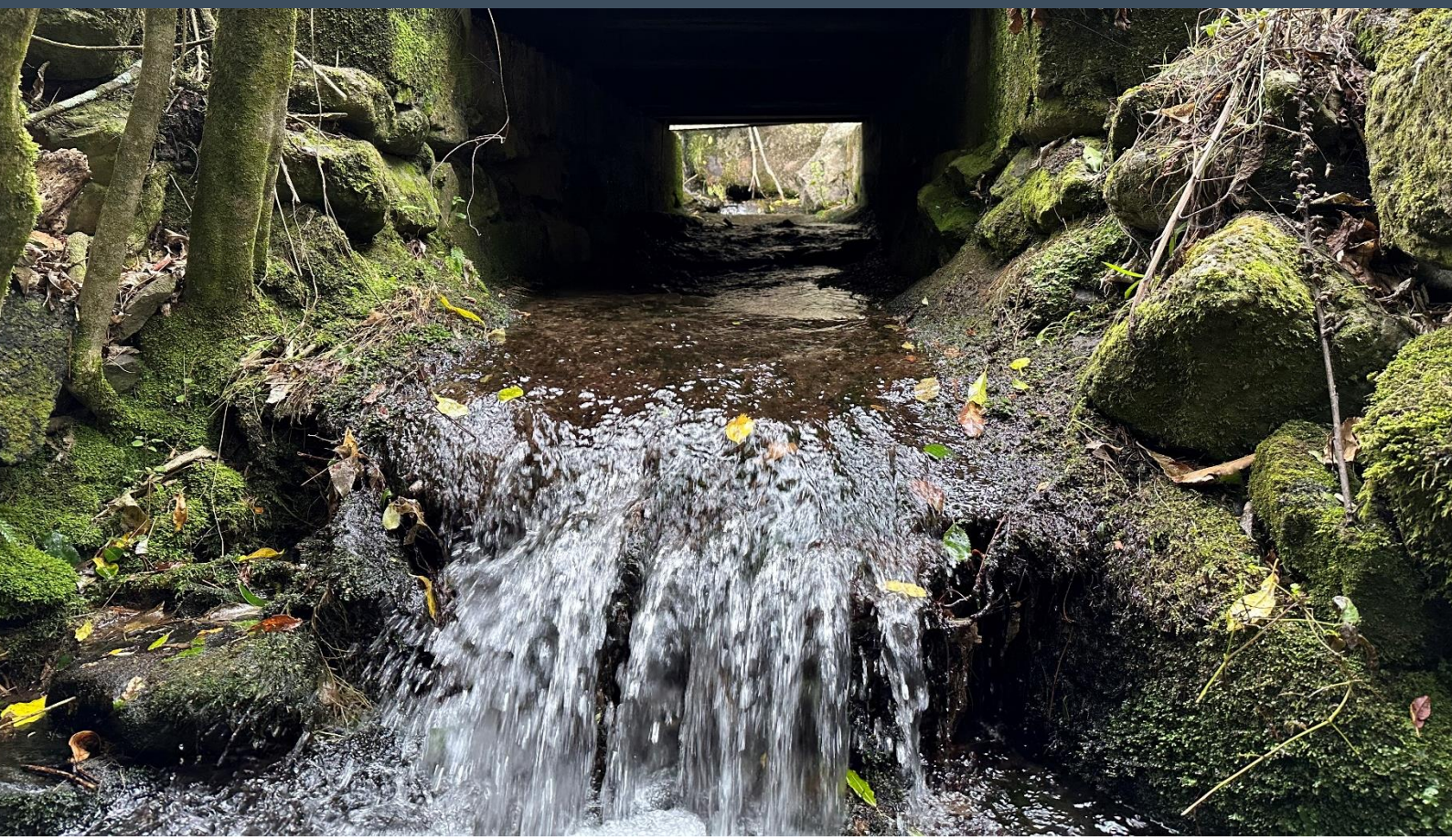
Christchurch Fish Barriers Update: 2023

October 2023

Prepared for:
Christchurch City Council



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EXECUTIVE SUMMARY

Many of New Zealand's migratory native fish species are impacted by artificial barriers such as culverts and weirs. To address this pressure locally, Christchurch City Council developed a fish barrier prioritisation database in 2021, which was updated in 2022. This report presents the results of another round of updates to the barrier prioritisation database. This update includes data from fish passage assessments and barrier fish surveys commissioned by the Council and completed over the 2022–23 summer, as well as all new data available since the 2022 update.

The updated prioritisation database included 2,554 structures, of which, 1,332 were identified as Council assets. A total of 19 Council structures were identified as high priorities for remediation (compared with 11 prior to the update), with a further four identified as high priorities for fish surveys (compared with two prior to the update). The substantial increase in the number of structures with a high priority for remediation was largely due to an update to the prioritisation model. The model update allowed for structures outside of the Council's priority catchments to achieve a high priority for remediation, which was not possible prior to the model update. In total, eight of the 19 structures with a high priority for remediation were located outside of priority catchments.

Since the initial prioritisation project, the number of Council assets in the database requiring fish passage assessment has decreased by 20%, with 755 structures remaining unassessed following the latest update. This includes 287 structures that have a low or very low priority for assessment, because they likely present a low risk to fish passage (e.g., bridges). This reduction is largely due to the systematic barrier assessments commissioned by the Council, targeting high priority structures. Of the structures still requiring fish passage assessment, there are 18 that are considered a high priority for fish passage assessment. The remaining priority structures comprise those that have been recently commissioned or remediated, and those that were not identified in the Council's GIS databases during the previous prioritisation rounds.

In addition to the Council's structures, 22 structures were identified as high priorities for remediation or fish surveys but were not recognised as being owned by the Council. Most of these structures were privately owned, and often associated with farms in the Banks Peninsula area. These private structures are relevant to the Council, as they may limit the success of Council remediation projects within the same catchments. A further 113 structures in the database have been identified as high priorities for fish passage assessment, but with unknown ownerships. Some of these structures are on Council land and are suspected to be unrecognised council assets.

Based on the results of the updated prioritisation database, key recommendations include: investigation into remediation options for the 19 Council structures with high remediation priorities; carrying out fish surveys at the four Council structures that are a high priority for fish surveys; completing fish passage assessments at the 19 Council structures that are high priorities for fish passage assessment; ownership reviews for the 113 structures with unknown ownership that are a high priority for fish passage assessment; and discussion with Environment Canterbury regarding options for remediating privately owned structures that are a high priority for remediation.

1. INTRODUCTION

Many of New Zealand's native fish species are diadromous, moving between freshwater and marine environments to complete their life histories. Several of these species are also threatened with extinction, or at risk of becoming so (Dunn *et al.* 2018). One of the key pressures facing New Zealand's migratory fish species is instream barriers, which may limit access to upstream habitats or disrupt reproductive migrations. Instream barriers may be natural, such as waterfalls, but often include artificial structures, such as culverts, weirs, or flap gates. In a recent study, Franklin *et al.* (2022) reported that access to approximately half (48%) of New Zealand's river network may be limited for migratory fish species, due to artificial instream barriers. This pressure on New Zealand's migratory fish fauna has been recognised by the National Policy Statement for Freshwater Management (NPSFM; Ministry for the Environment 2020), through the inclusion of requirements for councils to create a fish passage action plan (Section 3.26; Ministry for the Environment 2020). This action plan must include a work programme to identify potential fish barriers and to prioritise their remediation. To satisfy these requirements, Christchurch City Council (the Council), has carried out a series of prioritisation projects to aimed at identifying, assessing, and remediating potential fish barriers.

The initial project was completed in 2021, and involved the construction of a prioritisation database (Instream Consulting 2021). Briefly, this project involved combining fish passage assessments from the Fish Passage Assessment Tool database (FPAT; Franklin 2022) with information on instream structures from the Council's GIS databases. A decision tree prioritisation model was then developed, which categorised and prioritised structures in the database. All structures were assigned an alphanumeric code, for which, the letter denoted the required action, and the number denoted the priority. Structures were categorised as either requiring: a fish passage assessment (A), a fish survey (F), or, if there was adequate information on the previous two categories, remediation (R). Each structure was also assigned a priority score, ranging from 1–5 (low–high). For the purposes of this report, we consider structures with a priority score of 4 or 5 to be 'high priority' for action. In 2022 an update to the prioritisation database was commissioned by the Council. This involved fish passage assessments and fish surveys at high priority structures, identified during the initial prioritisation project. This data was used in combination with all new FPAT assessments in the district to re-run the prioritisation model.

This report describes the results of a second update to the prioritisation database. This update includes information from barrier assessments and barrier fish surveys commissioned by the Council and completed by Instream over the summer of 2022–23. It also includes all new information available in the datasets associated with the prioritisation model, including the Council's GIS layers, the FPAT database, and the New Zealand Freshwater Fish Database (NZFFD; Richardson 2005). Finally, it includes an ownership review of high priority structures that were of unknown ownership, and were identified during the previous prioritisation update.

2. METHODS

The following methods are based on those used during the previous update to the Council's barrier prioritisation database, described in Instream Consulting (2022), with any differences outlined in the sections below.

