Management Flows for Aquatic Ecosystems in the Waikouaiti River

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Otago Regional Council

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Executive summary

The Waikouaiti is a medium-sized river which rises in two branches arising in the ranges between Macraes and the Silver Peaks before combining to flow into the Waikouaiti Estuary, a shallow, intertidal dominated estuary (SIDE), that is a rich habitat for fish, shellfish, and waterfowl and is an important mahinga kai (food-gathering site). The estuary enters the Pacific Ocean at the seaside town of Karitane. Landcover in the North Branch catchment is dominated by agricultural grasslands, while the South Branch flows through indigenous hardwoods, mānuka/kanuka, and exotic forestry before flowing through low producing grasslands. Below the confluence, the lower catchment is dominated by high producing exotic grassland.

Schedule 2A of the RPW does not currently specify a minimum flow and/or allocation limit for the Waikouaiti catchment. However, the three main consumptive takes are subject to residual flows. The current allocation limit for the Waikouaiti catchment is 129.2 l/s.

This report presents information to inform water management decision-making in the Waikouaiti catchment. This includes hydrological information (including flow naturalisation and flow statistics), data on aquatic values (including the distribution of indigenous fish) and application of instream habitat modelling to guide flow-setting processes, and consideration of the current state of the Waikouaiti compared to the proposed objectives for the Dunedin & Coast FMU set out in the proposed Otago Land and Water Regional Plan.

The flow statistics based on the analysis of Lu (2023) and Dale (2011) are summarised below:

Hydrological site		Flow statistics (l/s)		
		Mean	Median	7d MALF (Jul-Jun)
Waikouaiti at 200 d/s DCC intake	Naturalised flows	2,497	909	251
	Observed flows	2,482	989	234
Waikouaiti at McGrath Road bridge (synthetic)	Simulated observed flows	2,490	906	233
Waikouaiti at downstream confluence	Dale (2011) (natural)	2,855	856	258

There are ten resource consents for primary water takes from the Waikouaiti catchment, with a total primary allocation of 129.2 l/s. Oceana Gold (New Zealand) Ltd. has six resource consents for water takes from the Waikouaiti catchment as part of their operations at the Macraes gold mine. For the purposes of this report, these permits are considered to be non-consumptive. Of the remaining four consents, three are for community water supply (Stoneburn Water Supply and Waikouaiti Community Water Supply Scheme, operated by Waitaki District Council and Dunedin City Council, respectively). However, the consents held by Dunedin City Council to operate the Waikouaiti Community Water Supply

Scheme (2006.002.V1 and 2006.075.V1) both have instantaneous maximum rate of take of 60 l/s but cannot be exercised concurrently.

There is limited information on the periphyton community of the Waikouaiti River. Information on periphyton composition (collected between 2001 and 2018) suggests that composition was variable, with the filamentous green algae *Mougeotia* and *Spirogyra*, and the diatoms *Didymosphenia*, *Fragilaria*, *Gomphoneis* and *Synedra* among the dominant periphyton taxa observed.

Macroinvertebrate communities in the Waikouaiti were dominated by the mudsnail *Potamopyrgus*, amphipod *Paracalliope*, riffle beetles (Elmidae), chironomid midges (Orthocladiinae) and oligochaete worms. MCI scores for the Waikouaiti at Confluence d/s site (2014 and 2022) put this site in C-band of the NOF while historical MCI scores for Orbells Crossing site were in D-band. In comparison, SQMCI scores for both sites were in D-band of the NOF. ASPM scores for the Waikouaiti at Confluence d/s site (2014-2022) put this site in C-band of the NOF. Historical ASPM scores for Orbells Crossing site put this site in D-band of the NOF.

The Waikouaiti River supports a highly diverse community of indigenous fish with eleven indigenous fish species recorded. Several of these species that are at risk – declining (longfin eel, torrentfish, bluegill bully, kōaro, inanga) or at risk – naturally uncommon (giant bully). Lamprey and Taieri flathead galaxias are classified as threatened – nationally vulnerable. Brown trout are the only introduced fish species that have been collected from the Waikouaiti catchment. The Waikouaiti supports a locally significant sport fishery.

