independent assessment undertaken by VisAdvies B.V of the Fishflow Innovations modified screw pump design is described as passing 23 European eels of 55 – 83 cm in length with all eels passing undamaged. The test results also identified these pumps as being 100% effective at passing European coarse fish (perch, roach, bream, ruffe, pike) of lengths ranging from 100 mm up to 440 mm unharmed *(*Vriese 2009*).*

Correspondence with FishFlow Innovations has outlined a guarantee for safe passage of 95% of all eels using the pump (the 5% damage being attributed to fish handling issues during field tests rather than pump damage). They also attested to these modified screw pumps as being considerably quieter (so less likely to produce an avoidance response than other type of pumps) and more energy efficient than the traditional screw pump design.

One constraint with traditional fixed screw pumps comprises their limited ability to operate over a range of water levels. However, this issue has been addressed through the ability to vary the speed and power applied to the screw and also more recently by positioning the base of the screw on a float that rises and falls with variations in water levels.

Another important aspect identified in relation to the upgraded Archimedes screw pump design is the potential for existing screw pumps to be able to be modified through implementing the above design measures to make them more fish friendly.



Figures 37 and 38: **Example of screw pumps with shroud around the blades, modified screw intake and floating intake. (from FishFlow Innovations, Holland).**

4.3.2 Hidrostal Pumps

Hidrostal pumps can be broadly described as a combination between a screw and impeller type pumps and have typically been used in applications requiring pumping of liquids containing high levels of solids or viscous materials. They are also commonly used to move fish catches within and off commercial trawlers. Consequently, these pumps are considered to provide a fish friendly option to standard impeller pumps.

Patrick and Sim (1985) contemplated using Hidrostal pumps to transfer live eels over an in-stream barrier with several metres of head. In their laboratory investigation they passed 975 live eels (300-500mm) through a 10 hp Hidrostal pump operating at 400-1200 rpm at a head of 1.4m. The intake pipe had a diameter of 150 mm and the outlet pipe 250 mm. Total mortality after 48 h was less than 3% and this did not change with impeller speed. However high avoidance of the intake pipe was observed most likely because of noise/vibration.

Further tests were made in a subsequent experiment with a 56 KW motor at a rotation speed of 1200 rpm, head of 6.5 m and discharge of 176 l/s (Patrick and McKinley 1987). A total of 2,300 eel ranging in size from 270 to 520 mm were passed through the pump and no latent death was recorded. However, again, the authors stressed that eels were likely to avoid such an intake because of noise/vibrations and that a means of attracting or crowding them towards the intake would need to be devised.

More recently, Pentair, a branch of Fairbanks Nijhuis, in co-operation with Fishflow Innovations has produced a patented fish friendly Hidrostal pump (often referred to in the UK as Bedford pumps – Figure 39) which was tested by VisAdvies in 2011 (Spierts & Vis 2012). At low rotation speed, negligible mortality and little injury was recorded but most of the eels used in the test were less than 600mm and although a couple of eels in the 700 and 800 mm range were part of the experiment the report does not comment on survival/injury of these larger specimens. At higher rotation speed (518 rpm and 2.3 m^3/s capacity) mortality of eels did increase slightly but was still below 8%. The test results also identified these pumps as being 97% effective at passing European coarse fish (perch, roach and bream) of lengths ranging from 170 mm up to 500 mm unharmed.

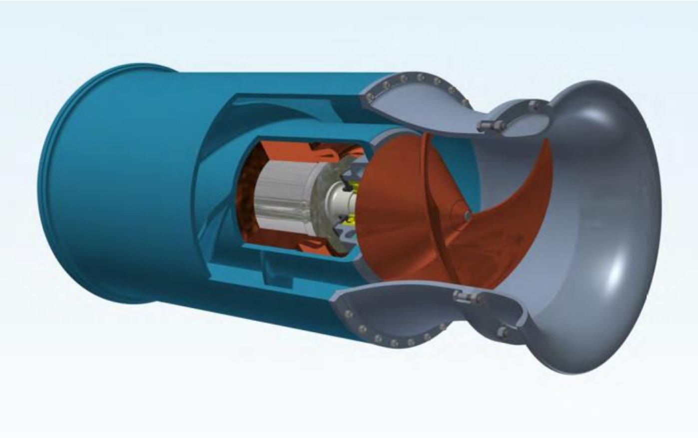


Figure 39: Bedford Pumps' Fish Friendly pumps (from - *www.fishfriendlypumps.co.uk/*)

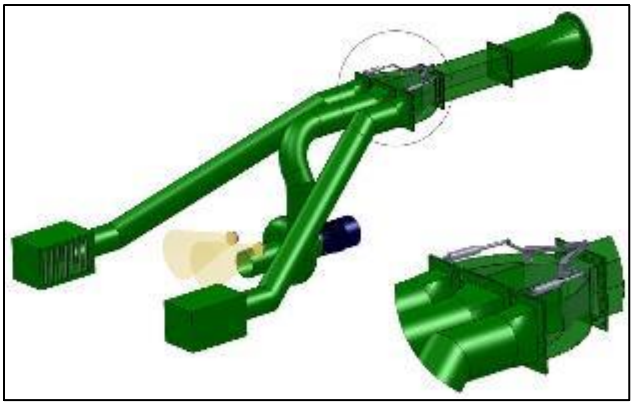
Results of other studies (e.g. Pentair 2013, www.fairbanksnijhuis.com) undertaken for other manufacturers/distributors have also indicated no immediate or delayed (24 hrs) fish death attributable to Hidrostal pumps. However, it should be noted that in all of the test cases described, the species targeted comprise European eel of average length 540mm and up to 780mm maximum only, so considerably smaller than the average migrating longfin female in New Zealand (but about the same size as male shortfins which dominate in lowland catchments). The low speed (and low head) at which most of these tests were undertaken also gives no indication of the impact on eel at maximum pump capacity.

From the information available it appears that the Hidrostal pumps are able to successfully pass small to medium sized eels under the low speed operating conditions tested (Fish & Vriese 2011). However, the effectiveness of the Hidrostal fish friendly pumps remains unknown for the New Zealand field conditions and it is recommended that a repeat of the test using large eels (660-1200mm) and with pumps running at design capacities, be undertaken to better replicate New Zealand field conditions and confirm their effectiveness in this setting.

4.3.3 Venturi Pumps

Venturi pumps comprise a central main pumping inlet which passes pumped water through a narrow aperture into a discharge chamber where a vacuum develops (i.e. the venturi effect). The vacuum then induces a water flow in two side-channels that are connected on the side of the discharge chamber behind the narrow aperture.

The system requires deterrent measures to be implemented on the main pumping inlet (usually an existing pump that continues to pump most of the flow) to prevent fish from entering this inlet (screens or even behavioural deterrents such as strobe lights are used in European examples). The intention is that the fish will then be attracted by the flows through the side vacuum inlets comprising dark and quiet inlet channels on the side of the channel (best located just upstream of the screens) allowing fish to pass unimpeded through these systems.



Figures 40 & 41: Venturi pump concept and actual pump produced by Fishflow Innovation. The main pump can be an existing one thus increasing the pumping capacity of the station. The intake to the pump needs to be protected by fine screens or other proven fish exclusion device. (from - http://fishflowinnovations.nl/en)

FishFlow Innovations have installed Venturi pumps at a number of pumping stations in the Netherlands, apparently with some success with the FishFlow innovations web site referring to monitoring undertaken on a pump station installation in the Netherlands. The monitoring indicated that with the use of both a strobe light deterrent and bypass channels the pumping station is 100 % fish friendly and large numbers of coarse fish and eels pass safely via the "fishway".

While there is limited information available in relation to fish passage through Venturi pumps, an initial assessment indicates that they are likely to present a reasonably complex and expensive system for retrofitting within an existing pump station scenario requiring multiple pump intake points. Furthermore, the fish passage system is still reliant upon deterrent/exclusion measures at the main pump intake to prevent fish entry because the Venturi pump is not designed to pump high volumes of water. Based upon these characteristics, the Venturi pump systems are not recommended at this point for trial within the land drainage setting within New Zealand.

4.3.1 Experience with Fish Friendly Pumps

4.3.1.1 Netherlands

The following comments were received from Wabe Jager of Landustrie Sneek BV – a European water and wastewater management company, which describes the situation of fish friendly pump installations in the Netherlands:

'In the Netherlands about half the rain water that falls has to be pumped out otherwise most of the country would be under water. In former days, there were screw pumps as well as large and slow rotating (c. 300rpm) open axial flow pumps in place. These were not really fish friendly, but at least the fish had fair chance of either getting through the pump or getting away from it because of low flow velocities. Later the cheaper, high speed axial flow pumps became popular, leaving fish no chance at all. Currently things are changing with emphasis on measurable fish friendliness. In this respect the Archimedean screw pump and Hidrostatal pumps are unquestionably the most fish friendly even in its basic forms.

With both the Hidostatal and Archimedian pumps, probably the most dangerous area for fish lies at the leading edge of the screw. This Landustrie [and others] have adapted, so that the starts of the flights are rounded off and have been shaped to minimise strike injuries (Figure 42). A cover has also been added around the blades of the screw, to prevent the fish from being squeezed between the starts of the flights and the start of the screw trough. There is also a lot of extra to gain to be made in term of fish mortality by having a smooth trough and a smart speed control of the screw.'

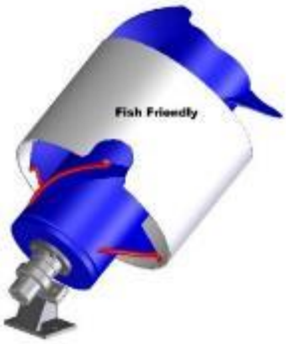


Figure 42: **Modification of leading edge of flight to reduce strike impacts on fish. (From Wabe Jager, pers. comm.)**

4.3.1.2 United Kingdom

Most pumping stations have axial flow pumps which, apart from the very large ones, have been shown to be highly dangerous for eels (Solomon & Wright 2012).

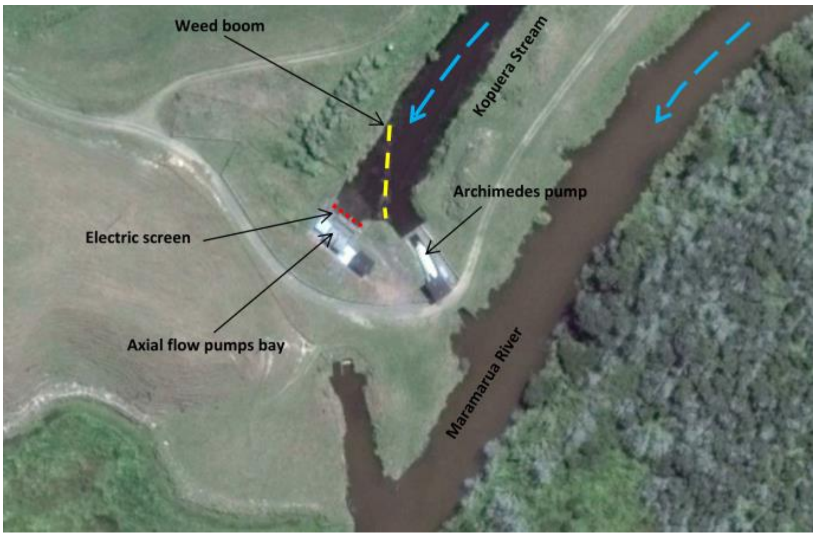
Replacement of some of the axial pumps with fish friendly pumps is under consideration with only one so far installed in the Anglia Region. Trials undertaken with this pump have shown slightly higher mortality than reported by the manufacturer but this could possibly have been caused by the orientation of the exit pipework (Jackson undated).

A small number of the pump stations in the UK have gravity flapgate outlets but it is considered that unless 75% of the flow is passed through this route remediation would still be required (Nicola Baker, University of Hull, UK pers. comm.).

4.3.1.3 New Zealand

Within New Zealand, only two traditional style Archimedes screw pumps are known to be in operation on council operated land drainage schemes. Both pumps located within the Lower Waikato drainage scheme area with the largest of these being the previously described Motukaraka pump station as shown in Figure 43.

While these systems have previously been accepted by the Waikato Regional Council's regulatory directorate as providing a means for fish passage out of the catchment, no research has been undertaken into the efficiency of these systems to safely pass native fish within New Zealand.



Figures 43: Motukaraka Pump Station Configuration and Archimedes Screw Pump (photos and graphics – R. Duirs, BBO)

4.3.2 Fish Friendly Pumps Summary

Overall, the implementation fish friendly pumps (Archimedes or Hidrostal) is considered to present one of the few practical available options for addressing downstream fish migration at pumping stations where no other safe downstream pathway is provided. Based upon the available information, these systems are considered to provide a significantly reduced level of mortality than the traditional axial flow pumps and have been adopted in Europe to address fish passage issues for both eels and coarse fish. On the basis that the upgraded Archimedes screw pumps are reputed to be quieter, and are able to pass large objects with either no screening or only coarse screening requirements (nominal 150 mm) they are considered to present the best option for providing safe downstream passage for large eels at drainage scheme pump stations. However, a level of uncertainty still remains in regard to the ability of these pumps to pass large longfins unharmed and under all site specific pumping conditions within the New Zealand land drainage setting. The results outlined in relation to the efficiency of these pumps to pass European coarse fish would suggest that implementation of these systems are also likely to be beneficial in enhancing downstream passage for New Zealand's smaller migratory species (e.g. galaxids).

The WRC are currently considering the implementation of a fish friendly pump on one of their schemes within the lower Waikato (Orchard Road pump station) which if it proceeds, is understood to comprise the first specifically designed fish friendly pump installation on a land drainage scheme within New Zealand. WRC have been considering a number of fish friendly pump alternatives including the modified Archimedes screw pumps and various Hidrostal pump designs. The Archimedes pump design option was discounted early in the assessment process based upon perceived greater power demand and potential higher mechanical/maintenance requirements. Two Hidrostal pump designs are now being considered with the preferred options for consideration outlined in **Appendix D**.

It should be noted that at present, suppliers of fish friendly pumps are limited to northern hemisphere based manufacturers which presents potential issues in regard to the ongoing maintenance and supply of parts/follow up service for these systems, particularly when repairs may be required at short notice to meet the required catchment levels of service.