2.1. Summer 2022–23 Barrier Assessments

Over the summer of 2022–23, 161 Council-owned structures were visited for barrier assessments. The methods and results of these assessments are summarised, in Appendix 1, with the data included in the prioritisation described below.

2.2. Barrier Fishing

Fish surveys were undertaken in relation to three Council-owned culverts in March 2023 (Table 1, Figure 1). The culverts in Sheppards Drain and Church Gully Stream were identified as high priorities for fish surveys during the previous prioritisation round (Instream Consulting 2022). A fish survey was carried out at the Cashmere Stream culvert at Sutherlands Road, to evaluate whether fish passage had improved following the culvert's recent replacement and the addition of fish baffles to enhance fish passage.

Table 1: Fish sampling locations and associated instream structures, ordered from north to south. Eastings and northings are in New Zealand Transverse Mercator 2000 projection.

Waterway (Catchment)	Easting	Northing	Structure type	FPAT ID	CCC ID	Methods
Sheppards Drain (Pūharakekenui – Styx River)	1574628	5190070	Culvert with flap gate	134654	SwPipe 37486	Fyke nets
Cashmere Stream (Ōpāwaho – Heathcote River)	1566102	5173995	Culvert	174784	SwPipe 45894	Fyke nets & electric fishing
Church Gully Stream (Whakaraupō – Lyttleton Harbour)	1577660	5168254	Culvert	152008	SwPipe 63196	None[1]

Notes: [1] The fish survey at this location was abandoned due to the presence of substantial natural barriers downstream, including a 6 m waterfall.

Fishing methods at each of the sites were selected based on the habitat present. Five unbaited fine mesh fyke nets were set both upstream and downstream of the culverts in Sheppards Drain and Cashmere Stream. The nets were left overnight and retrieved in the morning. Electric fishing was also completed at the Cashmere Stream culvert, including a minimum of 50 m of waterway length and a minimum area of 50 m², both upstream and downstream of the structure. The Sheppards Drain site was too deep to electric fish effectively. The fish survey was abandoned at the Church Gully Stream culvert, as we discovered substantial natural barriers downstream when we arrived to complete the survey, as discussed below in Section 3.1. At each fishing site a New Zealand Freshwater Fish Database card was completed, which includes a range of habitat data, as well as the fishing methods and results. An FPAT re-assessment was also carried out at the Cashmere Stream and Church Gully Stream culverts.

All fish caught were identified to the species level when possible, counted, and their lengths measured[1]. Eels were anesthetised in an ethanol-clove oil solution to aid in their measurement. Anesthetised fish were allowed to recover in bins, before all caught fish were returned to their resident habitats.

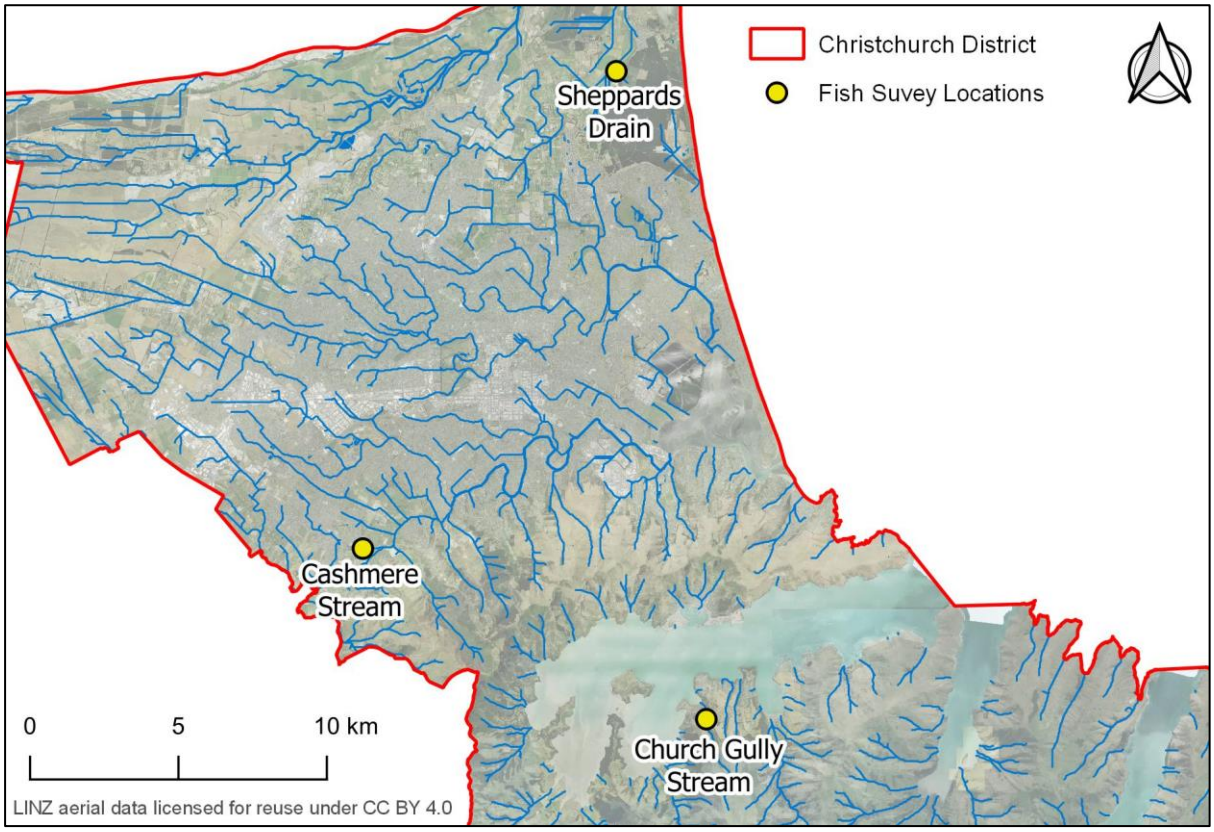


Figure 1: Fish survey locations. See Table 1 for site details.

2.3. Barrier Prioritisation Update

The barrier prioritisation update followed the same general methods as used previously (Instream Consulting 2021; Instream Consulting 2022). These methods are briefly described below, with any differences between prioritisation rounds identified. Data from all online databases was downloaded on 18 May 2023.

Prioritisation began by reviewing the Councils asset GIS layers for those relevant to fish passage, via the publicly available OpenData portal[2]. This review resulted in the inclusion of two new layers, 'WcFord' and 'WsInet', in addition to the layers already included in the database[3]. All Council layers were then checked for structures that were not currently included

[1] Some of the fish from the Sheppards Drain upstream site appeared sluggish, and we suspected that they were suffering from hypoxia (low oxygen). To reduce stress, we avoided anesthetising the eels and only recorded size class measurements to speed up the processing time.
[2] https://gis.ccc.govt.nz/server/rest/services/OpenData
[3] RAMM bridges, 'SwPipe', 'SwValve', 'SwFlowRestriction', 'SwPump', 'WcPumpstation', 'WcValve', and 'WcWeirs'

in the database, which mostly included newly commissioned structures. In total, 50 structures were added to the barrier database through this process.

All new FPAT assessments in the district since the previous prioritisation round were downloaded (75 assessments), filtered for double-ups or inaccuracies, and associated with Council structures when possible (54 of the 75 assessments). Structures that were visited during the summer 2022–23 barrier assessments that were not FPAT assessed (described in Appendix 1) were kept in the database, but were assigned minimum priorities for further action. Reasons for not completing an FPAT assessment included lack of aquatic habitat (i.e., the surrounding channel was dry), or the structure could not be accessed or located. All new NZFFD data in the district was also downloaded, which included 42 new unique sampling events[4].

Once the new data was collated, the automatic prioritisation model was re-run. The prioritisation model was consistent with previous prioritisation rounds, except for one update (Figure 2). The updated model allowed for structures outside priority catchments to achieve an 'R4' prioritisation. This update was recommended by Instream Consulting (2022), and was intended to shift focus beyond the priority catchments, allowing for ecologically significant structures outside of these catchments to achieve a high remediation priority.

The automatic priorities were manually reviewed for all structures with new FPAT assessments, and for structures with updated FPAT priority scores that shifted them between the categories included in the prioritisation model (High, Medium, or Low; Figure 2). For these structures, adjustments were made to their final priority by applying local context and expert ecological judgement, consistent with the previous prioritisation rounds. An 'Adjustment Reason' was provided for any structures whose priorities were manually adjusted, based of those described in Instream Consulting (2022). Structures that had neither shifted between the FPAT priority score categories, nor had any new relevant fish data, did not require manual review. As such, their final priorities remained unchanged from the previous survey round.

Ownership was then reviewed for all structures that were assigned high priorities for remediation or fish surveys. As with the previous prioritisation rounds, we considered 'high priority' structures to be those assigned a score of 5 or 4, in their respective action category (Assessment, Fish Survey, Remediation; Figure 2). Included in the ownership review were 17 high priority structures that were identified during the 2022 prioritisation round and were not recognised as Council assets (Instream Consulting 2022). Ownership reviews involved manually reviewing each of the structures to determine whether the asset was on public or private property, speaking with Council engineers, speaking with relevant contacts at the regional council, and checking for active or expired Environment Canterbury consents in the area.

