Connectivity assessment for migratory fish in the Middle Creek catchment, Kaikōura coast

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WATERLINK

Cover photograph:
Schoolhouse Road culvert on Luke Creek in the Middle Creek catchment, Kaikōura Plains.
Photo: S. Orchard

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1. Introduction

1.1 Background

The Environment Canterbury (ECan) Regional Fish Habitat initiative provides a coordinated region-wide approach to identifying, prioritising and remediating fish habitat. The regional initiative supports the goals of the Canterbury Water Management Strategy, Canterbury Regional Policy Statement, and Canterbury Land and Water Regional Plan (Environment Canterbury 2013, 2017). Identifying opportunities for habitat improvement will help to achieve targets for improving the health and integrity of streams and rivers in the region. Within this context, there is a particular need to assess barriers to fish passage which is important consideration for the management of migratory fish (Franklin et al. 2018). This contributes to the conservation of species that rely on waterway connectivity for completion of their life cycle. These species include the five diadromous galaxiids that contribute to New Zealand's whitebait fishery which migrate from the sea as post-larval 'whitebait' in search of suitable freshwater habitats upstream (McDowall 1984).

This report summarises a series of investigations designed to support management decisions on the status and potential remediation of barriers to fish passage in the Middle Creek catchment on the Kaikōura plains. The catchment was the subject of previous fish passage assessments by ECan staff using the NIWA fish page assessment tool that identified high risk fish passage barriers in Luke Creek and less severe connectivity barriers elsewhere (Fig. 1), in addition to an obvious barrier associated with a headwall at the Mt Fyffe Road bridge (Fig. 2). The New Zealand Freshwater Fish Database (NZFFD) includes records of five species in the Middle Creek catchment based on a single survey completed in 2017 in the reach adjacent to State Highway 1.

1.2 Scope and objectives

The primary objectives of the project were the development of a connectivity assessment to evaluate environmental risks and benefits associated with potential fish passage interventions at identified barriers. This requires attention to the potential benefits, as well as the potential downsides of improving fish passage, as recommended in current guidance (Franklin et al. 2018). Because migratory species are already known in the catchment (particularly īnanga and redfin bully), the major unknowns related to the composition of fish populations upstream of the barriers, and the need for improved information on the diversity of species in the catchment as a whole. Secondary objectives included further assessment of potential connectivity barriers, particularly those at Mt Fyffe Road on Middle Creek and Schoolhouse Road on Luke Creek, and recommendations for remediation following the assessment of fish population trends.

The scope of the project was limited to a series of trap-based surveys of fish populations at a representative set of reaches (n=8) spread across the catchment, supported by a series of site visits to establish these survey locations and assess the previously reported barriers. Other aspects of waterway connectivity were also considered in these site visits, particularly in relation to drying reaches and channel configurations in tributary streams and drains.