An instream habitat model developed for the mainstem of the Waikouaiti below the confluence of the North and South Branches has been applied to consider the effects of different flows on the physical characteristics of the Waikouaiti and habitat for periphyton, macroinvertebrates and fish.

The current minimum flow in the Waikouaiti catchment (150 l/s) is predicted to maintain between 45% (food-producing habitat) and 98% (the mudsnail *Potamopyrgus*) of habitat for macroinvertebrates at the naturalised 7-d MALF. It is predicted to maintain 65% of the bluegill bully habitat compared to the naturalised 7-d MALF. The current minimum flow is predicted to achieve >87% habitat retention for other indigenous species considered and between 79-87% habitat retention for the various brown trout life-stages considered.

Bluegill bully and torrentfish are among the most flow-demanding indigenous fish species in the Waikouaiti catchment and a flow of 218 l/s is expected to provide 80% habitat retention for these species in the Waikouaiti River. Flows of between 36 l/s (common bully) and 105 l/s (inaka/inanga) are predicted to provide 80% habitat retention for other indigenous fish species considered in this analysis. Flows of up to 120 l/s were predicted to provide 80% habitat retention for large longfin eels, while flows of up to 175 l/s were predicted to provide 90% habitat retention for large longfin eels. Habitat for kanakana/lamprey was predicted to be highest at low flows. Flows of 111-183 l/s are predicted to provide 80% habitat retention for the brown trout life stages considered.

The existing minimum flow and allocation limit are predicted to result in a hydrograph that is unimpacted relative to naturalised flows (based on the DHRAM score).

Contents

List of figures

List of tables

Glossary

Catchment	The area of land drained by a river or body of water.
Existing flows	The flows observed in a river under current water usage and with current water storage and transport.
Habitat suitability curves (HSC)	Representations of the suitability of different water depths, velocities and substrate types for a particular species or life-stage of a species. Values vary from 0 (not suitable) to ideal (1). HSC are used in instream habitat modelling to predict the amount of suitable habitat for a species/life-stage.
Instream habitat modelling	An instream habitat model used to assess the relationship between flow and available physical habitat for fish and invertebrates.
Irrigation	The artificial application of water to the soil, usually for assisting the growing of crops and pasture.
7-d Mean Annual Low Flow (7-d MALF)	The average of the lowest seven-day low flow for each year of record. Most MALF values reported here are calculated using flows from the irrigation season (October-April) only. This is to avoid the effect of winter low flows that may occur due to water being “locked up” in snow and ice in the upper catchment. However, if significant winter low flows do not occur, estimates of 7-d MALF calculated using data from the full hydrological year or from the irrigation season should be very similar.
Mean flow	The average flow of a watercourse (i.e. the total volume of water measured divided by the number of sampling intervals).
Minimum flow	The flow below which the holder of any resource consent to take water must cease taking water from that river.
Natural flows	The flows that occur in a river in the absence of any water takes or any other flow modification.
Naturalised flows	Synthetic (calculated) flows created to simulate the natural flows of a river by removing the effect of water takes or other flow modifications.
Reach	A specific section of a stream or river.
Residual flow	A residual flow is an environmental flow that applies to an individual resource consent. Typically, a residual flow must be maintained immediately below the point of take at all times.
River	A continually or intermittently flowing body of fresh water that includes a stream and modified watercourse but does not include any artificial watercourse (such

	as an irrigation canal, water-supply race, or canal for the supply of water for electricity power generation and farm drainage canal).
Seven-day low flow	The lowest seven-day low flow in any year is determined by calculating the average flow over seven consecutive days for every seven consecutive day period in the year and then choosing the lowest.
Taking	The taking of water is the process of abstracting water for any purpose and for any period.