[4] We are aware that there is a substantial backlog of NZFFD entries submitted and waiting to be approved by the NZFFD administrators.

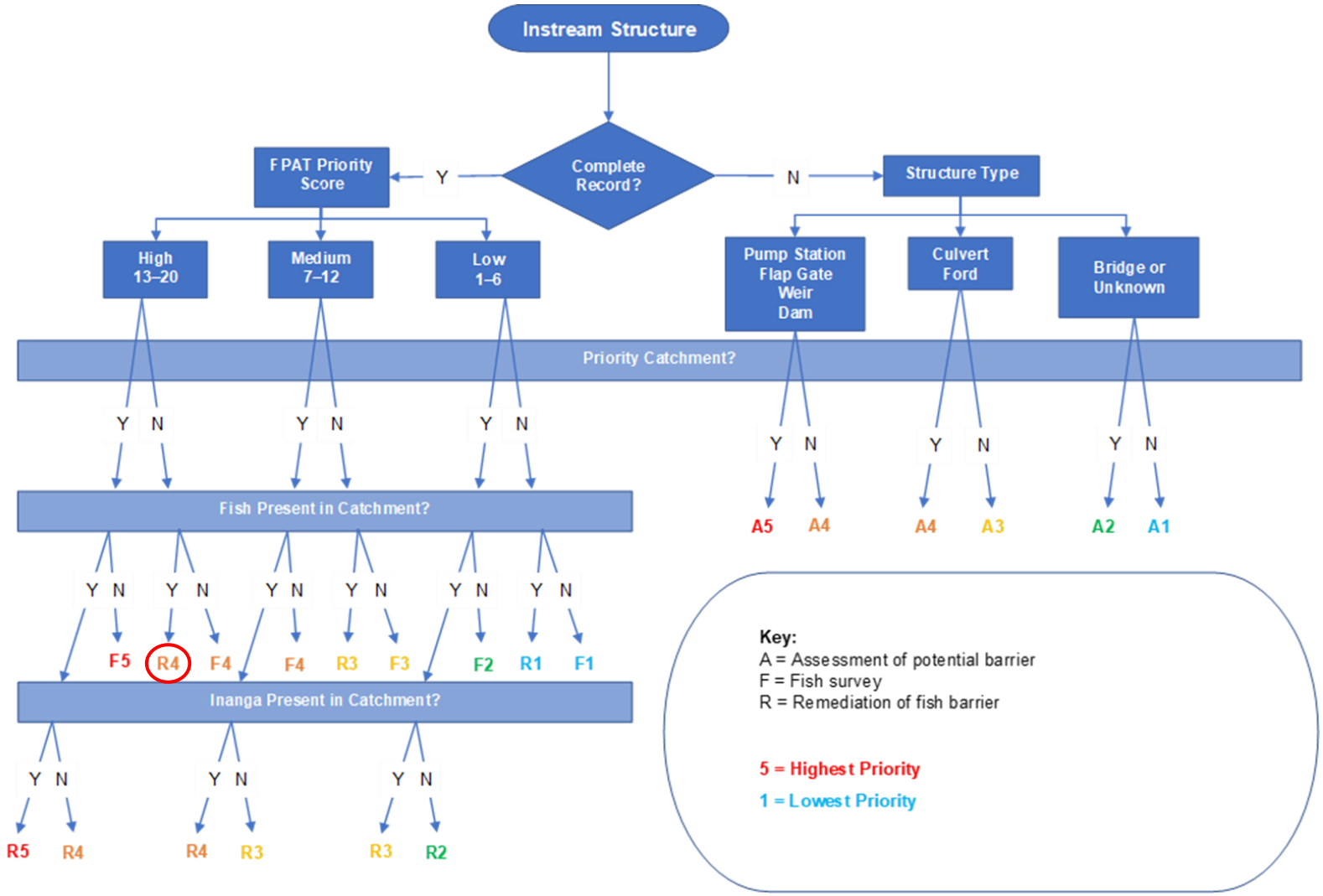


Figure 2: The decision tree model used to assign actions and priorities to structures in the prioritisation database, from updated from Instream Consulting (2022). *Y=yes, N=no. Red circle indicates the updated category, which was formerly 'R3'.*

3. RESULTS AND DISCUSSION

3.1. Barrier Fishing Results

3.1.1. Church Gully Stream

Church Gully Stream is a small hill-fed waterway on Banks Peninsula (Figure 1). It has a steep gradient and a bed that has a mixture of large boulders and bedrock slabs. Immediately downstream of the road culvert, surface flow is lost to the bed, resulting in discontinuous surface flow (see Appendix 2 for site photographs). Approximately 70 m downstream of the culvert is a 6–8 m tall waterfall that is a significant natural fish barrier. The perched road culvert (FPAT ID 152008) presents a very low risk to fish passage compared with the waterfall (FPAT ID 152009). We therefore did not undertake fishing in relation to the culvert, as any fish that could pass the waterfall would easily navigate the comparatively low risk culvert.

3.1.2. Cashmere Stream

Cashmere Stream is a small, spring-fed tributary of the Ōpāwaho – Heathcote River in Christchurch city (Figure 1). Well-established native plantings border the waterway upstream of the Sutherlands Road culvert, while new native plantings occur downstream (see Appendix 2). The new culvert under Sutherlands Road has a lower gradient than the previous one, plus it has the addition of weir-style baffles and a short rock ramp at the outlet to enhance fish passage. During the March 2023 FPAT assessment, the rock ramp had a mean water velocity of 0.7 m/s, a height of 0.27 m, and a length of 1.2 m (FPAT ID 174784). This presented a greater potential barrier compared to a site visit in October 2022, when water levels were higher, resulting in a lower effective ramp height and velocities (see photographs in Appendix 2). This suggests that the ramp may present a partial barrier when water levels are lower.

The combined fishing methods yielded a total of four native fish species, including shortfin eel (*Anguilla australis*), longfin eel (*A. dieffenbachii*), inanga (*Galaxias maculatus*), and upland bully (*Gobiomorphus breviceps*). The same species were caught upstream and downstream of Sutherlands Road culvert. Fyke netting yielded a much higher catch than electric fishing, with the fyke catch dominated by large numbers of inanga (Figure 3). A total of 608 inanga were caught in the nets downstream, compared with 119 inanga upstream. By comparison, electric fishing yielded only one inanga downstream and no inanga upstream. In addition, no longfin eels were caught during electric fishing, but nine longfin eels were caught during fyke netting. Electric fishing yielded a greater number of upland bullies at the upstream site compared to downstream site. This reflects local variation in habitat quality and is unrelated to fish passage, as upland bullies are non-migratory.

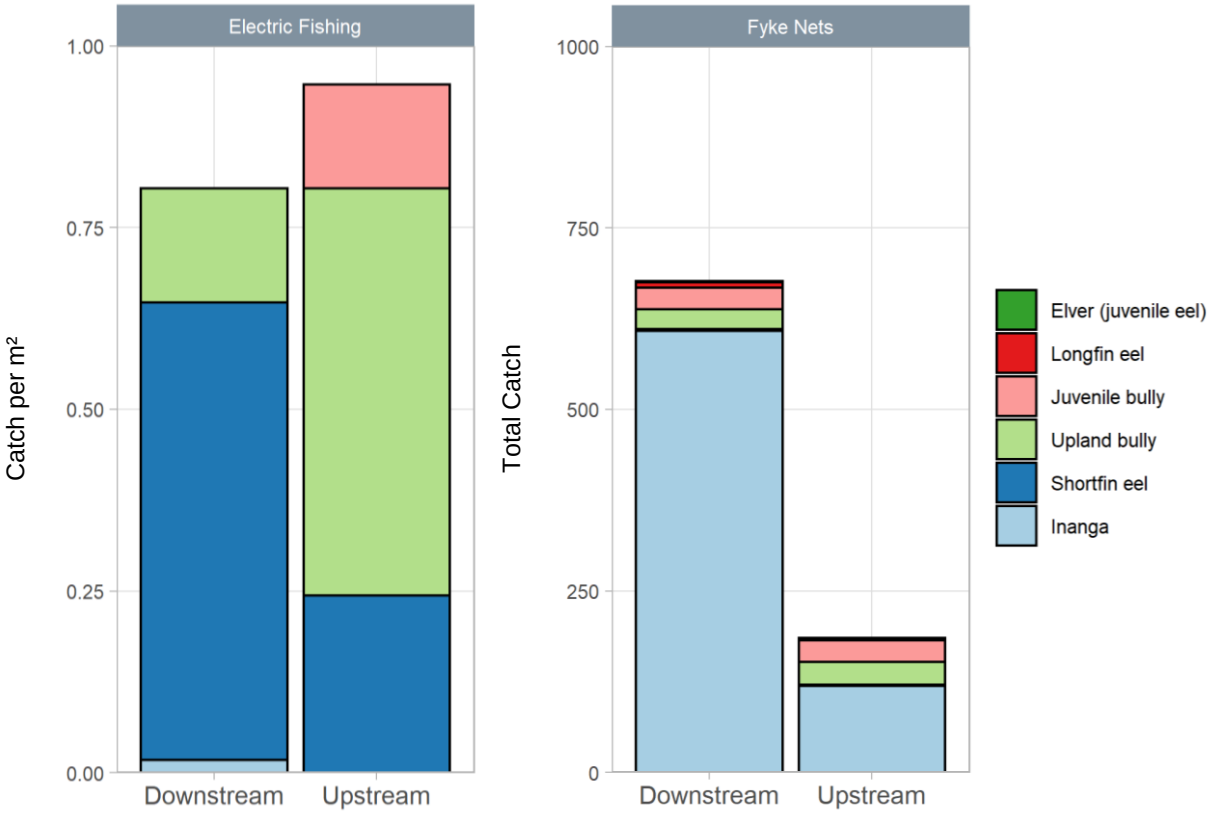


Figure 3: Fish catch downstream and upstream of the Sutherlands Road culvert in Cashmere Stream.