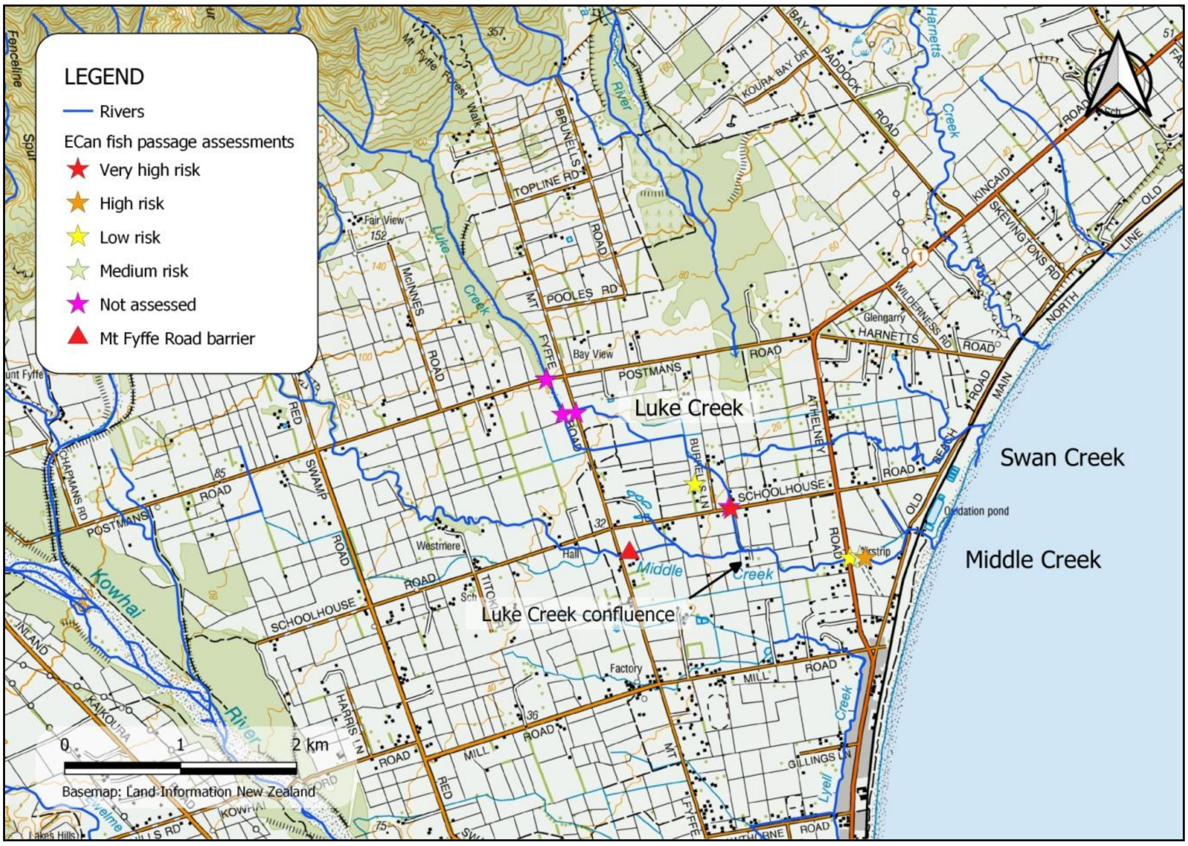

Fig. 1. Overview of the lower Middle Creek catchment on the Kaikōura plains showing the location of instream structures assessed by Environment Canterbury as potential barriers to migratory fish.

Fig. 2.A suspected fish passage barrier at Mt Fyffe Road bridge associated with a vertical headwall.

2. Methods

2.1 Survey area

The location of fish passage barriers were assessed via walkovers from access points throughout the catchment with the assistance of ECan staff members and local landowners. The most upstream reaches assessed were foothill tributaries at the base of the Seaward Kaikōura Range. In Luke Creek, the reach upstream of the river protection works at Postmans Road was not assessed due to the relatively long section of dry streambed in this area that effectively limits surface water connectivity in all but high flood flows. In the mid-section of Luke Creek, permanent surface water connections were traced upstream from Burrells Lane to a series of spring-fed farm drains which are likely fed by recharge from Luke Creek and adjacent catchments on the hillslopes above.

Following discussions with ECan staff members, eight reaches for fish surveys were selected to meet the project objectives based on results from the site visits and location of potential barriers. These included four survey reaches below the two major mid-catchment barriers (Middle Creek at Mt Fyffe Road and Luke Creek at Schoolhouse Road), and four above (Fig. 3).