4.4 Bypass Routes

A priority of a surface bypass is to convey fish safely to the pump tailrace (or to whatever device is available to transfer them further downstream) and deliver them in a condition that ensures survival (Schilt 2007).

The majority of the international scientific literature is focused on the downstream migration and facilitation of passage through bypasses for migratory salmonids, while in New Zealand much of the research conducted to date has been focused on downstream migrating eels. There are, however, factors which are common to all migrant fish species that need to be taken into account when designing bypass routes that facilitate downstream passage. The first of these is that there are likely to be a large number of migrants of a particular species that will require passage at any one time. As mentioned previously, there is also a tendency for downstream migrants to move passively with the flow. This indicates that the risk of fish entrainment at intakes increases as the proportion of river flow abstracted increases. For a bypass to be effective, a substantial portion of the flow should be diverted through the bypass, and in situations where there is no effective barrier at the intake, between 5–50% of the flow should be diverted through the bypass (Solomon & Beach 2004).

Surface migrating fish will generally find a surface bypass on their own accord when turbine or pump intakes are deeply submerged (Larinier & Travade 2002). However, in other situations a method of directing fish towards a bypass may be necessary. As discussed in Section 4.2, there are a number of options available to discourage fish from entering intakes, some of which could be used to encourage fish to move towards a bypass entrance. The bypass entrance should be positioned at a place where it has been proven that fish have been (or can be) guided to. In most situations this will be at the most downstream point of the physical or behavioural barrier but some studies of telemetered eels have also demonstrated that eels may return upstream once encountering a barrier and therefore there are opportunities to place bypasses some distance upstream of the dam/stopbank structure (Durif et al. 2003, Watene et al 2003). Areas where recirculation occurs (e.g. eddies adjacent to trash screens) are ideal as this is generally where fish will tend to congregate (Larinier & Travade 2002).

The hydraulic conditions at the bypass entrance should be suited to the fish species expected to use the bypass. Fish sensitive to velocity gradients may not enter a bypass if there is a sudden change in velocity, and generally a graduated change in velocity is preferable. However, for migrant eels, it is preferable that the water velocity at the bypass entrance is above ambient velocity (Hadderingh et al. 1999).

4.4.1 Surface vs. Bottom Bypasses

Surface bypasses function by permitting fish in the surface layers of the water to pass into the tailrace through a bypass channel. They operate by attracting fish to a collection area, from where they are encouraged to enter a conveyance pipe or chute which will move them downstream or into a collection and transfer device (e.g. a pump).

Studies at Wairere Falls Power Station have shown that migrant eels found and used two 100mm diameter surface bypass holes drilled side by side in the dam wall, approximately 1m below the water surface, to pass downstream (Boubée & Williams 2006). The position of a bypass entrance may not therefore be important although for eels it is generally accepted that a bottom entrance is preferable.

Within a land drainage setting, a bypass system is most likely to comprise a gravity flow piped outlet as an alternative to passage through the flood pumps. In this respect, it is assumed that based upon maximising flow efficiencies and minimising pumping operations, most scheme sites where a piped gravity outlet is able to be implemented will likely already have these measures in place. Nonetheless, where they are not present, consideration should be given to whether it is practical to install a gravity bypass system at the site.

Again, a bypass outlet at a pump station site will be reliant upon the implementation of appropriate screen/deterrent systems to both prevent fish entering the axial flow pump intake and to prevent debris blocking the bypass inlet as discussed in the previous sections. The bypass should be sized to convey as much of the channel flow as possible to maximise the potential for fish to move directly towards the bypass inlet. Given the likelihood that the bypass outlet will incorporate a flap gate control, it is likely that the bypass will be closed off over the peak of the flood cycle and hence it is important that the bypass inlet is positioned where it can be easily located by migrants once the flood waters subside and the flap gate opens allowing catchment flows to exit via the gravity system.

4.5 Flood and Tide Gates

At some pump stations, gravity fed flap gates are already in position or may be able to be installed where outside of flood times, downstream levels are lower than upstream levels. These flap gates when open during low level downstream conditions can provide free upstream and downstream passage for fish and as described in the Kurere Stream study undertaken by ICM and NIWA (Franklin & Hodges, 2015), these systems have been shown to maintain a certain level of access for native migrants. However observations have also shown that in many situations, even when flows are low, the gates can essentially remain shut hence still preventing fish passage. Consequently, these flap gate systems are considered to be resulting in adverse modifications to upstream habitat quality as well as restricting the movement of biota resulting in a decline in native migrant species (Franklin & Hodges 2015; Bocker 2015).

Therefore, to maximise downstream fish passage opportunities some mechanical means of maintaining flapgates open outside of flood periods is considered essential. In addition to the benefit of improving fish passage, allowing more water movement through the gates (through increasing open time) has a major influence on the quality of the upstream habitat and can reduce the amount of pest plant growth (Franklin & Hodges 2015).

Although the benefits of keeping flap gates open outside of flood periods is well established overseas, the concept is relatively new in New Zealand. Manual lifting of flood gates has been trialled in the Bay of Plenty, in the Hauraki Plains and on the Hikurangi Swamp in Northland.

In more recent times attempts have also been made to keep flap gates open for extended periods by retrofitting existing flap gates with fish friendly gate systems (FFGs). A number of FFG design options are available on the market which generally work by maximising the opening time of the gate across the tidal or flood water cycle and ensuring the gate returns to a full open position once downstream water levels recede.

ATS Environmental (http://www.ats-environmental.com/) is a New Zealand based manufacturer of FFGs that operate based upon a specifically designed mechanism which utilises a tensioned counter weight system. The system can be adjusted to change the water level/duration over which the gate will remain open thus allowing for maximisation of the time fish have to enter/exit a catchment. These systems can be provided either as a full new flap gate unit or retrofitted onto existing gates. Bocker (2015) investigated four sites in the Bay of Plenty where one or more existing flap gates had been retrofitted with FFGs produced by ATS Environmental. The study indicated that the FFGs increased the duration and distance over which the flap gates were opened across the tidal cycle and either enabled or increased upstream fish passage for a number of native fish species.

One of the many alternatives to the locally produced FFG is the self-regulating tide gate (SRT) such as those produced by Waterman Industries (http://watermanusa.wpengine.com/wp-content/uploads/2016/05/Self-Regulating-Tide-Gates-Spec-Sheet.pdf). These gates utilise an adjustable float system to again change the water level/duration over which the gate will remain open thus enabling maximisation of the ability for fish to move into/out of a catchment on the incoming/outgoing tide or flood water conditions (Figure 44). These gates, although considerably more expensive than the locally produced model, have a proven record in both North America and Europe.

Figure 44. Installation of a Waterman self regulating tide gate in the USA. These gates close at pre-set level maximising fish passage while maintaining flooding security. (from http://watermanusa.com).

Another alternative to this self-regulating tide gate design comprises a guillotine style, side swinging gate again controlled by a float system which controls the duration over which the gate remains open over the tidal cycle to maximize fish passage into and out of the catchment (Figure 45). A trial of this type of system undertaken by the Environment Agency in the UK concluded that it was an effective method for managing land drainage in an estuarine environment while also achieving enhanced fish passage benefits (Ridgway &Williams 2011).

Figure 45. Guillotine style self-regulating floodgate (photo: Ridgeway & Williams 2011)

Within the New Zealand setting, the replacement of existing, traditional style floodgates with fish friendly gates appears to present an effective means to enhancing upstream fish migration ability although there is limited current data available to confirm these benefits. Consultation with other Regional Councils has indicated a number of locations where FFGs have recently been installed and are currently being trialed (refer sections 2.5.3 and 2.5.6). NIWA are also currently implementing a trial study into the effects of an FFG on the Lower Waikato catchment. An initial concern raised by landowners in regard to this trial site was the potential for the invasive alligator weed species to enter the catchment as a result of extending periods when the gate is open. Weed booms are currently being investigated as a means of managing this risk.

Based on the available information, it is recommended that the installation of FFGs be considered and progressed on a priority catchment basis after careful consideration of physical catchment characteristics and any biosecurity risks to ensure long term function of the remedial action taken and achieve the desired upstream fish passage benefits.

Where FFG's may not be able to be implemented, consideration should be given to alternative management options which may be able to be employed to maximise the potential for fish to access the upstream catchment. This may include measures to maintain the gates in a semi open position during low risk flood periods with options described already being implemented within New Zealand including:

- Installation of a spacer board behind the gate to allow for a small gap between the gate and the headwall thus maintaining some level of access across all conditions; and
- Installation of winch units on gates to allow for manual opening of gates and maintaining gates in an open position for extended periods (Figure 46).
- Installation of a spring system to maintain the gate open at low downstream water levels.

Figure 46. Flapgate winched to open position outside of flow periods to maximise opening for gravity flows and fish passage (photo: J. Boubée - Niwa)

In addition, the WRC's Te Onetea Stream floodgate within the Lower Waikato catchment has been identified as being fitted with an automated, telemetered floodgate system which opens/closes based upon preset water level triggers measured by an electronic sensor system. In addition, the telemetry system allows for remote opening and closing of the gate in response to water level changes within the catchment. Such a system allows for ease of maintaining the gate in an open position outside of peak flood risk periods thus increasing the potential for upstream and downstream fish passage under the majority of flow conditions.

4.6 Upstream Passage

There is considered to be little point in addressing downstream fish passage issues for a species if there are existing constraints to upstream passage which are restricting or limiting fish populations within a catchment. In this respect, both upstream and downstream passage issues should be considered in combination during the catchment prioritisation phase to help determine the extent of the catchment fish passage issues as a whole (upstream and downstream) and appropriate remedial measures within any catchment.

An additional consideration is that in some instances it may be ecologically undesirable to provide upstream passage. For example, one study described during consultation with Greater Wellington Regional Council noted that drains where passage of eels was likely restricted due to drainage scheme infrastructure, were found to hold moderate numbers of the threatened brown mudfish which may have been due to reduced predatory effects of eels within this catchment (refer section 2.5).

Furthermore, improving or extending the duration of catchment connections may also create increased biosecurity risks through increasing the potential for an undesirable pest species (fish or plant) to migrate into a new catchment where it doesn't currently exist and where it poses a threat to the new catchment.
These are factors that should also be taken into consideration when prioritising catchments for upstream fish passage improvements.

4.6.1 Culvert Outlets

A key consideration in relation to upstream passage through controlled culverts is the ability of fish to move into and up through the culvert pipe structure under various flow conditions. In this respect, installation of a fish friendly gate would be rendered redundant if fish are not able to navigate the pipe structure directly upstream of the gate.

Passage into a culvert will be impeded if the lip of the culvert is perched above downstream water levels, either continuously or for significant periods. Passage through the culvert will be dependent on water velocity and depth and the presence of a climbing surface and/or resting areas. Elvers (juvenile eels) are reasonably good climbers so as long as a continuous climbing surface (i.e. without any break or sharp angles) is present some will be able to travel the length of the pipe on the wetted concrete margins as shown in Figure 47.

Figure 47. Elver climbing along vertical wall of a flooded stairwell Karapiro Power Station (photo - J Boubée, NIWA)

Some climbing galaxiids such as banded kokopu are also able to make use of the wetted margin to progress upstream. However, to provide better passage opportunities not only for good climbers but also non or poor climbing species like common bullies and inanga, additional measures may need to be provided on the floor and sides of the culvert. These measures may include fixing rock, substrate, baffle sheets or even multiple strands of mussel spat rope through the culvert to provide a roughened surface and/or resting areas to maximise the potential for fish to move through the culvert. In some instances, all that is required is to increase water depth at low flow (and hence also decrease water velocity) and this can be achieved by installing a low (but passable) weir at the outlet.

In addition to matters discussed above, there are two other factors which may affect upstream fish passage downstream of the culvert outlet at low flow. These include the potential for shallow, laminar flows over the concrete outlet apron and the presence of a vertical drop at the final outlet point. Potential remedial options for these situations includes installation of a low weir structure across the end of the apron to increase water depths and the use of spat ropes and/or fixed matting to provide a surface for fish to manoeuvre up the vertical drop (Figure 48). Again, these types of problems are common for all culvert outlet structures and best practice guideline publications for culvert structures should be consulted to help identify a suitable remedy.

As passage through the pipe is essentially the same as for a road culvert, the potential remedial measures are well documented and reference should be made to best practice publications such as Stevenson & Baker (2009) for retrofitting options. In any instance, it is recommended that an ecologist is employed when considering remedial options to ensure that all biological issues are considered and appropriate fish passage mechanisms through the culvert are incorporated.

**Figure 48. Modification of the Te Mata Pump Station outlet, Hikurangi Flood Scheme.
(photo - from presentation to stakeholders by Adam Twose, Whangarei District Council)**

4.6.2 Fish Passes

Where gravity flow through a culvert bypass system is not available for provision of upstream passage into the catchment, formation of an alternative upstream fish pass system may be necessary. At land drainage sites, the fish pass would typically need to be formed via a fish ramp/channel over or through the stopbank structure and will be reliant upon the supply of a flow of water to the top of the pass. This flow is necessary to both attract fish up the pass and to provide a wetted surface for fish to move up. In this respect, a fish pass is likely to be reliant on provision of an ancillary, smaller pumping system to deliver water to the top of the pass.

One limitation of these types of measures is that they are only likely to be able to be utilised by climbing species and hence many of the non-climbing native species that would naturally have inhabited lowland habitats behind flood pumps (e.g. inanga, smelt and common bully) would be unable to utilise these measures for upstream migration. Furthermore, potential scour or erosion effects upon the integrity of the stopbank is also likely to present a concern so any ramp structures would need to incorporate an appropriate lining to protect the underlying materials from these effects.

The design for any fish pass into a drainage scheme area will be site specific. However, a number of design option examples from hydro scheme operations in New Zealand are outlined below.