See Figure 4 for representative photographs of some of the fishes caught. See Appendix 3 for a breakdown of all fish caught at each site using netting and electric fishing methods.

This is the first record of inanga upstream of the Sutherlands Road culvert. Inanga have comparatively weak climbing ability compared to many other native fish species (Baker and Boubée 2003; Baker 2003), so their presence upstream of Sutherlands Road confirms the new culvert has improved fish passage. Lower numbers of inanga upstream of the culvert suggests that the culvert still presents a partial barrier to fish passage, or that there has been insufficient time for fish to colonise the newly available habitat. Alternatively, it may be due to habitat differences, with deeper pools downstream of the culvert. We therefore recommend further fish monitoring and modifying the fish ramp to ensure enhanced fish passage during lower and higher water levels in Cashmere Stream.

Figure 4: Representative photographs of fish caught during the barrier fishing surveys, including: An upland bully (top left), a common bully (top right), large eels caught in Cashmere Stream (bottom left), and the catch of single fyke net from Cashmere Stream, including many inanga (bottom right).

3.1.3. Sheppards Drain

Sheppards Drain is a sluggish, spring-fed waterway that discharges into the Pūharakekenui – Styx River. Upstream of the culvert at 234 Lower Styx Road, Sheppards Drain is artificially straight, has minimal shading, and has minimal flow. The water had a dark, tannin-stained appearance, reflecting the extensive wetland source in its headwaters. Dissolved oxygen levels were very low, with a concentration of 2.93 mg/L and 30.2% saturation measured upstream of the culvert on 7 March 2023. The culvert flap gate was closed during the site visit, which resulted in a lack of flow in Sheppards Drain and may have contributed to the observed low oxygen levels. Downstream, the culvert discharges into the Pūharakekenui River, which is comparatively broad and has moderate flow, but is also relatively straight and unshaded.

A total of 242 fish were caught downstream and 88 fish were caught upstream of the culvert (Figure 5). The fish catch in the Pūharakekenui River downstream of the culvert comprised six native species, including shortfin eel, longfin eel, inanga, upland bully, common bully (*Gobiomorphus cotidianus*), and giant bully (*G. gobioides*). Upstream of the culvert, only two species were caught, shortfin eel and longfin eel. The catch downstream was dominated by inanga, with 148 caught, followed by shortfin eels, with 34 caught. By comparison, the catch upstream of the culvert was almost entirely dominated by shortfin eels, with 79 caught. During

processing, five of the eels from the upstream site appeared sluggish, which was likely associated with stress caused by the low oxygen levels and being caught in traps.

Overall, there is a clear impact of the flap gate on the fish community and likely also water quality upstream. Therefore, we recommend investigating options for enhancing fish passage at this location. One solution would be to replace the existing flap gate with a fish-friendly tide gate that delays gate closure on an incoming tide.

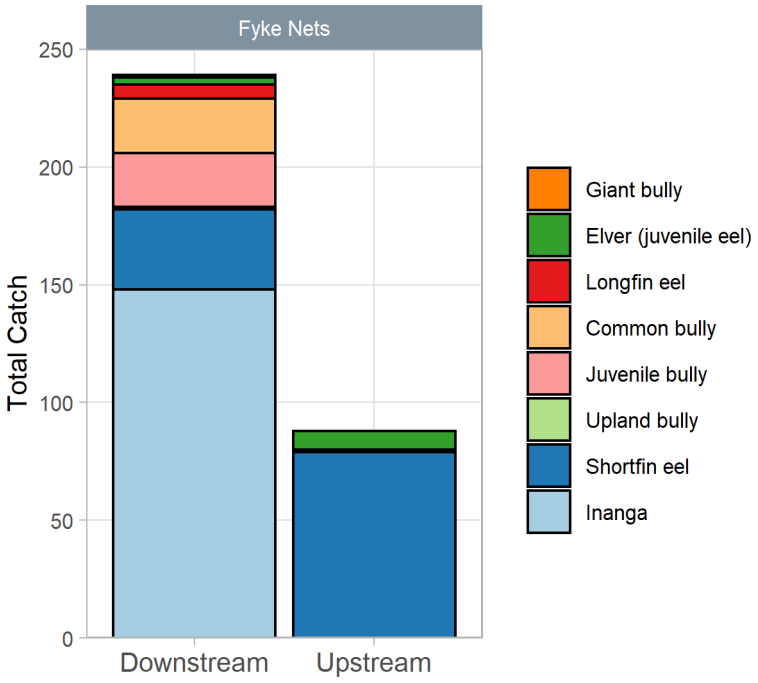


Figure 5: Fish catch downstream and upstream of the flap gate in Sheppards Drain, at the confluence with Pūharakekenui – Styx River.

3.2. Barrier Prioritisation Update

3.2.1. Council-owned Structures

A total of 2,554 structures were assigned priorities during the 2023 barrier prioritisation update, including 1,332 Council-owned structures (Table 2). Of the Council-owned structures, 41 were assigned a high priority (priority 5 or 4) for further action, comprising 19 remediation priorities, four fish survey priorities, with the remaining 18 structures being a high priority for fish passage assessment. The locations of each of the Council structures that received a high priority for remediation or fish surveys are presented in Figure 6, with brief descriptions provided in Table 3. Of the 23 Council structures described in Table 3, 12 had been identified during the previous prioritisation rounds, three were previously recognised as high priorities but not identified as Council assets, and the final eight structures were recognised as high priorities for the first time during the latest prioritisation round. A single structure was removed from the list of high remediation and fish survey priorities since the previous round, this being a culvert in Dunbar Waterway under Sparks Road (FPAT ID 132979), which no longer connects to open aquatic habitat upstream, as the waterway has been realigned and enhanced by Council.

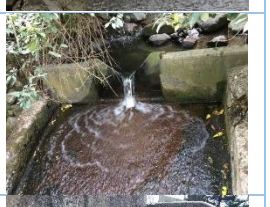
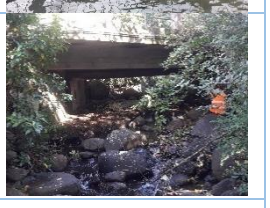
Table 2: The number of structures in each of the prioritisation categories by ownership, after updating the prioritisation database. Structures in the 'Other' ownership category include assets belonging to New Zealand Transport Authority, Environment Canterbury, Selwyn District Council, and private individuals.

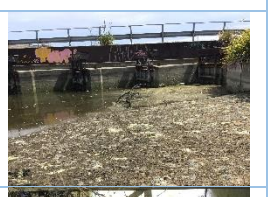
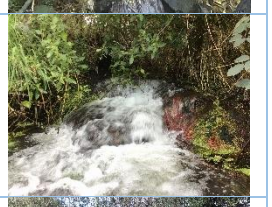
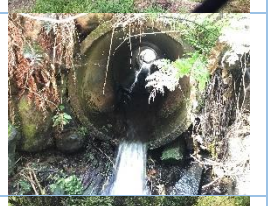
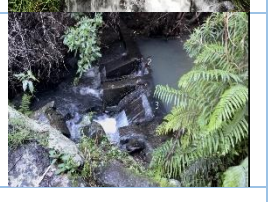
Priority[1]	Council	Other	Unknown	Total
R5	5	0	0	5
R4	14	11	2	27
R3	23	0	11	34
R2	30	2	11	43
R1	136	3	69	208
F5	2	2	0	4
F4	2	7	0	9
F3	54	5	10	69
F2	55	2	24	81
F1	220	19	91	330
A5	5	5	32	42
A4	13	54	81	148
A3	450	50	115	615
A2	64	0	155	219
A1	223	1	460	684
OS	36	0	0	36
Total:	**1,332**	**161**	**1,061**	**2,554**

Note: [1] 1 = low priority, 5 = high priority, 'R' = Remediation, 'F' = Fish survey, 'A' = FPAT Assessment, 'OS' = Offline Stormwater structure.

Figure 6: The location of each of the Council-owned structures that are a high priority for remediation or fish surveys.