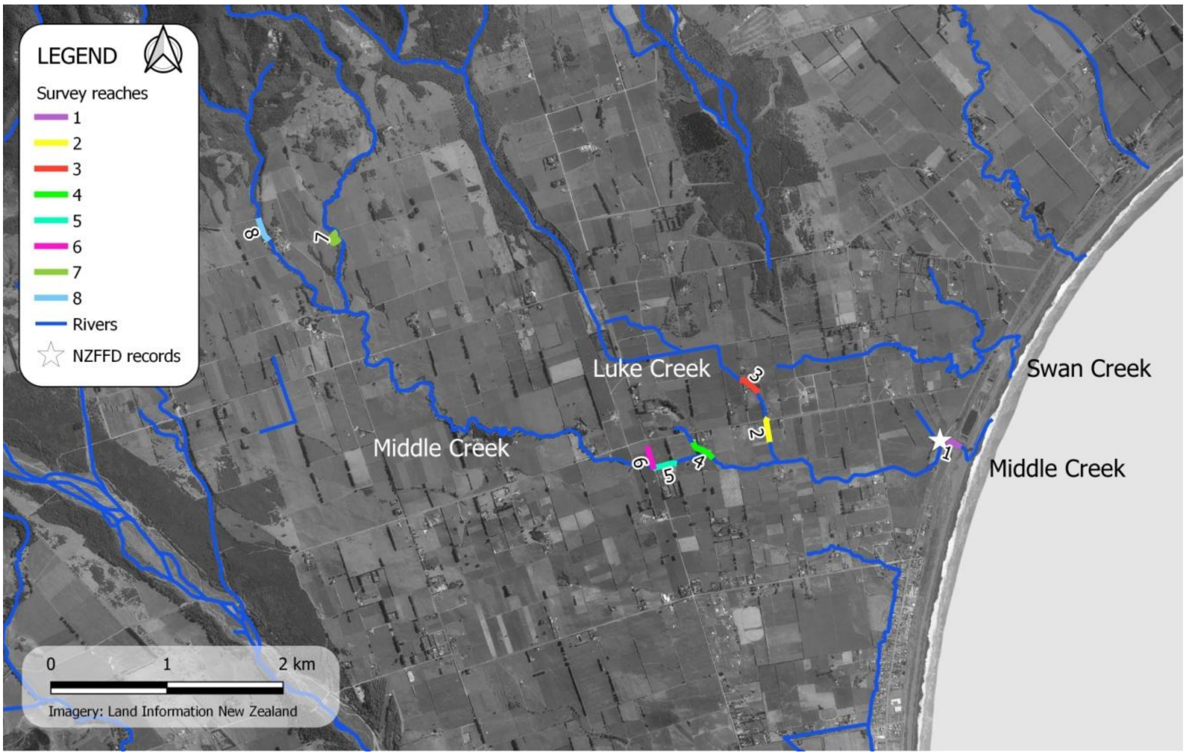

Fig. 3. Location of fish survey sampling reaches.

2.2 Fish surveys

Fish-trapping surveys were completed in 150 m reaches following Joy et al. (2013) using 12 Gee minnow traps (GMT's) per reach. Traps were deployed during the afternoon for an overnight set, and retrieved the following morning. On most sampling dates, two survey reaches were sampled concurrently with the first set of surveys being positioned above and below the barrier at Mt Fyffe Road (Table 1).

Table 1. Fish survey sites and times.

Sampling reach	Survey date	Waterway	Upstream coordinates		Downstream coordinates		Set time
			X	Y	X	Y	
1	25/1/21	Middle Creek at Old Beach Rd	1656381	5309238	1656529	5309212	1400
2	14/1/21	Luke Creek lower	1654872	5309428	1654898	5309267	1800
3	12/1/21	Luke Creek upper	1654675	5309765	1654789	5309686	1700
4	25/1/21	Donegal House Creek	1654252	5309217	1654377	5309144	1700
5	11/1/21	Middle Creek below Mt Fyffe Rd	1653918	5309028	1654079	5309066	1600
6	11/1/21	Middle Creek Mt Fyffe Rd drain	1653854	5309180	1653899	5309030	1730
7	13/1/21	Middle Creek upper eastern trib.	1651158	5311038	1651184	5310978	1500
8	13/1/21	Middle Creek upper western trib.	1650519	5311145	1650576	5310996	1700