4.6.2.1 Fish Trap

This system consists of a ramp lined with either gravel or studded substrate which leads to a holding tank (the trap) that needs to be positioned above flood flows (Figure 49). The tank and ramp must be protected from the sun and to prevent overheating and predation and needs to be supplied with water by a hose connected to a water tank which in turn is supplied by a water pump. At regular intervals but at no more than weekly intervals the tank is emptied and the catch transferred to varying locations upstream. This system is best suited to transfer fish species with good climbing ability to sites with multiple pumping stations but is labour intensive.

Figure 49. Fish trap and ramp, Waitaki Dam. Note that when operating the trap is covered with a shade cloth to keep the water cool and to keep predators at bay. (Photo N Blair, NIWA.)

4.6.2.2 Fish Ramp

In this option the fish access ramp runs the full length of the structure to allow fish to climb over the stop bank to access the upstream catchment (Figure 50). The ramp can be plastic, concrete or steel and is best lined with a studded mat but other climbing substrates may be used (see Paterson and Boubée 2010). At the end of the ramp a spay system (with a funnel and down pipe if necessary) allows the fish to drop directly into the upstream channel (Figure 51). A trap that regularly discharge its content to the upstream habitat may also be used at the end of the ramp. The main disadvantage of the fish ramp system is that predators soon learn where food can be gathered at the outlet so an excluding fence may be required. This design is also only suitable for climbing species.

Figure 50. Fish ramp at Wairua Power Station, Northland. The open lid panel reveals the studded floor lining used as a climbing medium. The ramp in this case is concrete and the lid aluminium. (photo J Boubée, NIWA).

Figure 51. **Projection of the fish ramp at Mokauiti Dam, King Country. The pipe passes through the stop bank above flood levels and allows fish to reach the open channel. For monitoring purposes or to transfer the catch further upstream it is possible to add a trap at the end of the ramp. (photo: J Boubée, NIWA).**

4.6.2.3 Fish Channel

This option comprises the formation of an open channel with natural bed features (e.g. rock) extending along the side of the stop bank. This option allows the upstream passage of both climbing and swimming fish species with water being fed to the top of the channel via a vertical pumping system (Archimedes or similar). In this system, fish accumulate at the outlet of the pump, near the top of the stopbank within a purpose built tank. The accumulated fish are then flushed from the tank at regular intervals via opening of a pre-set hatch mechanism into an upstream outlet channel or pipe allowing them to access the upstream habitat (Figure 52 and 53). The outlet of this flushing pipe must be well away from the flood pump and should open in an area with plenty of cover to minimise predation.

Figure 52. **Open channel fish pass at Mokauiti Dam. In this case the main flow is provided by a syphon and at the end of the channel a pipe (white pipe top left) has been sunk through the embankment to allow fish to reach the head pond (photo J Boubée, NIWA).**

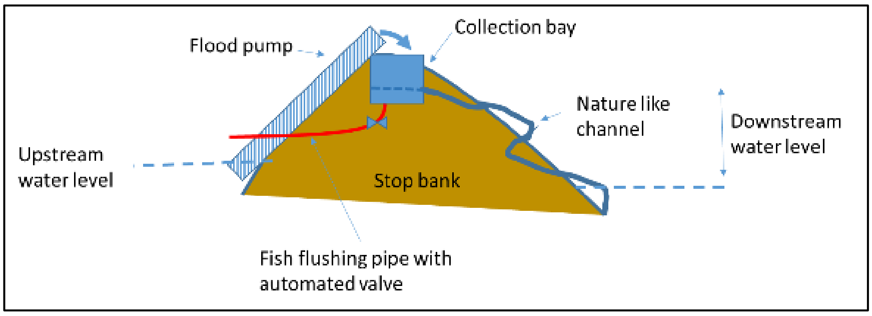


Figure 53. **Upstream fish passage for swimmers and climbers. In The Netherlands where the system uses a screw pump to supply water to the open channel, the system also provides for downstream fish passage.**

4.7 Trap and Transfer/Harvesting

Trap and transfer of both upstream and downstream migrants has now been operating for a number of years on a number of hydro power and water supply schemes within New Zealand. Use of fishers to target migrants, has also been attempted on some of the Bay of Plenty flood control schemes but we have been unable to determine if this has been successful.

Trap and transfer operations are considered to provide a feasible method to manage fish passage effects within priority catchments where alternative physical fish passage methods are unable to be implemented. The use of fyke nets to capture the migrants will be the easiest and cheapest to operate for downstream migrant eels but will not be 100% effective. To improve trapping efficiencies, traditional eels weirs (Pa Tuna) or mechanical system could also be contemplated (Figure 54).

Mechanical trap and transfer systems for upstream migrants typically comprise fixed, fabricated mechanisms with a submersible cage where the fish are collected with a winched or levered lifting mechanism to raise the cage over the stop bank to transfer the fish either upstream or downstream. Again, the cage needs to be located where fish will enter the cage and can be contained within the cage until it is ready to be lifted. In some instances, fish crowder devices have been developed to force the fish into the cage prior to transfer. Examples of these mechanical trap and transfer systems include the Killaloe Eel Weir in Ireland (Figures 53) and the Poutes Dam Fish Lift in France which was develop to move salmonids upstream (Figures 54).

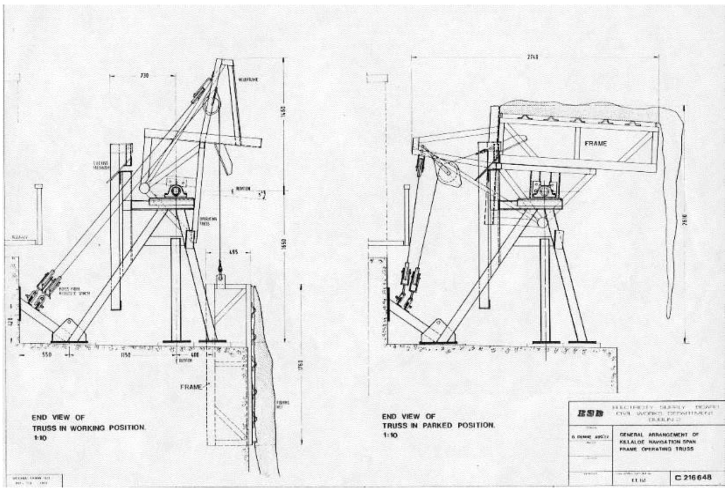


Figure 54. **Killaloe mechanical eel catching device, on River Shannon Ireland (from Nolan 1985)**

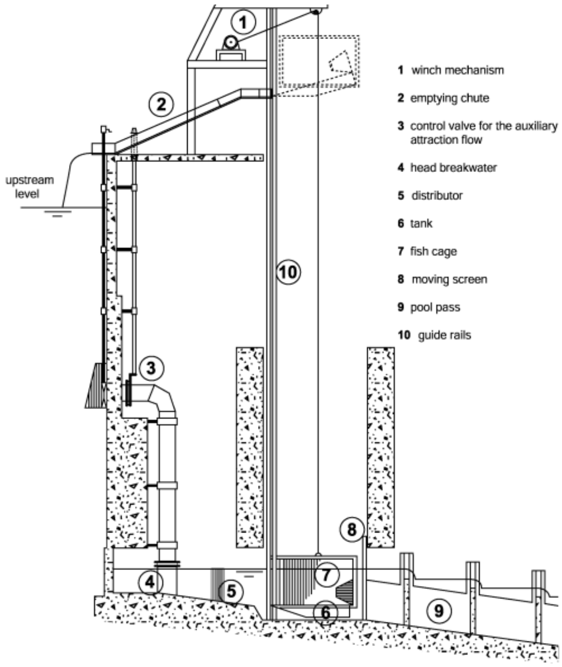


Figure 55: Cross section of a typical fish lift for salmonids (Poutes Dam , Allier River, France (from Travade & Larinier 2002).

For any trap and transfer operation to be effective it is critical that the operations are intensified around key migration periods for the relevant species. In this respect, these operations can be labour intensive given the need for routine, manual setting of nets and subsequent transfer of fish between the catchments, particularly when dealing with extended migration periods. The need to target relatively short peaks in migration will also mean the demand for qualified labour will also peak and at a time when many commercial fishers are likely to be targeting eels feeding in seasonally flooded areas.

The use of trap and transfer methods will likely trigger a requirement for a permit from the Ministry of Primary Industries and this requirement should be confirmed prior to implementation of these methods.

Encouraging commercial fishers to harvest eels within catchment where fish migration is affected by scheme infrastructure and discouraging them from fishing habitats with free access to the sea could be considered as a sustainable way of maintaining an eel population, especially under the quota management system that exists in New Zealand. However, under such a system there will always be habitat within the scheme catchments that will not be commercially viable to fish and these will tend to be smaller head water streams favoured by longfins and hence this method again, will not provide 100% protection. Furthermore, the potential for scheme operators to employ these methods to offset eel mortality within drainage infrastructure is likely to trigger adverse reactions with the public and is likely to be seen as a weak alternative to reinstatement of safe fish passage.

5 Recommendations

This report has reviewed a broad range of potential options and methods to address fish passage issues associated with scheme infrastructure. It is evident that the information available around the effectiveness of some of the available mitigation measures is limited and in many cases inconclusive. This is particularly the case in relation to addressing fish passage issues within a New Zealand setting where the morphology and behaviour of native target species and habitat conditions differs from that observed overseas where the majority of trials have been completed. Furthermore, there appears to have been minimal implementation of fish passage enhancement measures within New Zealand schemes and hence the ability to undertake any investigations into the benefits of these measures to inform decision making is very limited.

In this respect, the development and implementation of remedial options in the New Zealand setting, at least in the immediate future, will require scheme managers to accept some level of risk. Implementing remedial measures will also require further research and trials to be undertaken prior to wide scale implementation so as to provide a higher level of assurance that remedial options chosen are effective.

The following sections outline some key recommendations based on the available information including both management actions, further research and consultation processes to guide future decision making for fish passage options in New Zealand.

It is reiterated that in any situation where remedial options are being considered for fish passage at scheme sites, decision making around catchment prioritisation and choosing remedial options should always include inputs from relevant specialists including a freshwater ecologist, a local scheme engineer familiar with the catchment and a hydraulic/civil engineer that can together confirm which options may be feasible, practical and appropriate at the subject site.

5.1 Catchment Prioritisation

As a first step in addressing potential fish passage remedial requirements for land drainage scheme sites, drainage scheme managers should implement a programme of catchment prioritisation to identify catchments where either there is likely a high risk/occurrence of adverse fish passage effects from drainage scheme infrastructure or where simple upgrade measures may be able to be undertaken on lower priority catchments (e.g. fish friendly flap gate installation). See Section 4.1 for more details.

5.2 Pump Station Management Plans

For any larger scale pump station operations within New Zealand, it would be considered best practice that the operation of pump stations should follow a 'Pump Station Management Plan' which outlines the key design, operational and maintenance features/processes for the pump station which are required to ensure its effective function. To date, the contents of such plans would typically have been focussed upon land drainage/flood control functions to achieve the design level of service for the scheme area. It is therefore recommended that site specific management plans be developed for pump stations where there is considered to be a risk for adverse passage effects as a first step to minimising effects. The management plans should clearly document specific measures which may be able to be implemented to enhance fish passage through the existing scheme.

As a starting point, this may be as simple as providing information to increase the awareness of operational staff to fish passage issues or may extend to specific operational management measures which may be able to be implemented to maximise fish migration benefits. Where any fish friendly measures may be in place at a pump station (e.g. fish friendly pumps, behavioural barriers, physical screens, flapgates etc.) it is considered essential that operational staff understand the purpose, workings and operational requirements of these systems so they can maximise fish passage efficiencies. Examples of potential items which may be able to be incorporated within management plans to help achieve fish passage enhancement objectives include:

- Identifying the native fish species which may be present within the catchment and their key migration seasons;

- Methods for documenting (through observations and record keeping) any interactions between pump operations and fish. For example – if any noises or power fluctuations are noted during pump operations, are dead fish being observed downstream? If so what species?;

- Identifying the key risks to upstream and downstream fish migration within the pump station;

- Where fish friendly measures are not in place:
    - What measures may be possible at a site to maximise fish passage potential? For example:
        - fixing floodgates open outside of peak flood risk periods;
        - installing simple fish passage measures through culverts (e.g. spat ropes);

        - managing pumping times/durations to minimise potential effects (e.g. pumping during day light hours only to avoid peak night time migration);
        - implementation of a trap and transfer system during peak migration periods;
        - other remedial options to maximise upstream and downstream fish passage in priority catchments.

- Where fish friendly measures are in place:
    - Key management measures to maximise the effectiveness of these measures, such as:
        - Maintenance/operation of any deterrent measures to ensure effective diversion of fish to safe downstream outlets;
        - Maintenance of the screens so they are debris free;
        - Operational procedures for pump systems e.g. fish friendly pumps to always operate prior to any axial flow pumps;
        - Operational/adjustment procedures for fish friendly gates e.g. adjusting gate opening devices to maximise duration of opening under different flow conditions based upon flood risk;
        - Contingency measures in the event that fish friendly systems are damaged or require maintenance.

It is recommended that all drainage scheme operators undertake a review of their scheme infrastructure starting with priority catchments and where appropriate develop or update site management plans to ensure any measures possible to maximise fish passage potential are incorporated at the site and within the Pump Station Management Plan.

5.3 Deterrent/Exclusion Measures

- Deterrent/exclusion measures are only a partial solution in situations where there is no safe downstream passage provided (e.g. gravity bypass or fish friendly pump). In such situations, it is preferable to provide some form of safe passage rather than just minimise mortality.

- Available information indicates that bar racks with reduced bar spacings of 10-15 mm and through flow velocities below 0.5 m/s would provide the most robust and effective method of preventing downstream migrant eels from entering flood pumps. Hence it is recommended that screens with these reduced spacings will need to be considered and implemented where possible to prevent eel entrainment into axial pumps.

- Prior to implementing any smaller grade screens, hydraulic efficiencies through the screens will need to be considered to ensure that the design levels of service can be achieved and the risk of impingement is not significantly increased.

- Screens should be positioned to ensure velocities at the screen of less than 0.5 m/s to avoid fish impingement on the screen.

- Reduced bar spacings will increase maintenance requirement for debris removal and hence these measures will likely need to be coupled with enhanced channel maintenance (spraying/mechanical) and screen cleaner mechanisms to maintain efficient pump inflow rates.