*Table 3: All Council-owned structures that are a high priority for remediation or fish surveys, updated from Instream Consulting (2022). Structures are ordered firstly by action (i.e., remediation or fish survey) and secondly by priority score. Structures with the same priority score have been ordered from highest priority to lowest priority, based on expert ecological judgement and local knowledge. Council Asset refers to the relevant GIS layer and asset number of each structure. Structures that have only been identified as high priority during the current study, and those that have changed in priority since the previous prioritisation round, are indicated in **bold**. Structures that were identified as Council assets during the ownership review indicated with a '*' in the Priority Score column. Merged Priority Score and Comments fields indicate that multiple structures would need to be investigated simultaneously to achieve the maximum ecological benefit.*

Site Code	Waterway (Catchment)	FPAT ID	Structure Type	Council Asset	Priority Score	Comments	Photographs
1	Ōtūkaikino Creek (Ōtūkaikino Creek)	130047	Weir	WcWeirs 199	R5	The most substantial barrier in the Ōtūkaikino catchment. Distribution of fish database records indicates that the structure is a total barrier for inanga. Velocities over fish ladder are too high for inanga.	
2	Pūharakekenui – Styx River (Pūharakekenui – Styx River)	131907	Flap gate with culvert	WcValve 27	R5	High risk structure near the coast. Recommend an investigation into the gate's operation (opening frequency and duration) and impacts on fish movements and salinity (and associated implications for plant communities and inanga spawning).	
3	Takamātua Stream Branch No 7 (Takamātua Stream)	1411	Weir	Unknown	R5	Upstream of CCC bridge A33. A fish survey in 2020 identified abundant native fish downstream, including bluegill bully, redfin bully, longfin eel, and whitebait. No fish were caught upstream, confirming poor passage.	
4	**Sheppards Drain (Pūharakekenui – Styx River)**	**134654**	**Flap gate with culvert**	**SwPipe 37486**	**R5**	A high-risk flap gate and culvert at the confluence between Sheppards Drain and the Styx River. A fish survey in 2023 confirmed that the structure is a substantial barrier for most fish species, including inanga (as per Section 3.1.3).	
5	Wainui Valley Stream (Wainui Bay)	1140	Weir	WcWeirs 242	R5	The weir overtops during some high tides and inanga have been recorded upstream. However, fish accumulate downstream of the barrier at low tides, increasing their risk to predation. Therefore, although some fish are passing the weir, it remains a partial barrier. It is a high priority for remediation because it is the closest barrier to the coast, with a large upstream catchment.	
6	Miln Drain (Cashmere Stream)	130166	Other	SwPipe 87535	R4	Fish surveys upstream and downstream of the structure indicated that this structure is a substantial barrier to shortfin eels and inanga, as per the barrier fishing results discussed in Instream Consulting (2022).	
7	**Aylmers Stream (French Bay)**	**298**	**Bridge**	**RAMM A38**	**R4**	Inanga recorded up to, but not beyond this bridge. Current fish passage enhancement includes mussel spat rope, however, assessors recorded the ropes were placed poorly. Additional remediation options should be considered, including those that may help weaker climbing species, such as inanga.	
8	Okuti River Branch No 9 (Lake Forsyth (Wairewa))	278	Weir	RAMM W11	R4	Weir situated under bridge W11, but not listed in Council's weir database. Likely owned by the Council. Would need to remediate at the same time as another (presumably private) weir immediately downstream. Environment Canterbury is currently investigating remediation of these weirs, however, no progress has yet been made on determining the ownership of the downstream weir. Fish surveys upstream and downstream of the weirs indicate that the structures are partial barriers for longfin eel and kōaro (*Galaxias brevipinnis*).	
9	**Kate Sheppard Stream (Ōtākaro – Avon River)**	**134904**	**Flap gate with culvert**	**SwValve 320**	**R4**	Kate Sheppard and Corser Stream are the two major outlets from Travis Wetland. Fish records upstream include inanga, however, these structures may be partial barriers. Rudd (*Scardinius erythrophthalmus;* a pest fish), have also been historically recorded in Travis Wetland. However, due to the efforts of a targeted control programme, no rudd have been detected in the wetland over the past 10 years of monitoring. While the current gates are unlikely to prevent the spread of pest fish out of the wetland, remediating them could increase the risk of pest fish entering the wetland. Recommend investigating potential impacts of the structure on upstream inanga migration and to guide remediation. Inanga are known to spawn immediately upstream (Orchard and Measures 2017) and any remediation must consider potential impacts on tidal influence and spawning habitat availability. Recommend follow-up monitoring to assess remediation success and to monitor pest fish populations in Travis Wetland.	
10	**Corser Stream**	**141362**	**Flap gate with culvert**	**SwPipe 68303**	**R4**		

Site Code	Waterway (Catchment)	FPAT ID	Structure Type	Council Asset	Priority Score	Comments	Photographs
11	**Bells Creek (Ōpāwaho – Heathcote River)**	**134108**	**Flap gate**	**SwValve 576**	**R4**	Structures include the flap gate outlet from Bells Creek and an inline stormwater pump. Recommend investigating operation of the flap gate and pump to assess impacts of the structures on fish passage and to guide remediation. High abundances of eels have been recorded in Te Oranga Waikura ponds upstream, however, the impact of the pump on downstream migrating adult eels is unknown.	
12	**Bells Creek (Ōpāwaho – Heathcote River)**		**Pumpstation**	**SwPump 83**			
13	**Linwood Canal (Ihutai – Avon-Heathcote Estuary)**	**134909**	**Flap gate with culvert**	**SwValve 175**	**R4**	Abundant inanga caught upstream in the ponds in Charlesworth Reserve, however, the structure may still be a partial barrier. Recommend investigating operation of the gates to assess their potential impact on fish passage and provide options for remediation.	
14	**Totara Stream (Pigeon Bay Stream)**	**1050**	**Culvert**	**SwPipe 60168**	**R4**	A fish survey identified that the structure is passable by shortfin and longfin eel, however, inanga, upland bully, and common bully distributions may be impacted (Instream Consulting 2022). These results confirm that the structure is a high risk to fish that are weak climbers.	
15	Stream Reserve Drain (Lyttelton Harbour – Whakaraupō)	134866	Culvert	SwPipe 76048	R4	A fish barrier survey indicated that the structure is impacting fish passage, with reduced numbers of banded kōkopu (*Galaxias fasciatus*) and shortfin eel caught upstream (Instream Consulting 2022).	
16	Carews Peek Stream Branch No 8 (Carews Peek Stream)	143153	Culvert	SwPipe 59620	R4	High risk culvert near the confluence with Carews Peek Stream mainstem. Longfin eels and kōaro have both been recorded downstream in the mainstem, but only shortfin eels have been caught upstream.	
17	Storer Diversion (Ōtūkaikino Creek)	130043	Culvert	SwPipe 46740	R4	Structures include a high-risk culvert downstream, with a historical pump station (not in service), containing a substantial weir barrier, upstream. Gravity fed bypass around the pump station ends in flap gates. Both structures would need simultaneous remediation to achieve maximum ecological benefits. An alternative path upstream is available, however, it is blocked by a high-risk weir (WcWeirs 199; FPAT ID 130047), discussed above.	
18	Fisher Drain (Ōtūkaikino Creek)	130044	Pump station	WcWeirs 200			
19	**Little Akaloa Stream Branch No 2 (Little Akaloa Stream)**	**152283**	**Culvert**	**SwPipe 60637**	**R4**	Local fish records indicate that only strong climbing species are present at this elevation, however, the culvert includes a drop and undercut that may prevent passage of even strong climbing species.	
20	Takamatua Stream (Takamatua Bay)	1413	Water supply intake weir	WsInlet 425	F5*	These water intake weirs are <100 m apart. The downstream take (WsInlet 425) is no longer active and is listed as 'abandoned' in the Council's WsInlet GIS layer. The upstream take (WsInlet 443) is still active. There are no recent fishing records in the vicinity of these structures. A fish survey targeting both structures is recommended to determine the potential impact of the structures on fish distributions and to guide remediation.	
21	Takamatua Stream (Takamatua Bay)	1414	Water supply intake weir	WsInlet 443			
22	**Okana River Branch No 3 (Okana River)**	**174785**	**Water supply intake weir**	**WsInlet 475**	**F4***	This water intake weir was assessed as presenting a high risk to fish passage, however, there are no fish records in the catchment. A fish survey is recommended to determine the structures impact on fish distributions and to guide potential remediation.	
23	**Gibsons Drain (Pūharakekenui – Styx River)**	**152674**	**Weir**	**WcWeirs 85**	**F4**	Fishing records (including inanga) are present nearby in the Pūharakekenui – Styx River, however there is no upstream fishing data. A fish survey is recommended to assess the structure's impact. There are several culverts upstream (Council-owned and private) that should be assessed at the same time, to determine the potential habitat gained through remediation.	

Through the prioritisation rounds, the total number of Council structures requiring fish passage assessment as decreased by 20%, with 755 assets remaining unassessed after the latest update (Figure 7). This decrease is largely due to the Council's systematic assessment of their assets over the duration of the prioritisation programme, but also reflects assessments completed by other organisations and ongoing refinement of the database to remove duplicate records and structures not relevant to fish passage. Preliminary analysis of the Council's GIS layers in 2021, before the first round of prioritisation, identified 288 structures that were considered a high priority for fish passage assessment. Through the completion of barrier assessments over the summer of 2020–21, this number was reduced to 64 by the end of the first round of prioritisation (Figure 8). The remaining high priority structures were again targeted for assessment over the summer of 2021–22, and by the end of the associated prioritisation round, there were no remaining high priority Council structures for assessment. The latest round of prioritisation identified a further 18 structures that are a high priority for fish passage assessment. These 18 structures comprise newly commissioned structures, structures identified during the asset layer review, and structures that have had remedial work completed recently, and thus require reassessment.