The fish-trapping surveys and site walkover surveys were conducted progressively to enable results from initial surveys to inform decisions on site selection for others. This helped to build up a picture of features of interest for connectivity conservation within the constraints of the available time and resources. Examples include assessment of previously reported fish passage barriers on Middle Creek near State Highway 1 as low risk structures on the basis of site visits and capture of īnanga upstream of these sites. One of these sites (previously assessed as 'medium risk') has recently been remediated through installation of a bottom slope (Heath Melville, pers. comm.) which has improved connectivity for poor climbers such as īnanga (Fig. 4).

Fig. 4. A remediated section of Middle Creek where a bottom slope was installed at a small pour-over downstream of the State Highway 1 bridge. Photo: Heath Melville.

3. Results

3.1 Fish surveys

Fish were captured in five of the survey reaches (sites 1, 2, 4, 5 and 6) with no fish being caught in the other three. A total of five fish species were recorded across the catchment as a whole (Table 2). These included four diadromous species that general rely on connectivity to the sea: īnanga (*Galaxias maculatus*), torrentfish (*Cheimarrichthys fosteri*), Shortfin eel (*Anguilla australis*), and longfin eel (*Anguilla dieffenbachia*) (Fig. 5).

Table 2. Fish survey results. Grey shading indicates sites upstream of fish passage barriers that are being considered for remediation.

Survey sites	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Īnanga	39	0	0	1	4	0	0	0
Common bully	3	0	0	0	0	0	0	0
Torrentfish	0	0	0	1	0	0	0	0
Shortfin eel	1	0	0	2	0	0	0	0
Longfin eel	0	1	0	0	0	1	0	0
Site totals	43	1	0	4	4	1	0	0

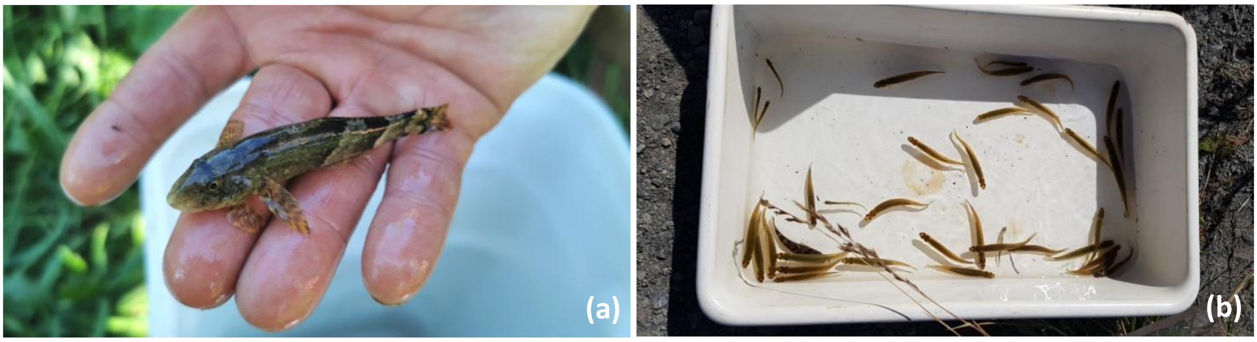

Fig. 5. (a) Torrentfish (*Cheimarrichthys fosteri*) caught in a riffle habitat at site 4. This is one of the few sites in the lower catchment that features native forest cover in the riparian zone. (b) Īnanga (*Galaxias maculatus*) caught at site 1 a short distance above the river mouth.

3.2 Relationship with suspected barriers

In Middle Creek, only one fish (a longfin eel) was caught above the obvious barrier at Mt Fyffe Road. There were no fish caught in either of the upper tributary reaches of Middle Creek (sites 7 and 8) despite the presence of suitable habitat for migratory species such as banded kōkopu (*Galaxias fasciatus*) which was considered to be potentially present prior to this project (Fig. 6).