- Automated screen cleaner systems should be considered for larger, priority catchments to address increased maintenance requirements on smaller grade screens while also reducing Health and Safety risks associated with these activities.

- Behavioural deterrent systems are considered to present multiple risk in terms of efficacy and are not as effective as fine screens from excluding fish from pump intakes.

- Electric barriers do however present a potentially useful option for deterring fish from pump intakes. NIWA is currently implementing a research project on a pump station in Northland to investigate the use of an electric barrier to deter eels from entering flood pumps. Once completed, the outcomes of this study should be reviewed to further assess the usefulness of these systems.

- There is limited information to support the use of light, sound and water jet bubble curtains as deterrent measures within the New Zealand land drainage setting and these options are considered to present increased operational/maintenance requirements and should be disregarded until more positive data is available to support their trial/usage within New Zealand.

5.4 Bypasses

- Bypasses provide the greatest potential to provide safe passage both upstream and downstream. Wherever hydraulically possible, install a culvert bypass for gravity flows in conjunction with an effective screen mechanism on the axial pump.

- The bypass needs to be designed and positioned to maximise the percentage of catchment flows diverted through this outlet and to ensure that fish can easily find it.

- Where debris screens are required to protect fish friendly bypass outlets, minimum bar spacings of 150 mm are recommended to pass the largest longfin migrants. Where smaller spacings are required (e.g. for smaller culverts or where recommended by fish friendly pump manufacturers) consideration should be given to the need for provision of an orifice or slot at the base of the screen to allow larger migrants to pass through.

5.5 Fish Friendly Pumps

- Where effective intake screening and bypass outlets cannot be implemented, consideration needs to be given to the installation of fish friendly pumps, particularly on priority catchments.

- Where a fish friendly pump is planned, the upgraded Archimedes screw design or Hidrostal type pumps have been shown to pass fish with minimal mortality effects in Europe and are recommended as the preferred options for pump upgrades in New Zealand. On the basis that the upgraded Archimedes screw pumps are reputed to be quieter, and are able to pass large objects with either no screening or only coarse screening requirements (nominal 150mm) they are considered to present the best option for providing safe downstream passage for large eels at flood pump stations.

- However, it should be acknowledged that the ability of these pumps (particularly Hidrostal pumps) to safely pass larger eels up to 1.5m in length and 200mm diameter (i.e. longfin migrants) has not been tested and hence until proven otherwise some risk remains for passage of larger eels in a New Zealand setting. The following recommendations are outlined in response to this issue:

    - Assurance should be obtained from foreign manufacturers of these fish friendly pumps that their pumps can safely pass eels up to 1.5m in length and 200mm diameter. It may be possible to air freight some larger eels to the manufacturer for trial purposes at existing facilities; or

    - If this assurance is not available, a trial installation of one or both of these systems should be implemented pumps accepting that there may still be some risk for larger specimens, with a monitoring programme to determine survival rates of various sized eels within a New Zealand setting.

- Undertake monitoring of eel passage through the traditional style Archimedes screw pumps in place in the Waikato to determine the determine survival rates of various sized eels passing through these high capacity pumps.

5.6 Fish Friendly Gates

- Fish friendly floodgates at the end of gravity fed bypass channel are the most effective way of providing upstream and downstream passage for fish outside of flood periods. As this solution is relatively new for New Zealand, potential maintenance and operational issues as well as potential solutions need to be fully documented.

- Fish friendly flap gates should be implemented on drainage scheme outlets wherever the upstream catchment provides potential fish habitat opportunities and these measures can be implemented effectively but starting with a focus on priority catchment areas.

- Implementation of any fish friendly floodgates should also consider the need for additional fish passage measures through the culvert pipe to allow fish to access the upstream catchment.

5.7 Fish Passes

- Where a culvert bypass outlet system is not available to facilitate upstream passage, installation of a specifically designed fish pass should be considered for priority catchments to enable fish to enter the catchment.

5.8 Trap and Transfer

- Where physical or financial constraints prevent the upgrade of existing infrastructure at priority sites, it is recommended that trap and transfer programmes be implemented as they afford the only practical alternative to providing safe fish passage;

- Trap and transfer programmes should be designed for target species and should be targeted over key migration periods to maximise efficacy.

5.9 Consultation/Advocacy

When making decisions regarding potential fish passage upgrade measures within drainage schemes, there are a number of additional parties outside of the core land drainage/ecological design/implementation management team that should be considered to participate in the decision-making processes. These parties include:

5.9.1 Regulators

As previously described, fish passage requirements are often driven by a requirement to comply with regulatory specifications outlined within national or regional legislation. Hence, where any fish passage measures are being considered on the basis of achieving compliance with legislative requirements, it is essential that consultation is undertaken with the parties responsible for assessing compliance with these documents. This consultation is to ensure that the proposed measures are agreed as being effective to achieve the compliance objectives.

In many cases, agreement will be achieved through a resource consent process, but where upgrades may be occurring outside of a consent process, it is recommended that written confirmation be sought from the regulators to confirm that the proposed measures are supported and are considered to achieve necessary compliance objectives.

5.9.2 Stakeholders

There are many stakeholder groups that may be able to constructively contribute to fish passage decision making within drainage scheme areas. This may include local landowners with in depth knowledge of the catchment/scheme area, stakeholder groups (DoC, Fish and Game) and local iwi or hapu representatives. In some situations, these parties may be able to become involved as part of the fish passage management processes such as within the Hikurangi flood scheme area where local tangata whenua have been involved in eel trap and transfer operations around pump stations.

In any case, it is considered beneficial to keep these parties advised of any upgrade works being undertaken so they are aware that positive efforts are being made toward remedying fish passage problems.

5.9.3 International Drainage and Flood Control Community

This study has identified that there have been limited efforts to date to address fish passage within scheme infrastructure in New Zealand. By comparison, this issue has been long standing within other parties of the world, particularly within the low-lying countries of Holland and Belgium with significant developments in technologies and methods to manage these effects.

Consultation and even collaboration with scheme managers and industry in these countries and other parts of the world is encouraged to expand council knowledge around fish passage options and to learn from the experiences of operators where these systems already exist.

5.9.4 Manufacturers/Industry

Again, development of fish friendly technologies for land drainage and flood schemes (particularly pumps) is focussed within countries where these issues are long standing and where implementation has been required through policy/legislative pressures. It is suggested that scheme managers within New Zealand advocate for local asset manufacturers to develop, supply and service fish friendly alternatives to the traditional axial flow pump utilised within New Zealand. Based upon the anticipated legislative pressure for fish friendly drainage systems, development of these technologies would appear to provide a viable market option for these businesses. Sourcing technology locally would reduce the reliance on foreign suppliers and the associated costs and risks associated with importing and maintaining that technology.

5.10 Decision Making Flow Charts

Appendix C contains two flow charts which outline the best practice decision making pathway to help guide scheme managers through the process of identifying measures for improving fish passage through scheme infrastructure. The purpose of the flow charts is not to guide decision making around whether fish passage should be implemented within a catchment (i.e. prioritisation) however may assist in determining whether practicable and affordable options are available to remedy fish passage issues at a site.

It should be acknowledged that the flow chart processes outlined are based upon decision making at a high level and are exclusive of numerous additional site specific considerations. In this respect, these flow charts will not be applicable in every situation with numerous other site specific considerations needing to be taken into account for individual land drainage sites. Nonetheless, the flow charts can be used as a tool to identify the typical decision making path and the likely measures required to enable fish passage at land drainage outlet sites.

6 Costs

Implementation of measures to enhance fish passage through scheme infrastructure in many cases will likely present a significant additional cost on the scheme. Indicative costings have been sought to provide examples of potential costs associated with various remedial options described/recommended within this report as follows.

It is reiterated that the costs provided are theoretical and indicative only and are based upon estimates and exchange rate obtained at the time of writing this report (June, 2016).

6.1 Fish Friendly Pumps

As previously described, the WRC's ICM is currently looking to upgrade their Orchard Road Pump Station in the Lower Waikato flood scheme area and are considering the replacement of the existing conventional axial flow pumps (MacEwans Pumps) with fish friendly pumps.

Indicative costings have been developed by ICM for supply of three different fish friendly pumps along with pump technical specifications and performance details which are outlined in detail within the Pump Upgrade Assessment Table included in **Appendix D**. The table also includes comparative pricing and specifications for maintenance of the status quo pump station configuration (i.e. non-fish friendly) through upgrade/refurbishing of the existing MacEwans axial flow pumps. Additionally, prices have been obtained for replacement of the existing axial flow pumps with brand new pumps of the same type.

In summary, the cost for supply of the various fish friendly Hidrostal pumps ranges from around $130,000 up to $270,000 (based upon supply of 2 pumps as required to service this catchment. By comparison, refurbishment of the existing axial flow pump is estimated at around $40,000 and full replacement of the axial flow pumps with new units is estimated at around $94,000.

Additionally, an indicative costing has been sought from FishFlow Innovations Limited (Holland) for supply of an upgraded Archimedes screw pump based upon a design to fit the same Orchard Road specifications. Supply of this pump has been estimated in the range of $135,000 to $165,000 (excluding shipping) dependent upon design/performance requirements. Refer **Appendix D.**

Note that these costings are based upon supply of the pump units only and are exclusive of the on site pump establishment costs which can be significant based upon the need for civil and structural engineering works to establish pump housings, inlet and outlet structures along with electrical connections.

This information confirms the significantly greater cost associated with supply of fish friendly pumps for implementation in drainage scheme areas in New Zealand in comparison to continued use of the traditional axial flow pumps through refurbishment and upgrade. A key aspect of the costs associated with fish friendly pumps is based upon manufacture and supply of these pumps from Europe factoring shipping and exchange rate allowance. Additionally, provision of follow up servicing and maintenance would also need to be considered when importing foreign pumps for implementation within New Zealand and whether a New Zealand agent is available to perform these services.

6.2 Fish Friendly Gates

ATS Environmental

Appendix D Includes a pricing table provided by ATS Environmental for supply of their fish friendly flapgate systems including separate pricing allowances for supply of the fish friendly gate mechanism only (i.e. a retrofit to existing gate) or for the entire gate and mechanism (i.e. new installation) along with price differences for headwall or pipe mounted applications.

Based upon a 750mm diameter pipe mounted application using a new gate with the fish friendly gate mechanism an indicative price of $4,660 is provided. An indicative installation fee of around $2,000 is also noted.

Waterman

An indicative price has been sought from Waterman USA who manufacture the self- regulating tide gates, based upon supply of a gate to fit a 1m diameter flood control culvert outlet. The indicative costing is detailed in **Appendix D** with an estimate of $41,000 provided for manufacture/supply of this gate exclusive of shipping.

6.3 Bar Racks/Screen Cleaners

An indicative price has been sought from New Zealand supplier/installer of debris screens and screen cleaning machinery Stewart & Cavalier Limited who have previous experience with supply and installation of these mechanisms at a number of hydro scheme sites.

An indicative price has been provided based upon a theoretical installation at the Motukaraka pump station site with indicative pricing provided as follows:

- Supply and installation of new bar screens with 15mm bar spacings - $100,000;
- Supply and installation of a Flex Rake Screen Cleaner system - $610,000.

The indicative costing is detailed in **Appendix D** and again confirms the significant costs associated with implementation of measures which may be required to address potential fish passage issues and associated maintenance requirements at drainage scheme sites.

6.4 Electric Screens

The cost of installing an electrical barrier screen at a pump station will vary significantly between sites based upon their physical characteristics and the type of screen to be implemented.

Appendix D provides indicative costings for a basic 12V electric screen at $9,800 compared to a commercial grade electrical guidance system from a European supplier at $185,000 (based upon implementation at the Motukaraka Flood Scheme site).

6.5 Bypass Culvert

Again the cost of installing a bypass culvert outlet at a pump station will vary significantly based upon the physical characteristics of a pump station site.

Appendix D contains a theoretical bypass layout based upon the Meremere pump station site in the Lower Waikato and based upon laying an approximate 30m length of 750mm concrete culvert including manholes and inlet/outlet structures.

Pricing has been estimated for this scenario using standard civil drain laying rates with an estimated cost for a culvert bypass around the pump station to provide for both gravity flows and fish passage of around $65,000. Note that this indicative pricing is exclusive of design/consenting requirements along with the provision of a flap gate outlet or any necessary fish passage measures through the pipe system.

6.6 Trap and Transfer

Indicative costings have been estimated for implementation of trap and transfer operations for both an upstream migration operation and a downstream migration operation.

The costings are outlined within the tables included within Appendix D with the following estimates:

Upstream Trap and Transfer

- Programme establishment and implementation in Year 1: $80,360
- Subsequent years: $36,535

Downstream Trap and Transfer

- Programme establishment and implementation in Year 1: $52,750
- Subsequent years: $43,000

6.7 Costs Summary

The indicative costings outlined above highlight that costs associated with upgrade of land drainage sites to incorporate best practice fish passage provisions are likely to be significant in many instances. In addition, the implementation of additional fish passage measures at land drainage sites, particularly large scale items such as pumps and screens will undoubtedly present additional maintenance and management requirements and associated costs for drainage schemes particularly during the initial establishment phases.

Nonetheless, the need for these measures cannot be overlooked and there is a need for drainage managers to begin to factor these requirements into design, maintenance and budgeting for their land drainage infrastructure. Again, a progressive approach is recommended for implementation of these measures based upon a priority catchment basis to ensure that benefits of this expenditure are optimised.

7 Conclusion

This report has considered the effects of land drainage and flood control schemes upon native fish migration and has determined that these activities are considered to be resulting in adverse effects upon native fish migration.

While there is currently very limited information available in relation to the quantum of the effects with in New Zealand, they are considered to be significant when the long standing nature of many of the schemes is taken into account along with the cumulative effects across multiple schemes.

Evidence from the European setting has shown a strong statutory response to a significant decline in eel populations resulting in the development and implementation of stringent policy in some countries to address the multiple factors impacting eel populations including the effects of land drainage and flood scheme infrastructure. This has seen the requirement for provision of fish passage through infrastructure with these measures now seen as standard practice (if not mandatory) within some countries.