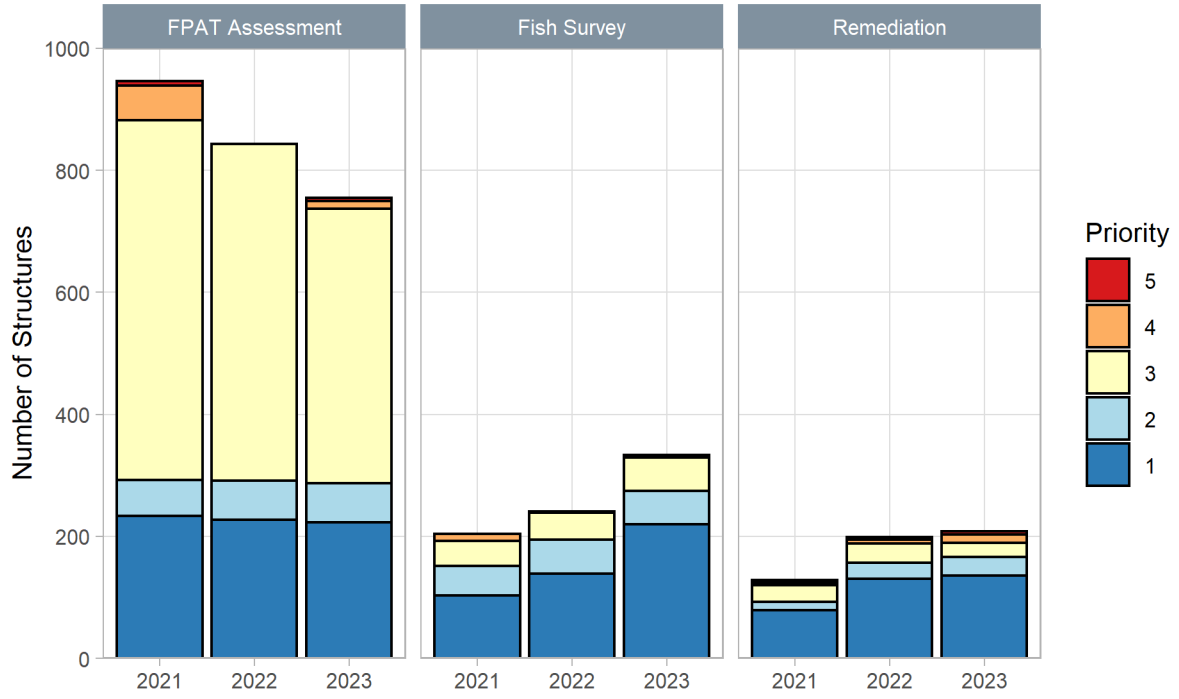


Figure 7: The number of Council-owned structures in each of the prioritisation categories at the end of each round of prioritisation.

As the fish passage assessments have been completed, structures have been shifted through the model into the fish survey and remediation categories. Thus, the number of structures prioritised for fish surveys has increased through each consecutive prioritisation round (Figure 7), however, the number of structures that are a high priority to receive fish surveys has remained low (Figure 8). This reflects the small proportion of barrier assessments that result in high priorities for fish surveys, as well as the barrier fishing that has been carried during each prioritisation round, which shifts these structures into the remediation category. As a result, the number of high priority structures for remediation has also increased with each consecutive prioritisation round. A larger increase in the number of high remediation priorities

was recorded in the current prioritisation round (Figure 8). This is largely due to the model update, which allowed for structures outside of priority catchments to be assigned an 'R4' value. Of the 19 structures with a high remediation priority in the current study, eight were located outside of priority catchments, which would have precluded them from being high remediation priorities, prior to the model update.

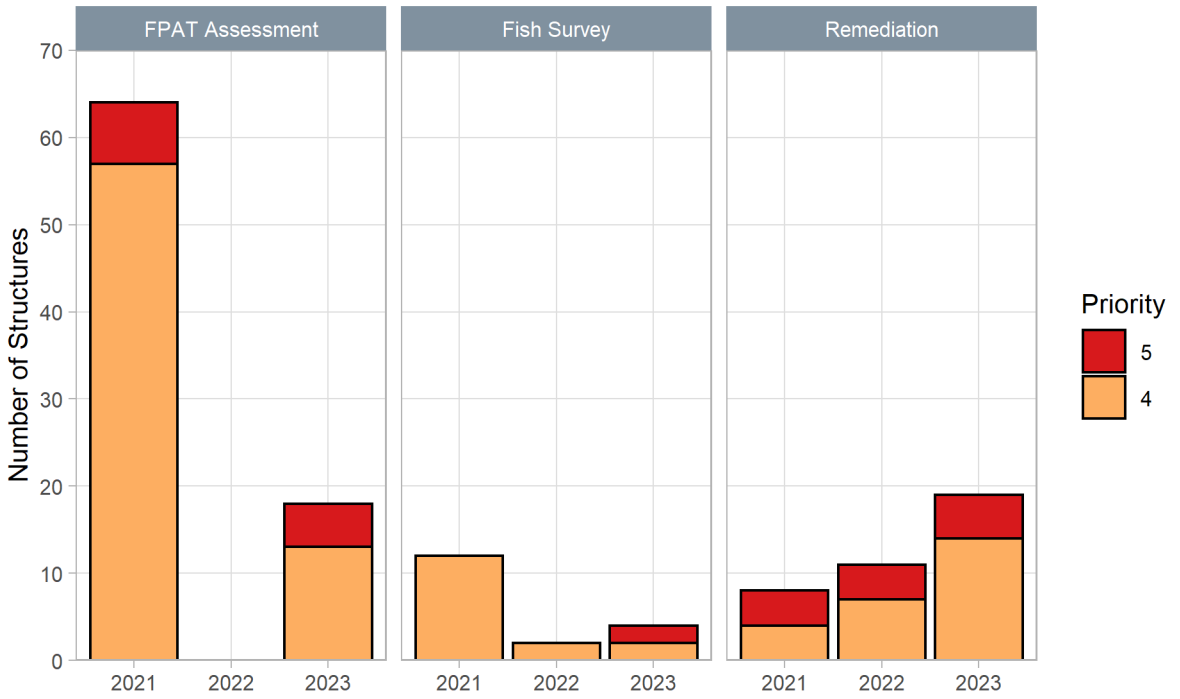


Figure 8: The number of high priority Council-owned structures in each of the prioritisation categories at the end of each round of prioritisation.

This model update was recommended during the previous prioritisation study, which identified several substantial barriers outside of the priority catchments, most notably, the Mona Vale weir (Instream Consulting 2022). In recognition of the significance of the Mona Vale weir as a fish barrier, the Council completed a remediation project to enhance fish passage in 2023. This involved the installation of a rock riffle over the existing step weir (Figure 9). The design of the remediation was intended to enhance passage for all native fish, including weakly swimming species. To achieve this, the design specifications included a gradient of 1:30, as recommended by Franklin *et al.* (2018), with rest areas along the margins. A monitoring programme has been established by the Council to assess the success of the remediation, which included a pre-remediation baseline fish survey. The structure will require a follow-up fish passage assessment, to ensure that the desired hydraulic conditions have been achieved, as well as follow-up fish monitoring, to confirm the ecological benefits are being realised. The update to the prioritisation model described in the current study draws attention to other such structures beyond the priority catchments, that have previously been precluded from receiving high remediation priorities.

Figure 9: Mona Vale weir, in 2020 priori to remediation (left) and in 2023, after remediation to enhance fish passage (right).

3.2.2. Other Structures

Of the 2,554 structures prioritised in the current study, 161 were owned by organisations or individuals other than the Council, while ownership was not certain for an additional 1,061 (Table 2). Of the structures not recognised as Council assets, 13 were structures with a high priority for remediation and a further nine were structures with a high priority for fish surveys (Appendix 4). Most of these high priority structures appear to be privately owned, with many located on farms in the Bank Peninsula area. Of particular concern are the private structures that present a high risk to fish passage near the coast, with large catchments upstream. Two catchments worthy of particular mention are Barrys Bay Stream and Pipers Stream in Akaroa Harbour (Figure 10). The structures in Pipers Stream are especially relevant to the Council, as there is currently a project underway to improve fish passage upstream at the Council's Pipers Stream water intake. The benefits of enhancing fish passage at the Pipers Stream intake will not be fully realised, while there are at least three high-risk private structures present downstream. Environment Canterbury should be engaged to discuss the remediation of such structures.

In addition to the structures identified as high priorities for remediation and fish surveys, there were an additional 172 structures that were identified as high priorities for fish passage assessments, and which have not been recognised as Council assets (Table 2). While the ownership is known for 59 of these structures, the ownership of the remaining 113 structures is not certain. Most (61 out of 113) of these structures are weirs, dams, or flow restrictions, that have been included through the Council's WcWeir GIS layer. We have recently become aware that, while many of these structures are likely privately owned, some of them are located on Council land and may be unrecognised Council assets. For example, some weir structures were recently recorded in the Pūharakekenui – Styx River catchment during routine ecological monitoring (Pers. Comm. Tanya Blakely, Boffa Miskell, May 2023). While many of these structures were already in the prioritisation database, most were of unknown ownership. This included a weir in Cavendish Stream, which, based on its location in the Council-owned Styx Mill Conservation Reserve, is suspected to be a Council asset. Therefore, we recommend an ownership review of the 113 structures that have been assigned high assessment priorities, but have unknown ownership status.