In Luke Creek, no fish were caught upstream of the potential barrier at Schoolhouse Road (Fig. 7a) despite the presence of suitable habitat for species such as īnanga. This includes a series of spring-fed farm drains featuring dense overhanging vegetation (e.g., *Carex* species) along the margins (Fig. 7b, c).

The overall pattern of fish survey results suggests that very few fish are present upstream of the barriers in Middle Creek and Luke Creek despite the presence of suitable habitat and the presence of migratory species downstream (Table 2). Options for the remediation of these barriers are included in Appendix 1.

Fig. 6. (a) Upper reaches of Middle Creek at the foot of the Seaward Kaikōura range.

Fig. 7.(a) Luke Creek upstream of Burrells Lane. (b) and (c) two views of the culvert in Luke Creek at Schoolhouse Road.

4. Discussion

4.1 Fish distribution

This assessment recorded five fish species in the catchment (Table 2), and redfin bully *(Gobiomorphus huttoni*) has also been previously recorded in the lower reach (vicinity of site 1). Tuna (eels), īnanga, torrentfish and redfin bully all rely on connections to the sea to complete their migratory life cycles. Strong patterns in the spatial distribution of fish-trapping results were observed in relation to the position of instream structures that present barriers to fish passage. These results provide evidence to support decisions on the remediation of these structures to improve connectivity for the migratory species present in the catchment.

The key results may be summarised in terms of the potential risks and benefits of barrier remediation, as follows:

- evidence from the four study sites upstream of the barriers of interest suggests the absence of vulnerable fish populations upstream of these points. Therefore, improvement of connectivity at these points is not expected to result in downside risks for native fish species (whilst noting the potential for effects on other species that have not been assessed).

- evidence from the lower catchment sites shows that there are at least five migratory species that may benefit from connectivity improvements. These benefits relate primarily to the accessibility of additional habitat. In this case, there is a considerable amount of in-stream habitat available in both Middle and Luke creeks upstream of the barriers of interest. Currently the upstream extent of the available habitat (with connectivity improvements) is influence by the seasonal characteristics of drying reaches in most of the tributary streams, and also by the presence of additional fish passage barriers higher in the catchment. These include perched culverts in the Middle Creek headwaters upstream of survey sites 7 and 8. Although these are of lesser priority for attention while barriers remain in place downstream, they may warrant consideration in the future to restore connectivity to forested habitat in the headwater streams. However, the effect of drying reaches as natural barriers should also be considered in relation to the merits of culvert remediation in these upper tributary streams. Despite this, simple fish ladders (e.g., rubber ramps or mussel spat ropes) are likely to offer cost effective options for connectivity improvements in both of the above cases. Any such work should proceed in conjunction with monitoring in the reaches upstream and downstream of these points following current guidance in Franklin et al. (2018).

4.2 Assumptions and limitations

Limitations of this study in relation to its objective of providing a comprehensive connectivity assessment include the inability to sample all reaches and habitats of interest. The most significant omissions are small foothill streams in forested habitat of which only two were sampled. Reaches of potential interest that were not sampled include the upper Luke Creek catchment, the western tributary of Middle Creek that crosses Red Swamp Road, and the Middle Creek mainstem between Schoolhouse and Postmans roads which contains a sizeable forest remnant on private land. For the most part, however, many of these waterways have emphemeral flow patterns with periodically dry reaches being commonplace. For this reason it was expected that fish species of interest might be found in the reaches immediately below dry sections and other barriers where they are more likely to have concentrated if upstream migration was occurring to that point over time.

Seasonal aspects of īnanga distribution

In this study, the timing of the surveys during the summer months coincided with the īnanga spawning season in which mature adult fish are expected to have migrated downstream (Benzie 1968; Orchard & Schiel 2021). This seasonal effect likely explains the low numbers of adult īnanga caught at lower catchment sites for which there are no obvious connectivity issues (sites 2, 4 and 5) in comparison to site 1 where īnanga were more abundant than elsewhere. However, field observations also showed that medium-sized fish (e.g., 6-8 cm length) were relatively abundant in the reach below State Highway 1 (S. Orchard, H. Melville, pers. obs.).