1. Introduction

The Waikouaiti is a medium-sized river, which rises in two branches: the North, which flows southwards from Macraes to the confluence with the South Branch, which flows northwards from the Silver Peaks. From the confluence of the North and South Branches, the Waikouaiti flows for about 4.5 km before entering the Waikouaiti Estuary, approximately 7 km upstream of where it enters the Pacific Ocean at the seaside town of Karitane.

The Waikouaiti Estuary, a shallow, intertidal dominated estuary (SIDE), is a rich habitat for fish, shellfish, and waterfowl and is an important mahinga kai (food-gathering site). The area is also renowned for inaka (whitebait), tuna (eels), and pātiki (flounders); as well as shellfish such as tuaki (cockles), and pipi. The Waikouaiti River was granted mātaitai status in 2016 under the Fisheries (South Island Customary Fishing) Regulations 1999, which provides the local Kāti Huirapa ki Puketeraki Rūnanga with greater capacity to enhance the fishery of the river. The effect of flow management in the Waikouaiti River on habitat and water quality in the estuary has been identified as an important consideration by Kāti Huirapa ki Puketeraki Rūnanga, and so requires particular consideration.

The Waikouaiti catchment is within the Dunedin & Coast Freshwater Management Unit (FMU). The Regional Plan: Water (RPW) does not include a minimum flow for the Waikouaiti River, although the two main consumptive takes from the Waikouaiti River have resource consent conditions requiring maintenance of residual flows[1].

A previous study considered the flows required to maintain the habitat of the fish species in the Waikouaiti River (Dale 2011).

1.1. Purpose of the report

The purpose of this report is to present information to inform water management decision-making in the Waikouaiti catchment. This includes hydrological information (including flow naturalisation and flow statistics), data on aquatic values (including the distribution of indigenous fish) and application of instream habitat modelling to guide flow-setting processes, and consideration of the current state of the Waikouaiti compared to the proposed objectives for the Dunedin & Coast FMU set out in the proposed Otago Land and Water Regional Plan.

[1] Residual flows differ from minimum flows in that residual flows are the flow required to be maintained downstream of the point of take and are applied as a condition of resource consent, whereas minimum flows are flows that must be maintained at a hydrological monitoring site. When a minimum flow is reached, resource consent holders must cease taking water.

2. Background information

2.1. Catchment description

The Waikouaiti rises in two branches. The North Branch flows southwards from Macraes to join the South Branch 3.5 km downstream of Bucklands Crossing. The South Branch flows northwards through indigenous forest in the Silver Peaks Scenic Reserve. From the confluence of the North and South Branches, the Waikouaiti flows for about 4.5 km before entering the Waikouaiti Estuary, approximately 7 km upstream of where it enters the Pacific Ocean at the seaside town of Karitane.

Oceana Gold Ltd. operates a hard-rock goldmine at Macraes Flat, including several open pits and underground mining. The Macraes open pit mine has operated since 1990, and the Frasers underground mine was commissioned in 2008. The existing mine operation holds a resource consent to take and discharge water and potential contaminants from tailings storage facilities to the tributaries of the Shag/Waihemo and Murphys Creek, a tributary of the North Branch of the Waikouaiti River.

2.1.1. Climate

The climate of most of the Waikouaiti catchment is classified as 'cool-dry' (mean annual temperature <12°C, mean effective precipitation ≤500 mm) (River Environment Classification, Ministry for the Environment & NIWA, 2004). The upper North Branch receives very low rainfall (500-550 mm median annual rainfall) with annual rainfall increasing to 650-700 mm near the coast, although the highest rainfall in the North Branch catchment being 800-900 mm in high elevation areas around Swampy Hill and Mount Royal (Figure 2