While eel populations within New Zealand are not considered to be at critical levels, a review of resource management and iwi based legislation relevant to the Waikato Region indicate a directive to increase environmental enhancement initiatives through future resource management decision making. This directive would likely include increased pressure for provision of best practice fish passage measures through catchments where it would otherwise occur and is currently restricted.

Based upon the experience from Europe and the direction of resource management decision making in New Zealand, it is considered that scheme managers in New Zealand need to start considering and implementing measures to maximise fish passage through drainage scheme infrastructure in accordance with best practice methods.

A number of remedial options have been identified and assessed to address fish passage effects at land drainage sites. Again, there is considered to be relatively limited conclusive information available in regard to the effectiveness of these measures within the New Zealand setting. A combination of measures is likely to be required at any site particularly if both upstream and downstream passage is required. Furthermore, the implementation of fish passage measures are likely to present a significant additional costs and will likely determine the need to reconsider current management and maintenance practices at drainage scheme sites.

Nonetheless, if these options are not considered and implemented, adverse effects on the native fisheries will continue and environmental compliance or enforcement actions should be anticipated.

On this basis, an innovative and adaptive management approach is required from drainage scheme managers to begin to implement these measures and to adapt them to New Zealand conditions. Given the lack of existing information on the effectiveness of many measures, particularly within the New Zealand setting, development and trialling of these measures will have to accept a degree of risk, at least initially. Furthermore, a consultative and collaborative approach between scheme managers, regulators, iwi/hapu, and other stakeholders as well as industry is recommended to ensure sharing of information and that fish passage outcomes are optimised.

References

Adams B, Schwevers DU 1997. Behavioral surveys of eels (*Anguilla anguilla*) migrating downstream under laboratory conditions. Institute of Applied Ecology, Neustader Weg 25, 36320 Kirtorf-Wahlen, Germany.

Allan DG 2010. Eels in the Waikato catchment. Client report prepared for Mighty River Power Ltd, Hamilton.

Baker N 2016. The fine-scale behaviour of downstream migrating silver European eels (*Anguilla anguilla)* immediately upstream of pumping stations. NIWA Seminar Series. 26 April 2016. NIWA, Hamilton.

Bocker EJ 2015. Restoring connectivity for migratory native fish: investigating the efficiency of fish friendly gates. MSc thesis, University of Palmerston North.

Boubée J AT 2001. Downstream migrant eel study at Wairere Power Station. NIWA Client Report KCE2205.

Boubée JA, Mitchell CP, Chisnall BL, West DW, Bowman EJ, Haro A. 2001. Factors regulating the downstream migration of mature eels (*Anguilla spp*.) at Aniwhenua Dam, Bay of Plenty, New Zealand: New Zealand Journal of Marine and Freshwater Research 35:.121-134.

Boubée J, Bowman E, Waiwai B. 2015. Waikaremoana Power Scheme - Tuna monitoring 2014/2015. NIWA Client Report HAM2015-084-077 prepared for Genesis Energy Ltd.

Boubée JAT, Williams EK 2006. Downstream passage of silver eels at a small hydroelectric facility. Fisheries Management and Ecology 13: 165–176.

Chisnall BL 1987. Juvenile eel biology in the backwaters of the Waikato River. MSc thesis, University of Waikato, Hamilton.

Buysse D, Mouton AM, Stevens M, Van Den Neucker T, Coeck J 2014. Mortality of European eel after downstream migration through two types of pumping stations. Fisheries Management and Ecology 21: 13-21.

Cullen P, McCarthy TK 2000. The distribution of catches of silver eel, *Anguilla, anguilla* (L) across the Killaloe eel weir in the lower River Shannon. Biology and Environment. Vol 110B, No. 3: 165-169.

Decker W., Casselman J 2003. The 2003 Québec declaration of concern about eel decline – 11 years later: Are eels climbing back up the slippery slope? Fisheries, 39:12, 613-614.

Doehring K, Young RG, Hay J, Quarterman AJ 2011. Suitability of Dual-frequency Identification Sonar (DIDSON) to monitor juvenile fish movement at floodgates. New Zealand Journal of Marine and Freshwater Research 45(3): 413-422.

Durif C, Elie P, Gosset C, Rives J, Travade 2003 Behavioural Study of Downstream Migrating Eels by Radio-Telemetry at a Small Hydroelectric Power Plant. In: Dixon, D.A. (ed). Biology, Management and Protection of Catadromous Eels. American Fisheries Society, Symposium 33, Bethesda, Maryland.

EIFAC/ICES Working Group on Eels 2001. Report of the EIFAC/ICES Working Group on Eels, St. Andrews, N.B., 28 August – 1 September 2000. Advisory Committee on Fisheries Management, International Council for the Exploration of the Sea, ICES CM 2001/ACFM: 03, Copenhagen.

EPRI 1986. Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application. Electric Power Research Institute, Palo Alto, CA AP-4711

EPRI 2008. Evaluation of Strobe Lights for Reducing Fish Impingement at Cooling Water Intakes. Electrical Power Research Institute, Palo Alto, CA. TR- 1015577.

Fay RR, Popper AN 2000. Evolution of hearing in vertebrates: the inner ears and processing. Hearing Research 149: 1–10.

Fish H, Vriese FT 2011. Research into the fish-friendliness of Hydrostal pump. VisAdvies Report VA2009_33 to STOWA.

Franklin PA, Hodges M 2015. Modified tide gate management for enhancing instream habitat for native fish upstream of the saline limit. Ecological Engineering 8 (10): 233-242.

Gleeson L 1997. Use of electric fields to direct eel movement: eel passage. Presented at the Fish Passage Workshop 6-8 May 1997, Milwaukee, Wisconsin.

Glova GJ, Jellyman DJ 2003. Monitoring of fish movements at the Lake Wairarapa barrage gates. NIWA client report CHC 2002-38.

Goodman J M, Dunn NR, Ravenscroft PJ, Allibone RM, Boubée JAT, David BD, Griffiths M, Ling N, Hitchmough RA, Rolfe JR 2013. Conservation status of New Zealand freshwater fish. New Zealand Threat Classification Series 7.

Hadderingh RH, Jansen, H. 1990. Electric fish screen experiments under laboratory and field conditions. In: Cowx, I.G. (ed.). Developments in Electric Fishing. Fishing News Books, England.

Hadderingh RH, Van der Stoep JW, Habraken JM 1992. Deflecting eels from water inlets of power stations with lights. Irish Fisheries Investigations series A (freshwater) 36: 80-90.

Hadderingh RH, Van Aerssen GHFM, De Beijer RFLJ, Van der Velde G 1999. Reaction of eels to artificial light sources and water currents: an experimental deflection study. Regulated Rivers: Research and Management 15: 365–371.

Haro A, Richkus W, Whalen K, Hoar A, Busch W, Lary S, Brush T, Dixon D 2000. Population decline of the American eel: Implications for science and management. Fisheries 25(9): 7-16.

Jackson D (undated). The application of fish friendly pumps for the land drainage pump stations. Paper available through Hydrostal (sales@hydrostal.co.uk)

Johnston RL, McKinstry CA, Cook CB, Tamo DK, Faber DM, Francis S, Simmons MA, Simmons CS, Brown RS, Thorsten SL, LeCaire R 2005. Strobe light deterrent efficacy test and fish behaviour determination at Grand Coulee Dam third power plant forebay. Report prepared for US department of energy by Pacific Northwest national Laboratory, Nespelem, Washinton USA.

Karlsen HE, Piddington RW, Enger PS, Sand O. 2004. Infrasound initiates directional fast-start escape responses in juvenile roach *Rutilus rutilus*. Journal of Experimental Biology 207: 4185–4193.

Larinier M, Travade F 2002. Downstream migration: problems and facilities. Bulletin Français de la Pêche et de la Pisciculture 364: 181–207.

Lowe RH, 1952. The influence of light and other factors on the seaward migration of the silver eel (*Anguilla anguilla* L.). Journal of Animal Ecology 21: 275-309.

Maes J, Turnpenny AWH, Lambert DR, Nedwell JR, Parmentier A, Ollevier F 2004. Field Evaluation of a Sound System to Reduce Estuarine Fish Intake Rates at a Power Plant Cooling Water Inlet. Journal of Fish Biology 64: 938–946.

McDowall RM 1977. New Zealand Freshwater Fishes. Heinmann Educational Books, Auckland, New Zealand

Mitchell CP, Boubée JAT 1992. Impacts of turbine passage on downstream migrating eels. New Zealand Freshwater Fisheries Miscellaneous Report No. 12.

Nolan EP 1985. Mechanical improvements to Killaloe eel weir Ireland. Electricity Supply Board, Dublin, Ireland.

Odeh M, Orvis C 1998. Downstream fish passage design considerations and developments at hydroelectric projects in the North-east USA. In: Jungwirth M., Schmutz, S. Weiss, S. (Eds). Fish Migration and Fish Bypasses, Fishing News Books, 267–280.

Paterson C, Boubée J 2010. Best Practice Guidelines for the Passage of Upstream Migrating Fish at Hydroelectric Dams in New Zealand. NIWA Client Report: HAM2010-087.

Patrick PH, Sim B 1985 Effectiveness of a Hidrostal pump in live transfer of American eels. Hydrobiologia 128: 57–60.

Patrick PH, McKinley RS 1987. Field evaluation of a Hidrostal pump for live transfer of American eels at a hydroelectric facility. North American Journal of Fisheries Management 7: 303–305.

Pentair 2013. Fish friendly pump. Brochure produced by Fairbanks Nijhuis, The Nertherland www.fairbanksnijhuis.com.

Pratt TC, O'Connor LM, Hallet, AG, McLaughlin RL, Katopodis C, Hayes DB, Bergstedt RA 2009. Balancing Aquatic Habitat Fragmentation and Control of Invasive Species: Enhancing Selective Fish Passage at Sea Lamprey Control Barriers. Transactions of the American Fisheries Society 138: 652–665.

Richkus WA 2001. Review and Documentation of Research and Technologies on Passage and Protection of Downstream Migrating Catadromous Eels at Hydroelectric Facilities, EPRI, Palo Alto, CA.

Richkus WA, Dixon DA 2003. Review of Research and Technologies on Passage and Protection of Downstream Migrating Catadromous Eels at Hydroelectric Facilities. *In*: Dixon, D. (ed.) Biology, Management and Protection of Catadromous Eels. American Fisheries Society, Symposium 33, Bethesda, Maryland.

Richkus WA, Whalen K 2000. Evidence for a decline in the abundance of the American eel, *Anguilla rostrata* (LeSueur), in North America since the early 1980s. Dana 12: 83 97.

Ridgway, G., Williams, M, 2011. Self-regulating tide gate: a new design for habitat creation. Environment Agency Project SC070031, Bristol UK. 50pp.

Roth B, Moeller D, Slinde E 2004. Ability of electric field strength, frequency and current duration to stun farmed Atlantic salmon and Pollock and relations to observed injuries using sinusoidal and square wave alternating current. North American Journal of Aquaculture 66: 208–216.

Sand O, Enger PS, Karlsen HE, Knudsen F, Kvernstuen T 2000. Avoidance responses to infrasound in downstream migrating European silver eels, *Anguilla anguilla*. Environmental Biology of Fishes 57: 327–336.

Schilt CR 2007. Developing fish passage and protection at hydropower dams. Applied Animal Behaviour Science 104: 295–325.

Solomon DS, Beach MH 2004. Fish Pass Design for Eel and Elver (*Anguilla anguilla*). R&D Technical Report W2-070/TR1. Environment Agency, Bristol, U.K.

Solomon, D.J., Wright, R, (2012). Prioritising pumping stations for the passage of eels and other fish, Environment Agency, Anglia Region, UK. Final report. 49pp.

Sonny D, Knudsen FR, Enger PS, Kverstuen T, Sand O. 2006. Reactions of cyprinids to infrasound in a lake and at the cooling water inlet of a nuclear power plant. Journal of Fish Biology 69: 725–748.

Spierts ILY, Vis H 2012. Test of fish survivability of Bedford Pups model SAF 90.05.12. Report prepared by VisAdvies for Bedford Pumps. Report Number VA2011_28.

Stevenson C, Baker C 2009. Fish passage in the Auckland Region – a synthesis of current research. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Technical Report, 2009/084 (note re-published by the ARA as report TR2009/084).

Stokstad E 2003. Can well-timed jolts keep out unwanted exotic fish? Science 301: 157–159.

Tesh FW 2003. The eel. Blackwell Publishing, Oxford UK.

Thon M 1999. Protection of Migrating Silver Eels (*Anguilla anguilla*) in Regulated Rivers. RWE Energie AG: Rheinland-Pfalz, Germany

Travade F, Larinier M 2002. Fish locks and fish lifts. Bulletin Français de la Pêche et de la Pisciculture 364: 102–118.

Turnpenny AWH, O'Keffe N 2005. Screening for intake and outfalls: a best practice guide. Environmental Agency Science Report SC030231.

Vriese, FJ 2009. Research into the fish-friendly screw pumps. Report prepared by VisAdvies for FishFlow Innovations. Report Number VA2009_19. 14p.

Watene EM, Boubée JA, Haro AJ 2003. Downstream movement of mature eels in a hydroelectric reservoir in New Zealand. *In*: Dixon, D.A. (ed.) Biology, Management and Protection of Catadromous Eels. American Fisheries Society, Symposium 33, Bethesda, Maryland.

Week LE, Bird VG, Geary RE 1989. Effects of passing juvenile steelhead, chinook salmon, and coho salmon through an archimedes' screw pump. California department of Fish and Game, Region 3 Yountville California, USA, Report 4512a/capA54 17pp

Welton JS, Beaumont WRC, Clarke RT 2002. The efficacy of air, sound and acoustic bubble screens in deflecting Atlantic salmon, *Salmo salar* L., smolts in the River Frome, UK. Fisheries Management and Ecology 9: 11–18.