These seasonal migration considerations suggest that larger populations of īnanga may be present upstream from the rivermouth at other times of the year, particularly in the bigger size classes. The same effects may also influence the likelihood of fish being found above the suspected fish passage barriers even though the two barriers of most interest are located relatively low in the catchment in Middle and Luke creeks respectively. These limitations could be further resolved by sampling for īnanga at other times of the year. In the context of this connectivity assessment, however, this additional information is not necessary for decision-making on connectivity improvements given the lack of evidence of vulnerable fish populations upstream of these barriers. Instead, additional monitoring is recommended in the future to assess the outcomes of remediation work, to include attention to these aspects (for example, by sampling at more than one time of the year above and below the remediated barriers).

Sampling method

Other limitations to note in the current study include the choice of sampling method which has a bearing on the detectability of the species that were ultimately recorded. In particular, there is a bias towards detection of small bodied fish inherent in the use of minnow traps as a survey method (Joy et al. 2013). In addition, there was a lack of temporal replication in each study reach. These limitations are important to bear in mind when drawing conclusions across these relatively extensive stream catchments.

5. Concluding remarks

Reducing the impacts of man-made connectivity barriers is an important aspect of conservation for migratory species. There is a critical need to restore the longitudinal connectivity of degraded river systems that have suffered from the cumulative impacts of dams, water abstraction channelisation, drainage and associated infrastructure. In this context, ecological engineering can facilitate the re-establishment of native fish and other aquatic species that have lost access to suitable habitat due to connectivity effects. These are particularly likely to impinge on migratory species due to their specific life cycles.

The major caveat in pursuing connectivity conservation improvements of this type relates to the potential for other non-migratory species to have become established in disconnected habitats upstream of barrier since they offer potential refuges from predatory species downstream. In the New Zealand context such predators includes larger native fish species and introduced species such as salmon and trout (McIntosh et al. 2010). These considerations are important in the Middle Creek catchment since large brown trout are present in the lower reaches and juveniles are frequently observed in the vicinity of the SH1 bridge (ECan historical data, S. Orchard pers. obs.).

In this case, we have demonstrated the application of a connectivity assessment to support decisions on the remediation of barriers to upstream fish migration that are associated with poor infrastructure design. Such assessments serve two key purposes; evaluating the severity of suspected fish passage barriers for the species that are present and providing evidence to assess risks associated with the potential for undesirable effects on non-target species upstream. Limitations to note include the balance that must be struck when determining the level of resourcing to be allocated to this investigative work in advance of decisions being made on engineering work. Aspects that factor into this decision include the size and complexity of the catchment above and below the suspected barriers, and characteristics of the species and habitats present, both of which have a bearing on the scope of the information ideally required. Additional considerations include the availability and currency of previous records, and decisions on sampling approaches (and their inherent limitations).

In this example, the choice of eight survey reaches in a range of habitat types and stream network positions above and below the suspected barriers offered a reasonable compromise between robustness of the assessment and the resources available. This approach provides a clear illustration of the concept of a connectivity assessment that provides information on both the risks and benefits of barrier remediation proposals. The results have yielded a relatively consistent picture of fish distribution patterns in relation to the suspected barriers that will be helpful in assessing intervention options for the ECan Regional Fish Habitat initiative.

6. Acknowledgements

Thanks to Heath Melville and Chloe Armour at Environment Canterbury, and to local landowners for facilitating access to the survey reaches and sharing their knowledge of the waterways.

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Appendix 1. Barrier remediation options using close-to-nature designs

The following sections outline potential options for the remediation of fish passage barriers on Middle Creek at Mt Fyffe Road and Luke Creek at Schoolhouse Road following close-to-nature principles (FAO 2002).