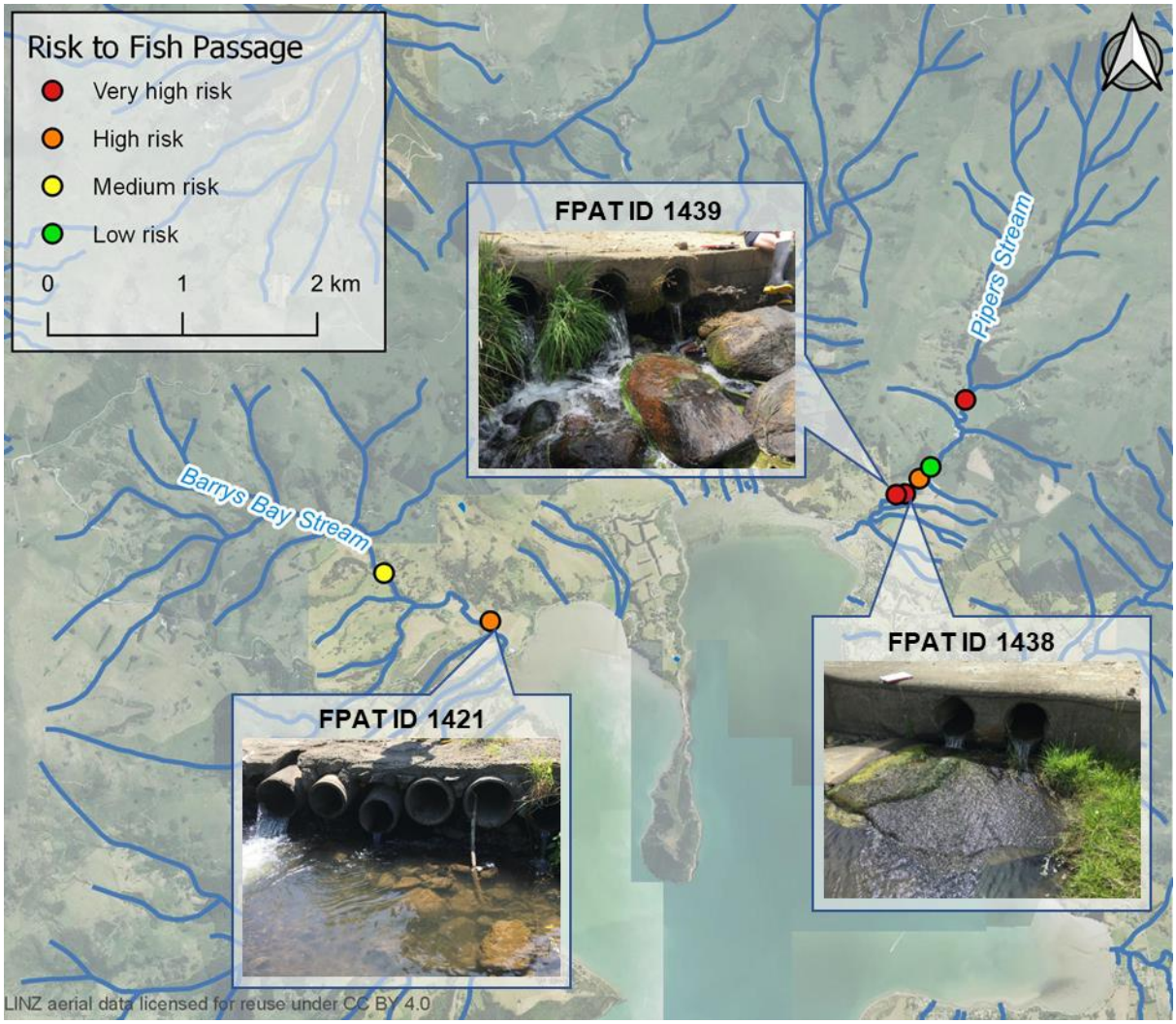


Figure 10: Examples of high and very high risk private structures, near the coast in Akaroa Harbour.

Figure 11: The weir in Cavendish Stream in Styx Mill Conservation Reserve that is suspected to be a Council Asset.

4. CONCLUSIONS AND RECOMMENDATIONS

Based on the results discussed above, the following conclusions and associated recommendations update those made previously by (Instream Consulting 2022):

- Nineteen Council structures were identified as high remediation priorities.
    - Remediation options for these structures should be investigated and should incorporate knowledge of the local fish communities in the remediation design.
    - Seven of these structures include flap gates or pump stations for which the impact on upstream and downstream fish migration is not clear. An investigation into these structures should be carried out to assess their impact and to inform remediation design.

- Four Council structures were identified as high priorities for fish surveys. Fish surveys should be carried out at these structures to quantify risks to fish passage and to identify any species-specific remediation design considerations. These structures include:
    - Two water intake weirs in Takamatua Stream (FPAT ID's 1413 and 1414)
    - A water intake weir in a tributary of the Okana River (FPAT ID 174785)
    - A weir in Gibsons Drain (FPAT ID 152674)

- Eighteen Council structures were identified as high priorities for fish passage assessment.
    - These 18 structures comprise newly commissioned structures, structures identified during the asset layer review, and structures that have had remedial work completed recently. Fish passage assessments should be carried out on these structures to assess their potential as fish barriers.

- There are 113 structures with a high priority for fish passage assessment in the database that are of unknown ownership.
    - Most of these are weirs, with locations held in the Councils WcWeir GIS layer. Some of these structures are located within Council land. An ownership review of these structures should be completed to ensure that all Council assets are identified in the prioritisation database.

- The remediation of the Sutherlands Road culvert in Cashmere Stream has been proven to have enhanced passage, however, the structure may still be a partial barrier during lower water levels.
    - Adjustments to the downstream ramp should be made ensure enhanced passage during all water levels.

- Numerous significant private barriers were identified, including some that may impact the success of Council remediation projects.
    - Environment Canterbury should be engaged to discuss options for remediation of these structures.

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APPENDIX 1: SUMMER 2022–23 FPAT ASSESMENTS

All barrier assessments were carried out by Instream staff, between 9 March and 18 May, 2023. Over this period, 161 Council-owned structures were visited. Of these structures, 158 were culverts located on Banks Peninsula, two were water takes associated with public water supply, with the final structure was a culvert in Cashmere Stream at Sutherlands Road. The Banks Peninsula culverts were selected for assessment as this structure type was identified as often presenting a high risk to fish passage in the Banks Peninsula area, during the previous barrier prioritisation update (Instream Consulting 2022). The water takes were assessed at the request of the Council, to gather information that may be used to inform proposed renewal projects. These water take structures had not previously been recognised as Council assets in the previous prioritisation rounds, as the relevant layer ('WsInlet') was not supplied by the Council during the initial prioritisation project. Finally, the culvert in Cashmere Stream at Sutherlands Road was also re-assessed at the request of the Council, to determine the efficacy of recent remediation works on the structure.

For each structure, assessors completed FPAT assessments via the FPAT mobile application (Franklin 2022), when possible. This included the measurements required by the FPAT application, which relate directly to the structure (e.g., length of culvert, height of weir) or to the surrounding waterway (e.g., width of stream, water velocity). Photographs were also taken of the upstream and downstream ends of the structure, as well as the upstream and downstream aquatic habitat. In the FPAT comments section, the assessor recorded additional notes based on a predetermined template, which included: risk justification, i.e., the basis on which the assessor made their qualitative risk assessment; aquatic habitat, i.e., notes on the quality and abundance of aquatic habitat available; other barriers, i.e., other barriers in the vicinity of the structure that may impact fish passage; and any other incidental observations. This template was developed to include information that is useful when prioritising structures for remediation or further investigation, based on our experiences during the previous prioritisation rounds. This template also improved the quality of the data collected, by ensuring FPAT assessments included a consistent level of detail.

If an FPAT assessment was not possible (e.g., the structure could not be located or accessed) or not appropriate (e.g., the waterway was dry), a purpose-built digital Esri ArcGIS Survey123 form was completed on site. The Survey123 form automatically recorded the date and time of the assessment, as well as the location of the device. The assessor then selected the Council asset ID of the structure in question from a premade list, recorded the reason the FPAT assessment could not be completed, and took photographs of the structure and surrounding habitat when possible, and recorded any additional comments. These records were then uploaded daily to the Instream ArcGIS Survey123 online database.

Of the 161 visited structures, 46 (29%) resulted in completed FPAT assessments, while the remaining 115 were not suitable for FPAT assessment. Of the 115 structures that were not FPAT assessed, 102 (89%) were due to the surrounding channel being dry, with no residual pools, providing no aquatic habitat. Fieldwork was undertaken during a relatively wet summer, so we were confident that the dry watercourses are indeed ephemeral, and only flow after rainfall. The remaining 13 structures were not assessed due to a combination of lack of access, the structure not being located by the assessor, or, the assessor could not locate any open upstream habitat (e.g., the structure was associated a stormwater network).