APPENDICES

Appendix A: Eel Mortality Photo Records

Figures 1 – 8: Eel kill incidents at Motukaraka (Waikato) and Hikurangi (Northland) Flood Scheme sites (photos - Boubée, WRC and Whangarei District Council)

Figures 9 & 10: **Eel remains showing various degrees of dismemberment along with intact eels showing strike injuries collected from the Orchard Road Pump Station outlet during the WRC ICM trial study (photos – WRC)**

Figure 11: **Inside of the body cavity of a whole eel collected from below the Orchard Road Pump station showing liquefied internal organs (photo – WRC).**

Figure 12: **Dorso ventral x-ray image of cranial trauma to eels collected from the Orchard Road Pump Station outlet during the WRC ICM trial study. Note – the eel at right comprises an unpumped, control specimen (photo – WRC).**

Figure 13: The remains of fish observed downstream of the Mangawhero Pump Station following a fish kill caused by poor water quality in the catchment above the pump with their corpses subsequently passing through the pump to be deposited downstream (photo – WRC)

Appendix B: Waikato Regional Council Drainage Staff Meeting Minutes

FISH MORTALITY IN FLOOD PUMPS:

MINUTES FROM DISCUSSIONS WITH ICM GORDONTON DEPOT STAFF

Observations/Knowledge of Fish Kill Incidents at Flood Pump Sites

- The scale of the Motukaraka incident is considered to be a one off incident with no staff knowledge of any similar scale incidents occurring in the region;

- Questions raised over whether the eel kill at Motukaraka should be directly attributed to the pump given knowledge of dead eels within the scheme drains prior to the incident occurring due to landowners blocking drains/holding back water which could have lead to reduced water quality and eel deaths over the summer months with the bodies being washed downstream during the large storm event in early autumn;

- The large scale of the incident at Motukaraka likely attributed to both the large scale catchment area serviced by this pump and the controlled inlet culvert which allows fish to migrate into the catchment unimpeded (when open) – i.e. other catchments do not have an inlet mechanism through the stop banks and hence fish passage is prevented;

- Outside of the Motukaraka incident, fish mortality in pumps is generally considered to be a minor/infrequent occurrence. Noises are sometimes heard when visiting pumps (clunking of pump/fluctuations in power) which are assumed to be eels passing through the pump though no observations of dead eels. Some of the smaller pumps are prone to jamming which is often attributed to eels. Some of the pumps are fitted with reverse switches to remove jams which are often attributed to eels – though no documented evidence to confirm that eels are causing the problem i.e. could be other debris etc;

- Noise/jammed pumps would be noted on approximately 1 in 20 visits to the sites and would typically coincide with autumn – eel migration period so high likelihood that these are migrating eels;

- Staff acknowledge that they are only at the sites a very small proportion of the time that pumps are running so not sure what could be happening outside those periods. However there has been very limited observation of any dead eels within/below the pumps during inspections to date;

Any Particular Higher Risk Sites Where Greater Chance of Eel Deaths Based Upon Catchment Characteristics?

- Whangamarino/Meremere/Island Block (north end)/Bell Road;

Existing Efforts to Prevent Fish Mortality Through Pumps

- Archimedes Screw – no observations of any fish ever passing over the pump though assume this is working as no significant build up of eels at bottom end of catchment. Based upon the mechanics of the system, even this pump would present a high risk of eel death.

- Screens on propeller pumps – 49mm spacings – still let small – medium sized eels through, landowners maintain screens;

- Electric screen on duty pump at Motukaraka and known usage in Hawkes Bay or BOP;

Possible Options to Minimise Fish Mortality at Pump Sites and Associated Management Concerns

Screens

- Present significant maintenance costs to clean small aperture screens;

- A screen alone is not the answer as still require a mechanism to allow fish to move around the pumps on non-gravity flow systems i.e. most of the flood pump systems in this area;

Fish Friendly Pumps

- Archimedes pumps – able to pass large volumes of water so good for flood pump functions, however limited data re their fish passage efficiency/effectiveness in NZ settings, still pose a risk to fish unless properly designed, significant power requirements to drive the pumps, do not work on smaller catchments;

- Other options available – larger impellor, slower moving pumps. Other fish friendly pumps from UK. Talk to MacEwans to see if they have any ideas;

- Significant cost to upgrade pumps – current pumps are working well and generally maintained with replacement parts i.e. no need for full replacement in the near future due to flood pump functions;

- Talk to MacEwans – any ideas/plans re fish friendly pumps?

Eel Fishermen

- Potential to focus fishing in flood pump catchments to minimise numbers of fish through these systems;

- Talk to eel fishermen – any observations/comments re fish movements around pumps and management options at key sites.

FISH MORTALITY IN FLOOD PUMPS:

MINUTES FROM DISCUSSIONS WITH ICM HAURAKI DEPOT STAFF

Observations/Knowledge of Fish Kill Incidents at Flood Pump Sites

- No observations of any fish kill incidents of the scale at Motukaraka or multiple/large number kills within the Hauraki flood pump network have occurred;

- Fish mortality in pumps is generally considered to be a minor/infrequent occurrence. Noises are sometimes heard when visiting pumps (clunking of pump) which are assumed to be eels passing through the pump. An estimate of the frequency of these occurrences would be 1 or 2 noises heard during a half day spent at the pump. During a big flood event 1-2 eels may be observed being spat out of the pump. From time to time pumps have needed to be reversed to remove blockages. Dead eels have been observed within pump systems.

- Staff acknowledge that the noises heard may be other fish or debris (carp/catfish/weed) and during flood events the pump outlets are typically well submerged below flood waters and hence observation of dead fish would be limited.

Hauraki Flood Scheme Characteristics

- Staff described that pumps in the Hauraki area are probably typically larger than other parts of the region and hence it may be easier for fish to pass through without being killed/injured. They also noted that nearly all of their pumps incorporate a vertical bar screen at approx. 5mm spacings with a flapgate culvert outlet adjacent to or near the pump. During typical flows and flood events, the highest volume of water would pass out of the floodgate culvert. Hence most fish are likely to be able to migrate out of the catchment without needing to pass through a pump – compared to Motukaraka where the pumps provide the only method for fish to exit the catchment. Based upon the provision of floodgates at most sites and the nature of the catchment areas many of the flood pumps operate very infrequently – i.e. sometimes no pump operation within a year.

Any Particular Higher Risk Sites Where Greater Chance of Eel Deaths Based Upon Catchment Characteristics?

- Sites without floodgates – Tee Head and Applegate;
- Alexander and Stocks – large catchments likely to hold large numbers of eels.

Existing Efforts to Prevent Fish Mortality Through Pumps

- Floodgates as a bypass outlet to the pumps for fish;
- Screens on pumps to divert fish to the floodgate culverts.

Possible Options to Minimise Fish Mortality at Pump Sites and Associated Management Concerns

Screens

- Smaller screens would present significant maintenance costs to clean;

- Electrified screens – questioned whether any electrolysis effects on the pumps viz zinc anodes

Eel Quota/Fishermen

- ICM could purchase an eel quota to offset any eel kill effects;

- ICM could purchase live longfin eels from fishermen and return to the streams.

Mitigation

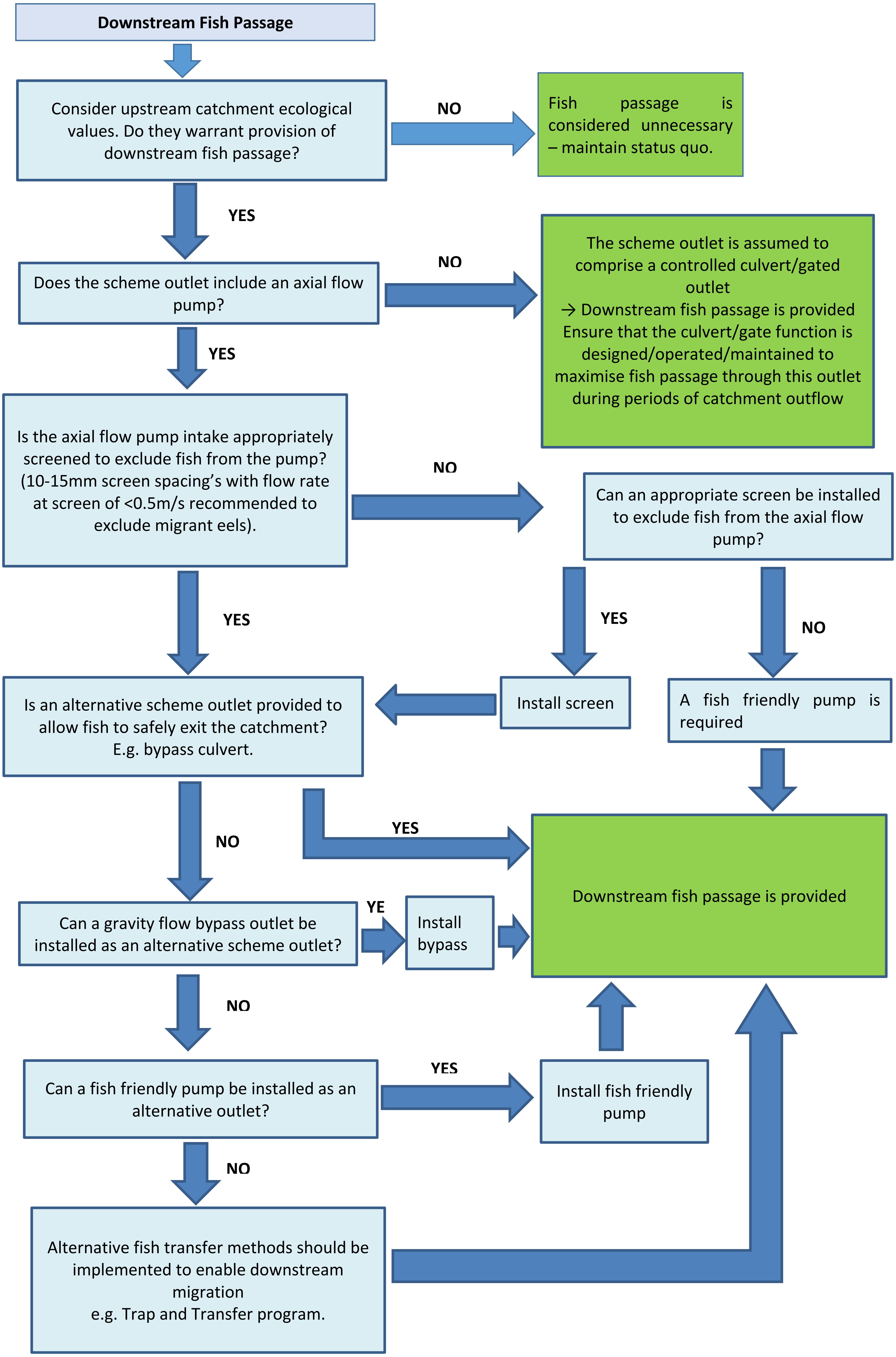
- ICM implement and coordinate km's of riparian planting within the catchments resulting in enhanced habitat values for fish populations. Can this be seen as a form of mitigation for any effects upon fish populations that are occurring from ICM flood pump operations?

Monitoring

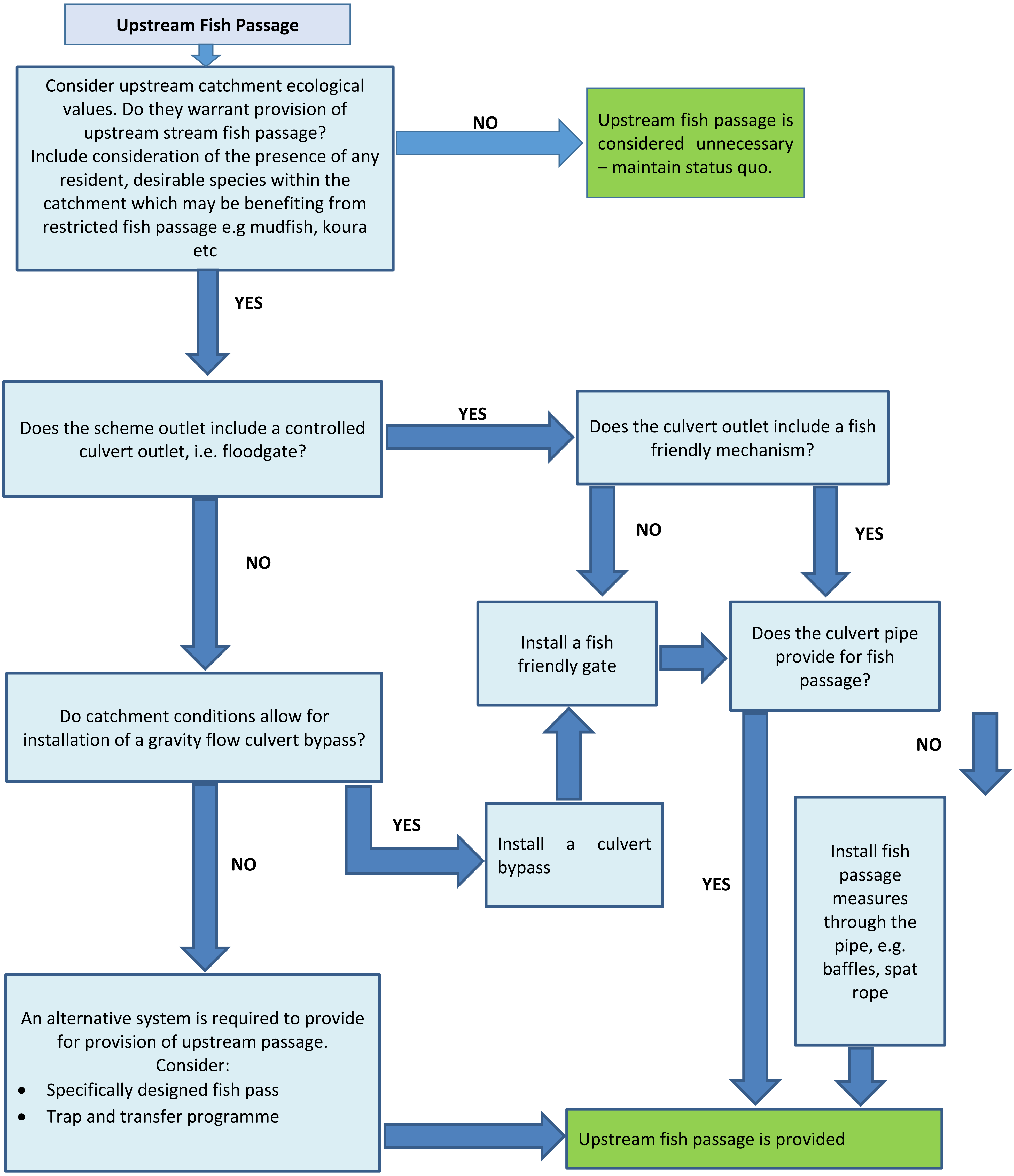
- Monitoring of pump operation in relation to fish mortality should be undertaken prior to deciding upon any management changes within the flood pump systems which could impact pump operation costs and staff requirements i.e. more information is required. ICM staff would be keen involved in monitoring.