5.1 Middle Creek at My Fyffe Road

The recommended option involves construction of a 'bottom ramp' (constructed rapid) using local rock. The configuration of the streambed downstream of the barrier suggests this would be relatively straightforward since there is ample room for attaining a suitable finished gradient (e.g., 1:15).

Following guidance in FAO (2002), a boulder bar construction is recommended in view of the ample room available (Fig. A1). In this design, the rock ramp is broken into sections by boulder bars to form a pool-drop configuration. This creates excellent resting places for fish migrating up the ramp and can help to retain sediment on the ramp as a whole which is important to assist the build up of fines to plug the gaps between the placed rock. The main engineering requirement involves construction of a low-flow channel that retains water on the ramp e.g., by using larger rocks on the flanks. Other construction points include the need to embed a series of large rocks (e.g., either side at the position of each of the boulder bars) to anchor and protect the entire structure against movement during high flows (FAO 2002).

A schematic of the site is provided (Fig. A2) that may help to guide rock placement. However, this should be adapted to suit the materials available and an adaptive approach is recommended whereby the structure is monitored for performance and amended as needed over time. Particular emphasis should be placed on ensuring the ramp retains sufficient water depth which is partly dependent on fines having accumulated to prevent water from percolating through the structure, and otherwise dependent on the configuration of the channel cross-section (i.e., invert) at low flows. Other aspects of design and installation should follow the current New Zealand guidance (Franklin et al. 2018).

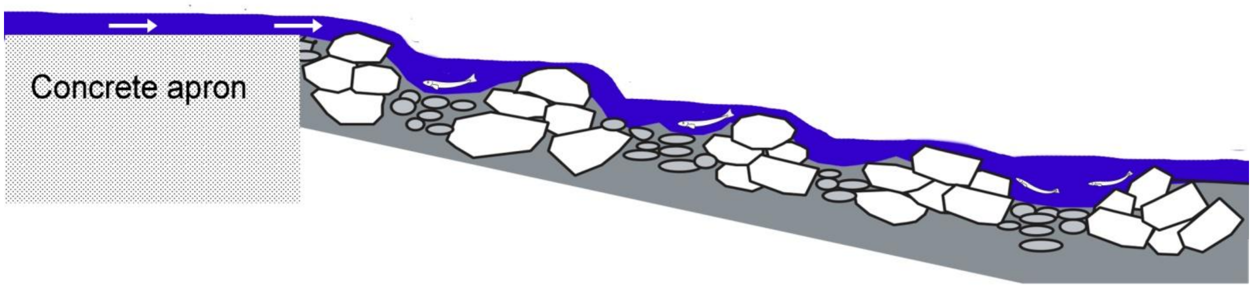

Fig. A1. Rock ramp construction using a boulder bar design that breaks uo the ramp into a series of pools. Adapted from FAO (2002).