APPENDIX 2: BARRIER FISHING SITE PHOTOGRAPHS

Church Gully Stream

Figure 1: Church Gully Stream upstream of the road culvert (left) and immediately downstream of the culvert (right), showing the perched apron.

Figure 2: Church Gully Stream downstream of the road culvert, showing natural barriers in the form of lacking surface flow (left) and a waterfall (right).

Cashmere Stream

Figure 3: Downstream end of Cashmere Stream culvert at Sutherlands Road, in October 2022 (left) and March 2023 (right), when water levels were lower and the FPAT assessment was made.

Figure 4: Upstream end of Sutherlands Road culvert in March 2023, showing the inlet (left) and weir baffles (right).

Figure 5: Cashmere Stream downstream of Sutherlands Road culvert, showing fish sampling habitat.

Figure 6: Cashmere Stream upstream of Sutherlands Road culvert, showing fish sampling habitat.

Sheppards Drain

Figure 7: Sheppards Drain upstream of the culvert with flapgate (left); Styx River downstream of the Sheppards Drain culvert (right).

APPENDIX 3: BARRIER FISHING RESULTS

Table 1: The fish catch for each sampling reach, including abundance, and in brackets size (mm). Note that only size classes were recorded at the Sheppards Drain upstream site, to reduce fish handling time due to low oxygen concentrations. EFM = Electric Fishing Machine.

Location	Method	Site	Inanga	Shortfin eel	Longfin eel	Elver (juvenile eel)	Upland bully	Common bully	Giant bully	Juvenile bully
Cashmere Stream	EFM	Downstream	1 (55)	36 (128–410)			9 (37–70)			9 (25–35)
		Upstream		17 (121–530)			39 (41–76)			10 (27–36)
	Fyke	Downstream	608 (25–93)	3 (168–555)	7 (689–1202)	2 (121–155)	27 (31–66)			30 (24–45)
		Upstream	119 (52–106)	2 (496–712)	2 (556–751)	1 (121)	31 (26–72)			30 (17–34)
Sheppards Drain	Fyke	Downstream	148 (46–102)	34 (205–746)	6 (483–1038)	3 (88–136)	1 (41)	23 (48–89)	1 (193)	23 (22–38)
		Upstream		79 (100–800)	1 (700–800)	8 (<200)				

APPENDIX 4: NON-COUNCIL PRIORITY STRUCTURES

Table 1: High priority remediation and fish survey structures that were not identified as Council assets. Ownership status indicated by the letter in the site code: 'U' = Unknown, 'P' = Private, 'E' = Environment Canterbury. Table ordered first by Priority Score, then from north to south.

Code	Waterway	Catchment	FPAT ID	Structure Type	Easting (NZTM)	Northing (NZTM)	Priority Score
P1	Te Wharau Stream	Te Wharau Stream	1174	Ford with culvert	1576306	5166132	R4
P2	Pipers Stream	Pipers Stream	1428	Ford with culvert	1596242	5156506	R4
P3	Pipers Stream	Pipers Stream	1440	Ford with culvert	1595984	5156008	R4
P4	Pipers Stream	Pipers Stream	1435	Other	1595899	5155921	R4
P5	Pipers Stream	Pipers Stream	1438	Ford with culvert	1595794	5155808	R4
P6	Pipers Stream	Pipers Stream	1439	Ford with culvert	1595728	5155802	R4
P7	Barrys Bay Stream	Barrys Bay Stream	1426	Ford with culvert	1591923	5155219	R4
P8	Barrys Bay Stream	Barrys Bay Stream	1421	Ford with culvert	1592713	5154862	R4
U9	Okuti River Branch No 9	Okuti River	276	Weir dam or flow restriction	1586377	5150922	R4
P10	Walnut Stream	French Bay	28207	Weir dam or flow restriction	1597266	5149027	R4
P11	Walnut Stream	French Bay	1133	Bridge	1597262	5149012	R4
P12	Walnut Stream	French Bay	28214	Weir dam or flow restriction	1597287	5148968	R4
U13	Aylmers Stream	Aylmers Stream	304	Weir dam or flow restriction	1597307	5148257	R4
P14	Bamfords Road Drain	Allandale	28208	Weir dam or flow restriction	1571520	5167657	F5
P15	Te Wharau Stream	Te Wharau Stream	1177	Ford with culvert	1576552	5165478	F5
E16	Coutts Island Drain West	Waimakariri River	140924	Culvert or pipe	1565765	5190581	F4
P17	Bamfords Road Drain	Allandale	1196	Weir dam or flow restriction	1571532	5167612	F4
P18	Bamfords Road Drain	Allandale	1184	Ford with culvert	1571534	5167559	F4
P19	Little Akaloa Stream	Little Akaloa Bay	1241	Ford with culvert	1598640	5163935	F4
P20	Opara Stream	Opara Stream	1107	Ford with culvert	1600148	5158584	F4
P21	Pawsons Stream	Pawsons Stream	1412	Ford with culvert	1594698	5157143	F4
P22	Hukahuka Turoa Stream Branch No 10	Hukahuka Turoa Stream	133560	Ford with culvert	1583594	5155952	F4

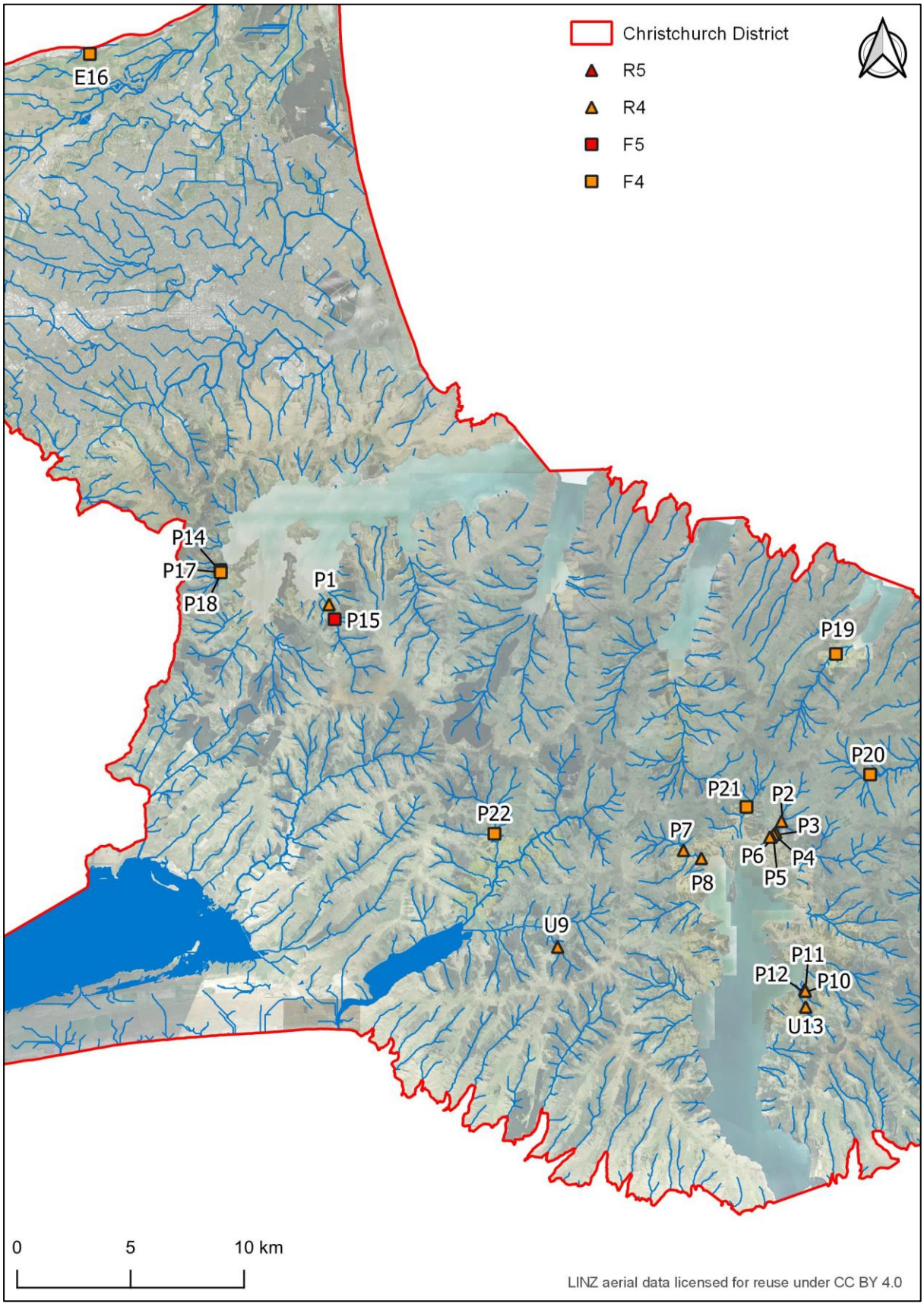

Figure 1: The location of high priority remediation and fish survey structures, not recognised as Council assets. Text labels correspond to the site codes presented in Table 1.