Appendix C: Fish Passage Decision Making Flow Charts

DOWNSTREAM FISH PASSAGE DECISION MAKING FLOW CHART

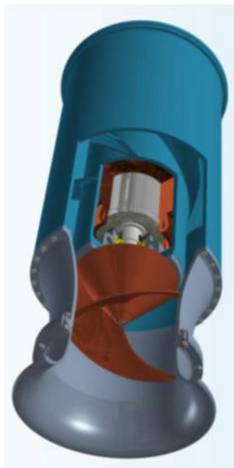


UPSTREAM FISH PASSAGE DECISION MAKING FLOW CHART



Appendix D: Indicative Costings for Fish Passage Upgrade Measures

Comparison of Hydrostal and Conventional Flood Pumps

Manufacturer		Bedford Pumps Ltd		Pentair	MacEwans
Country		United Kingdom		Netherlands	New Zealand
NZ Agent?		No	No	Yes	Yes
Pumpset Type	Picture				
	Drive	Shaft Driven	Submersible	Shaft Driven	Shaft Driven
	Impellor type	Fish friendly	Fish friendly	Fish friendly	Conventional
	Model	DAF.45.05.06	SAF45.05.06	VPF1-500.130	PPF 15/18 C+2
Extras	Included in price	Manual	Manual	Manual	
		Shipping to Auckland	Shipping to Auckland		
		Pump condition monitor	Pump condition monitor		
	Not included in the price	Stainless steel shaft (optional)	Stainless steel shaft (optional)	Freight to Auckland: $6,536	
				1 week visit to assist with installation: $9,460	
				Frequency converter: $14,141.84	
Warranty		12 months	12 months	Not specified	Not specified
Cost ($NZ)	Pumpsets (x2)	$ 239,299	$ 127,466	$ 274,433	$ 40,600
	Canisters (x2) (for submersible pumps)		$ 33,982		
	TOTAL	**$ 239,299**	**$ 161,448**	**$ 274,433**	**$ 40,600** (0r $94,000 for full pump replacement with new units)

Technical Specification

Pumps	No. of Pumps	2	2	2	2
	Discharge Diameter	450	450	600	380
	Bellmouth Diameter	624	820	700	460
Electric Motors	Nominal Running Speed	857	857	466	960
	Rated Motor Power (kW)	37	32	45	22
	Motor Efficiency	92%	92%	Not specified	Not specified
Materials	Casing	Cast steel	Cast steel	Mild Steel	Mild Steel
	Suction shroud	Cast steel	Cast steel	Mild Steel	Mild Steel
	Bellmouth	Cast steel	Cast steel	Mild Steel	Mild Steel
	Impellor	Aluminium bronze	Aluminium bronze	Bronze	Bronze
	Shaft	Carbon steel*	Carbon steel*	Stainless Steel	Hi Tensile Steel
Protective Coating	Pump Body	Epoxy paint	Epoxy paint	Epoxy paint	Paint or galvanise
	Riser tubes	N/A	Epoxy paint or galvanised	N/A	N/A

Performance

Manufacturer		Bedford Pumps Ltd		Pentair	MacEwans
Maximum Duty	Design Flow (m^3/min)	15.70	15.70	15.70	15.70
	Design Head (m)	5.60	5.60	5.60	5.60
	Actual Head (m)	5.60	5.60	5.60	5.60
	Power Consumption (kW)	24.4	24.4	24.8	18.5
	Pump Efficiency	59%	59%	59%	74%
Medium Duty	Design Flow (m^3/min)	20.80	20.80	20.80	20.80
	Design Head (m)	3.80	3.80	3.80	3.80
	Actual Head (m)	4.92	4.92	4.80	4.00
	Power Consumption (kW)	22.8	22.8	24.3	16.0
	Pump Efficiency	73%	73%	68%	80%
Minimum Duty	Design Flow (m^3/min)	25.80	25.80	25.80	25.80
	Design Head (m)	2.00	2.00	2.00	2.00
	Actual Head (m)	3.79	3.79	4.10	2.00
	Power Consumption (kW)	19.5	19.5	23.6	10.5
	Pump Efficiency	73%	73%	74%	55%

Notes:
1. The initial cost for the MacEwans pump option is based on upgrading and refurbishing the existing pumps
2. Stainless steel shafts are available for the Bedford pumps as an optional extra.

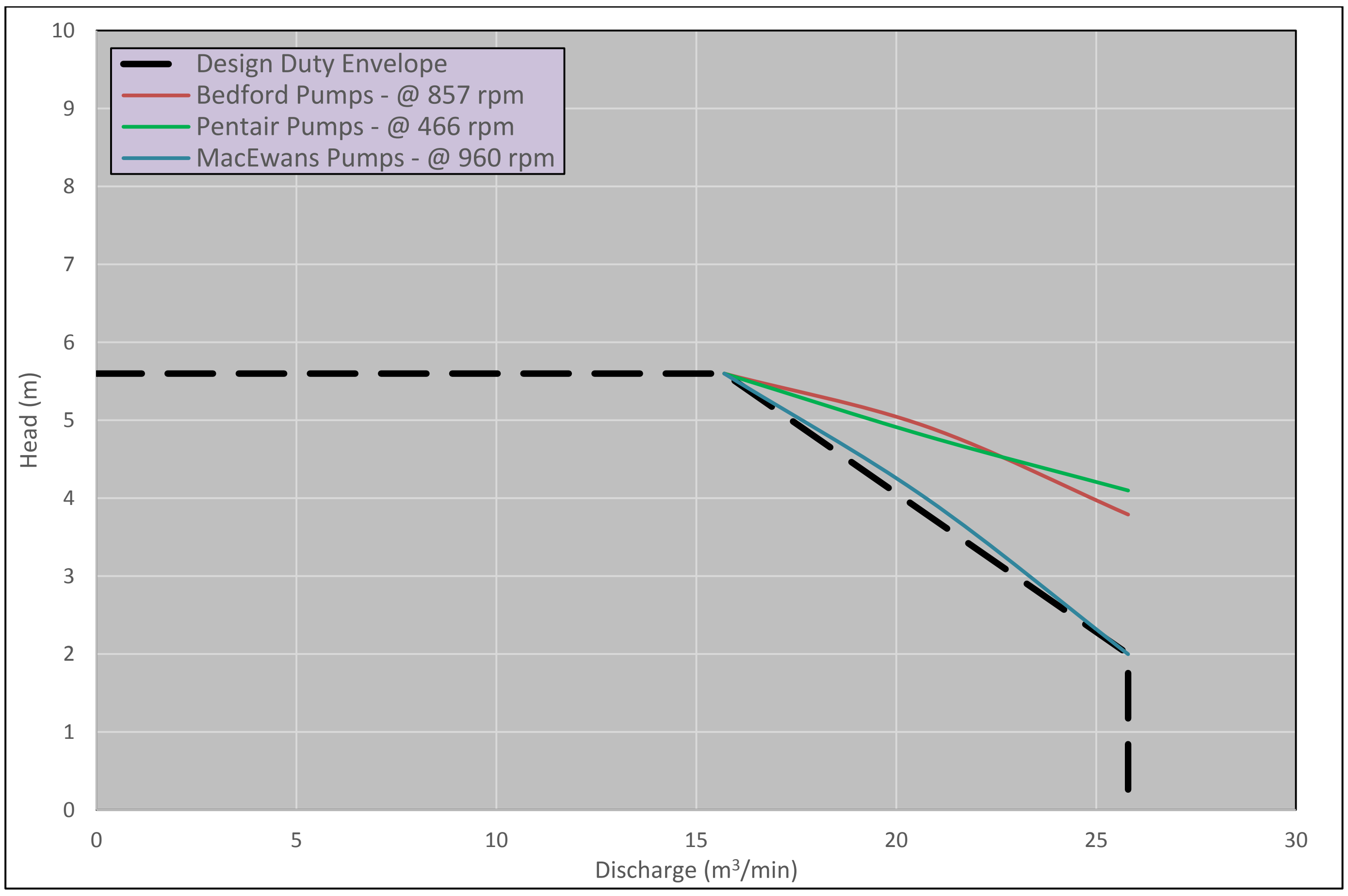


Figure 1: Pump Performance Curves

Costing for modern Archimedes Screw Pump

Indicative Supply Costings provided by FishFlow Innovations based upon the WRC ICM Orchard Road site. Options presented are based upon uncertainties over pump design requirements at the time of pricing.

Option 1

- 5.6m head and a desired capacity of 15.7 m^3/min (0.26 m^3/sec)
- Outside diameter: 1.5 meters
- Rpm: 15.3
- Hydraulic efficiency: 97% (minus 10% for gearbox, motor and inverter would make about 87% total efficiency).
- Power usage: 14.7 kWh hydraulic +10% = 16.2 kWh. We can fit a 24 kW motor on it.
- Length: 9.1 m

<u>Price: € 108.000,- (NZ$165K)</u>

Option 2

- 3.8m head and a desired capacity of 20.8 m^3/min (0.35 m^3/sec)
- Outside diameter: 1.5 meters
- Rpm: 20.6
- Hydraulic efficiency: 95% (minus 10% for gearbox, motor and inverter would make about 85% total efficiency).
- Power usage: 13.8 kWh hydraulic +10% = 15.2 kWh We can fit a 22 kW motor on it.
- Length: 8.7 m

<u>Price: € 104.000,- (NZ$160K)</u>

Option 3

- 2.0m head and a desired capacity of 25.8 m^3/min (0.43 m^3/sec)
- Outside diameter: 1.5 meters
- Rpm: 25.3
- Hydraulic efficiency: 90% (minus 10% for gearbox, motor and inverter would make about 81% total efficiency).
- Power usage: 9.4 kWh hydraulic +10% = 10.3 kWh We can fit a 20 kW motor on it.
- Length: 4.6 m

<u>Price: € 88.000,- ($NZ135K)</u>

All prices are ex shipping, but including mechanical installation (not the electrical installation / connection to grid).

Prices at June, 2016

Fish Friendly Gates

ATS-Environmental FFG and Flap Gates

All 316 Stainless Steel
Exclusive of GST & Freight
Fitting service available.
Allow $1500 for FFG and $1900 for FFG+ Flap. (excluding disbursements)

				Headwall mounted			Pipe mounted		
		Nominal bore (mm)	Wall thickness (mm)	FFG only	Flap Gate only	FFG + Flap	FFG only	Flap Gate only	FFG + Flap
Culvert Size	450	457	39	1965	1495	3335	2165	1695	3660
	525	533	41	2085	1625	3585	2285	1825	3910
	600	610	45	2165	1945	3985	2365	2145	4310
	675	686	47	2175	2185	4235	2375	2385	4560
	750	762	51	2185	2275	4335	2385	2475	4660
	825	838	53	2265	2315	4455	2465	2515	4780
	900	914	63	2295	2385	4555	2495	2585	4880
	975	995	70	2365	2405	4645	2565	2605	4970
	1050	1067	76	2375	2415	4665	2575	2615	4990
	1200	1219	76	2450	2500	4825	2650	2700	5150
	1350	1372	76	2555	2725	5155	2755	2925	5480
	1600	1590	82	2725	3235	5835	2925	3435	6160
	1800	1830	88	2815	3650	6340	3015	3850	6665
	2050	2050	?	2885	4215	6975	3085	4415	7300
	2100	2100	140	POA	POA	POA	POA	POA	POA

As at 01 Jan 2016 – prices are subject to change.

Waterman USA Self Regulating Tide Gate Cost Estimate

$41,000.00 ea. (Prices are for budgetary purposes only; this is not an offer to sell)

Based on
1 Meter Diameter Self-Regulating Tide Gate
Gate Aluminum B-209 AL.6061 T6
Gate Mounted on Grout Pad (Grout by Others)
Float Balls Polyurethane Foam
Seals Neoprene ASTM D-2000
Paint Flap and Floats With Anti-Fouling Paint
Mill Finish on Aluminum Surface
Submittal Drawings
Excludes Shipping

Ref: Website: http://watermanusa.com/products/large-custom-gates/self-regulating-tide-gates/

Waterman

www.WatermanUSA.com

Bar Racks/Screen Cleaners

STEWART & CAVALIER LTD
ENGINEERS
Te Awamutu

Ref. BM5499-16

29th July 2016

Bloxam Burnett & Olliver
Po Box 9041
Hamilton 3240

Attention: Richard Duirs

Dear Richard

RE: WRC Flood Pump Screening Estimates

We have much pleasure in submitting our estimates for the above concept project

Our Estimate:	**A:**	**610,000.00 + GST**
	B:	**100,000.00 + GST**

SCOPE OF WORK

A: FlexRake

- Supply , Installation and Commissioning of a Duperon FlexRake Front Cleaning Front Return Screen Cleaning System , based on an intake size of Approximately 2m in Height by 10m in Length.
  - Estimate includes the following
    - Supply and Importation Cost for 2 off Duperon FlexRakes
    - Manufacture of NZ Based Components for the Above FlexRake under license to Duperon
    - Transportation of the items to site
    - On Land Assembly and installation of FlexRake onto new Galvanized Bar Screens
    - Manufacture and Installation of a Galvanized Collection Trough behind the FlexRake for Weed and Debris
    - Electrical Work associated with The Installation
    - Commissioning of the complete system on Completion

A: New Bar Screens

- Supply, Manufacture, Galvanizing and Installation of New Bar Screen with 15mm bar spacing's for a 2m High x 10m wide intake.
  - Estimate includes the following
    - Supply Manufacture and galvanizing of 4 off 2.5m x 2m Bar screen ex 75x5 Carbon steel flat
    - Transportation of Screens to Site
    - Removal of Existing Screens
    - Installation of New Screens ready for FlexRake

NOTES AND CLARIFICATIONS

- Imported Components are Based on an Exchange Rate of NZ$1 = US$0.70
- Following Items have been excluded from our Estimate
  - Design Costs associated with changes to the Intake or the new screens.
  - All or any required council Consents or design permits fees etc.
  - Any Modification needed to an intake to accommodate the new screens or FlexRake.