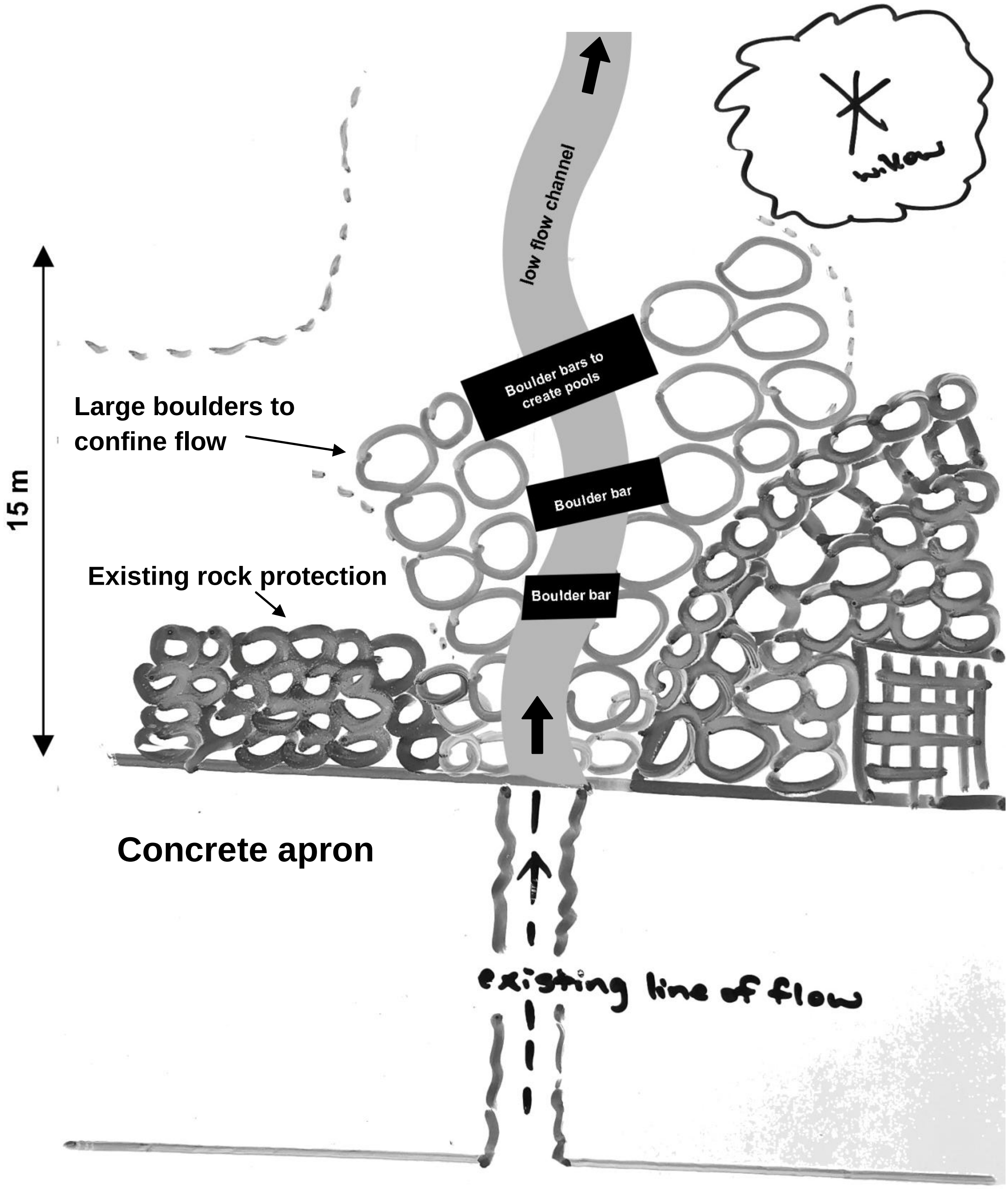

Fig. A2. Schematic of a constructed rock ramp at Mt Fyffe Road positioned downstream of the existing concrete apron. The finished ramp length should be 15 – 20 m extending from the apron lip to existing streambed level downstream. The vertical drop is approximately 1.2 m.

5.2 Luke Creek at Schoolhouse Road

This perched pipe end is relatively straightforward to remediate by building upon the existing rock protection nearby. Placement of a line of additional large rocks in the pool immediately below the pipe end, including one large partially embedded boulder either side, should be sufficient to enable a short rock ramp to be built around the pipe end. As the free-fall drop was observed to be only 10-15 cm in typical flows, this ramp only needs to be 1 - 2 m in length to assist fish access to the barrel of the pipe.

Field observations also suggested that the combined effects of current speed and pipe length may prove to be a further limitation for weak swimmers such as īnanga. However, it is recommended that the perched pipe end be remediated as the initial priority followed by re-assessment of this aspect to determine if any further enhancements are necessary (or otherwise). Overall, this should present a relatively straightforward opportunity to improve connectivity for migratory fish.