Yours faithfully
STEWART & CAVALIER LIMITED

B. Mexted

Brent Mexted
Contracts Manager/ Director

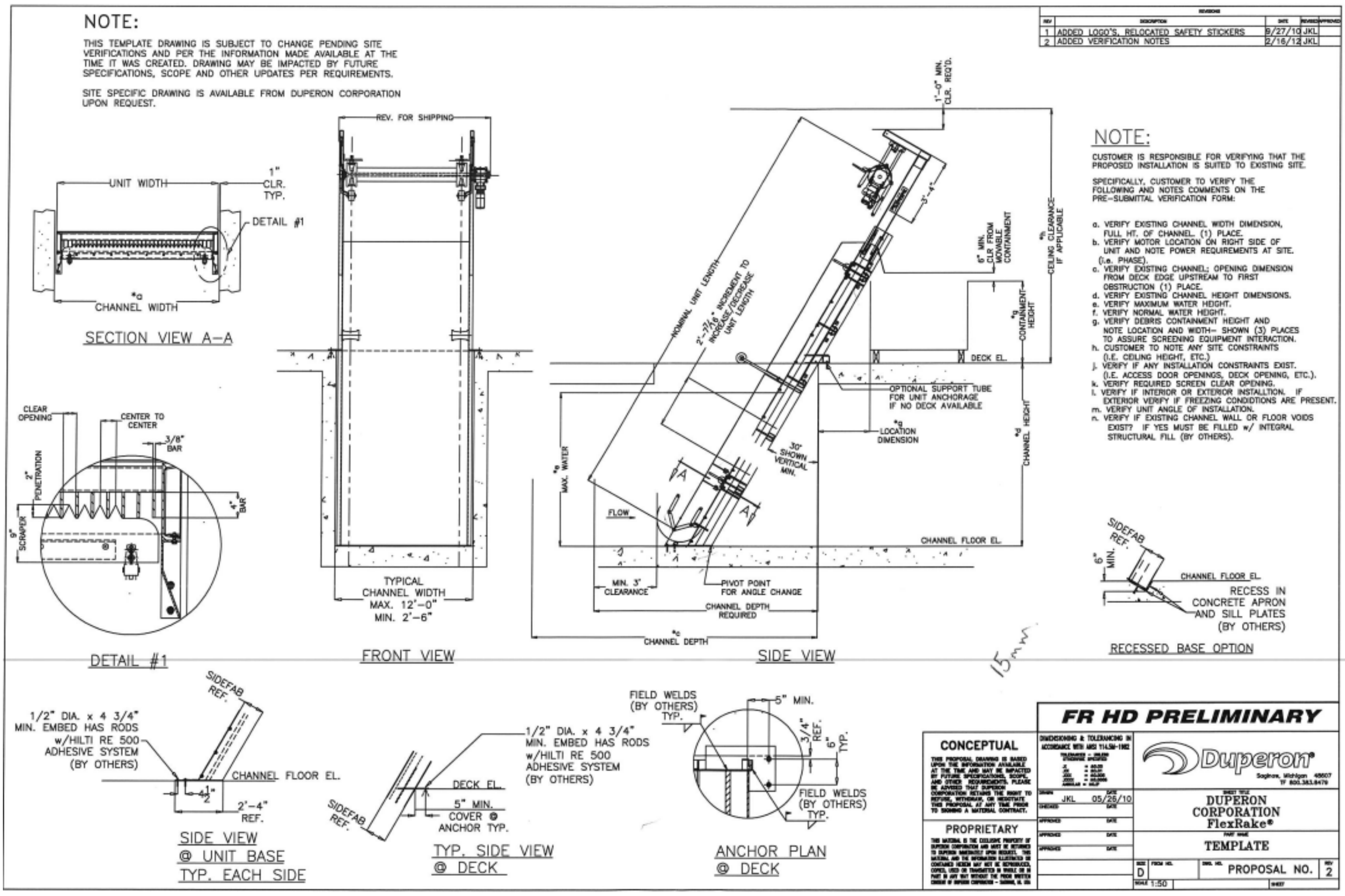


Figure 1: Duperon FlexRake Automated Screen Cleaner

Electric Screens

Electrical Barrier Screen Costs Estimates

Basic 12 V Pulsed DC Electric Barrier for Intake Screens

Item	Estimated cost
Initial site visit	$1200
230-230 V isolating transformer	$ 250
0-30V 5A DC power supply	$ 250
Pulsing unit (NIWA or OMH3CRA8E24 timer)	$ 500
Monitoring/alarm equipment (optional)	$ 500
Cabling & probes (recycled power board cable)	$ 300
On/off switch connected to pump relay (electrician)	$1800
Sundries	$ 200
Installation (allow 2 days 2 people)	$4800
Total	**$9800**

Commercial Electrical Guidance System (based upon installation at Motukaraka pump station – Lower Waikato)

Estimated installation and material cost plus on site specialist for design and installation advice:
120,000 € (NZ$185,000.00)

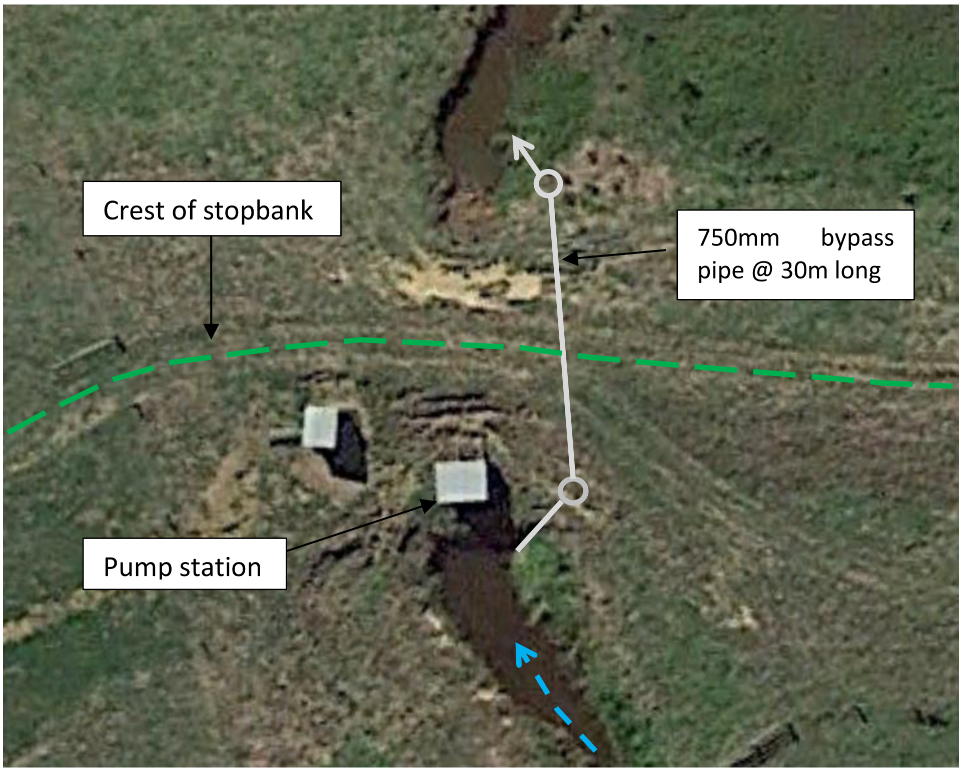
Power use 2-10KW
(Note the probes would need to be set up along the existing debris boom and would be set about 2 m apart – some regular maintenance to remove accumulated weeds is likely to be required.)

Prices at July, 2016

Bypass Culvert

Culvert Bypass Design Estimate

Based upon theoretical design scenario at Meremere Pump Station:



Typical civil construction rates provided by Bloxam Burnett & Olliver Civil Engineers:

- Topsoil strip and stockpile = $5.00/m2
- Topsoil re-spread from stockpile =$6.00/m2
- Hydro mulch/seed = $1.00/m2
- 30m of 750mm concrete culvert = $500/m (includes trenching, bedding, pipe, laying pipe and backfilling with sand)
- 2 x MHs; Minimum size MH for 750mm pipe is 1350mm (ID) = $7000 each (includes excavation, bedding, placing MH and backfill with sand)
- Inlet/outlet structures (headwalls) = 750mm Headwalls = $2000 each (includes excavation, bedding, placing HW and backfill with sand)
- Rock Rip Rap on geo-fabric cloth for stabilising outlet (d50=200mm) = $35/m2
- Installation – excavation through/reinstatement of a stop bank; day rates for 15t excavator = $200/hour, day rates for roller = $150/hour

Indicative costing for culvert bypass installation works based upon above rates:
$65,705.00 excl. gst

Excludes design/consents/supervision.
Excludes Fish Friendly Flapgate (refer ATS pricing matrix)
Excludes any required fish passage measures through the culvert e.g. baffles/spat rope.

Prices at July, 2016.

Trap and Transfer

Upstream Trap & Transfer Programme – Indicative Pricing

(Prepared by J Boubée – NIWA)

<u>Upstream Trap and Transfer</u>

- Trap and transfer would be required where it is not possible (or too expensive) to build a fishway that would allow fish to reach the upstream habitat.
- Trap and transfer can be made with a partially submerged fish trap set downstream of pumps or with a trap and ramp set on the stop bank.
- In some situation it may be possible to transfer the fish caught at another location (but still within the same catchment).
- When a ramp is involved only "climbing" fish species such as kokopu or elvers will be able to be transferred.
- Ramps have the advantage of minimising the risk of transferring pest species.
- Where the manual handling and transfer of fish is necessary a permit from MPI, DoC and iwi partners is required.
- Monitoring and reporting is usually a requirement of such permits.

<u>Fish passes</u>

- In some cases it may be possible to build a fishway that will allow fish to reach the upstream habitat without handling.
- No permit is required for such operation although some monitoring is still advisable to ensure the system is effective and remains so.
- The cost of building a fishway for climbers is similar to that of a trap and transfer system but in the long term will be cheaper as monitoring will be less onerous.
- The cost of building a fishway for swimmers will be site specific and more expensive (probably 1.5 to 2x the cost of a system for climbing fish species).

Upstream Trap and Transfer Costing Schedule

	Resource	staff 1 (h)	Staff 2 (h)	advisor (h)	contractor	vehicle (days)	vehicle (km)	fees	material
	Rate	50	50	150	1	165	0.7	1	1
design	permit			10					1500
	liaison			16		2			
	site visit			16		2			
	H&S Training			16		2			
	H&S plan			16					
	design of trap			16					
	sourcing of material			16					
	contractor visit/pricing			8		1			
	staff search & appoint			16		2			
construction	water pump								2000
	hose								500
	water tank								2000
	holding tank								1000
	ramp								5000
	outlet pipe								500
	taps etc.								800
	construction			16	10000	2			5000
training	site visit and planning	8	8	8			100		
	H&S training	8	8						

running of program	wages 4 hrs 2 x /week - Dec to Feb)	50	50				5000		
	check visits (allow 3)			24		3			
	buckets								100
	scales								1200
	recording form								250
	cell phones								500
	ID books								100
reporting	data entry	8	8	24		2			
	graphing and reporting			40					
	Total Y1	74(h)	74(h)	242(h)	$10000	16(days)	5100(km)	0	20450
	Cost Y1	3700	3700	36300	10000	2640	3570	0	20450
	Grand total Y1								**$80,360**
	Total subsequent years	74	74	144	0	11	5100	0	2150
	Cost subsequent years	3700	3700	21600	0	1815	3570	0	2150
	Grand total Y1								**$36,535**

Downstream Trap & Transfer Programme – Indicative Pricing Table
(Prepared by J Boubée – NIWA)

- The objective is to catch downstream migrants upstream of the pump and manually transfer them across the pump station.
- The downstream migration of shortfins and longfins occurs mostly during rain events in autumn (January to June). Some longfins also migrate in spring (October to December).
- The best way to catch these migrants is to stretch a net (with a central or side trap) across the channel at night during autumn rain events.
- As there is much debris moving at the same time as the eels the net will need regular clearing through the night.
- It may also be possible to deploy a net or trap in front of the pumps screen to catch the eels that accumulate there.
- Because it is illegal to hold more than seven eels without a permit, and in the Waikato the catch of migrant eels is forbidden, a permit will be needed from both MPI and iwi partners.
- It would be best to contract commercial fishers to do this work.
- For monitoring purposes the eel capture need to be identified measured and weighed and the eye diameter measured (the later to determine migration status).
- To do the measurements eels will need to be anaesthetised.
- Reporting is likely to be a requirement of the permit.

Downstream Trap and Transfer

		contractor (d)	Staff 2 (d)	advisor (h)	vehicle (d)	Vehicle (km)	boat (d)	material
	rate	500	500	150	165	0.7	300	1
Downstream passage								
Design	permit			5				1500
	liaison			8	1			
	site visit			8	1			
	H&S Training			16	2			
	H&S plan			8				
	Nets	1		8				5000
	contractor visit/pricing	1		8	1			
	staff search & appoint	1			1			
Training	site visit and planning	1	1	8		100		
	H&S training	2	2			200		
Running of program	wages allow 6 trip of 2 days each	12	12			1800		
	check visits (allow 2)			20	4			
	buckets							100
	scales & micrometre							1500
	anaesthetic							500
	recording form							250
	bins							900
Reporting	data entry	8		8	2			
	graphing and reporting			30				
	Total Y1	26	15	127	12	2100	0	9750
	Cost Y1	13000	7500	19050	1980	1470	0	9750
	Grand total Y1							**$52,750**
	Cost subsequent years							**$43,000**

Note: Substantial saving could be made if the two programs are combined or if more than 1 site are involved.