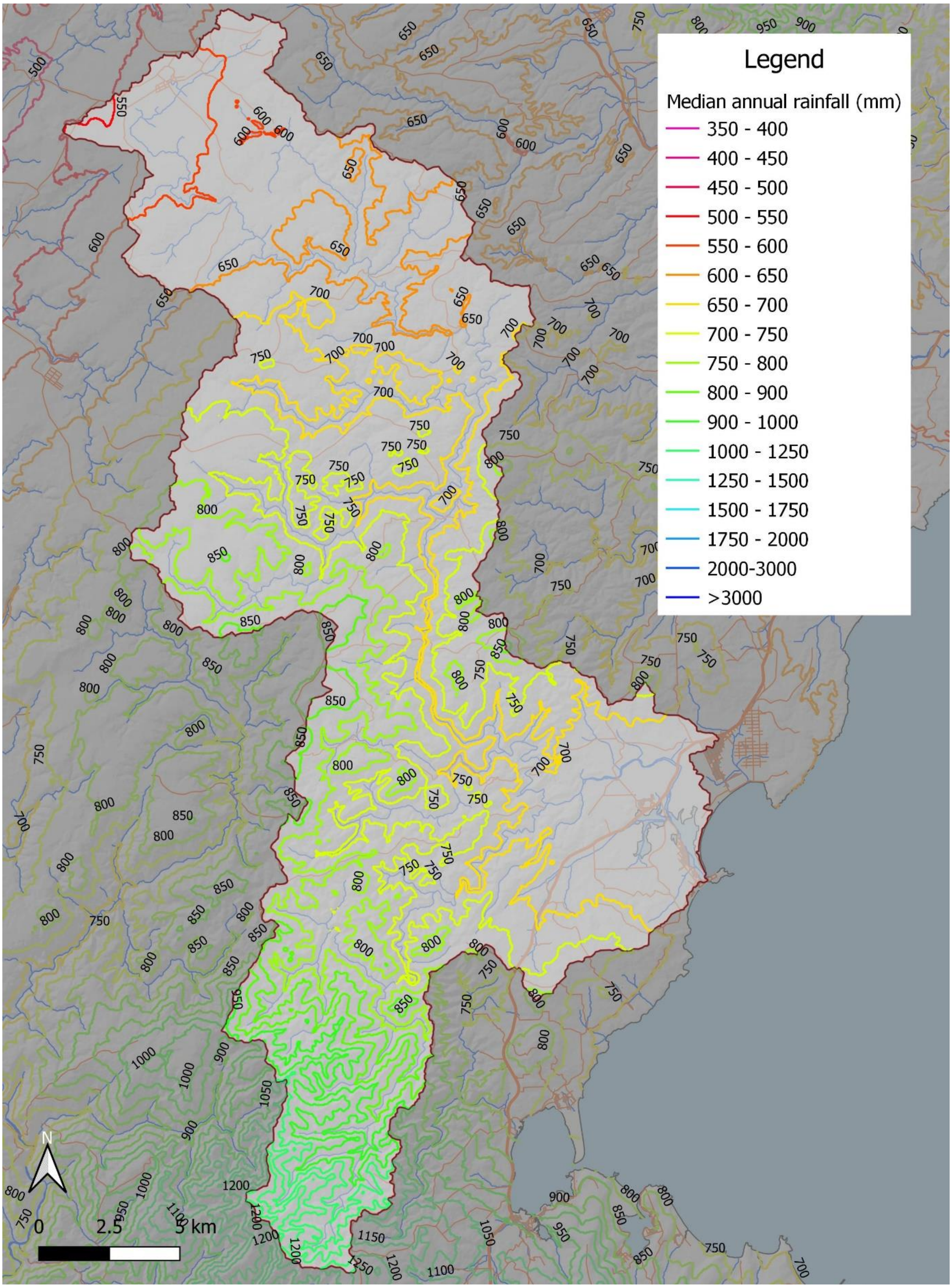

Figure 2). In contrast, the highest rainfall in the South Branch occurs in the upper reaches in the Silver Peaks (1,000-1,250 m) and decreases with altitude to 650-700 mm at the confluence with the North Branch (Figure 2)

2.1.2. Geology & geomorphology

Much of the Waikouaiti catchment consists of schist (Rakaia terrane) with localised shallow volcanic intrusions (Dunedin Volcanic Group) and non-marine quartzose conglomerate, sandstone, mudstone and lignite (Hogburn and Taratu Formations) (Bishop & Turnbull 1996, Forsyth 2001).

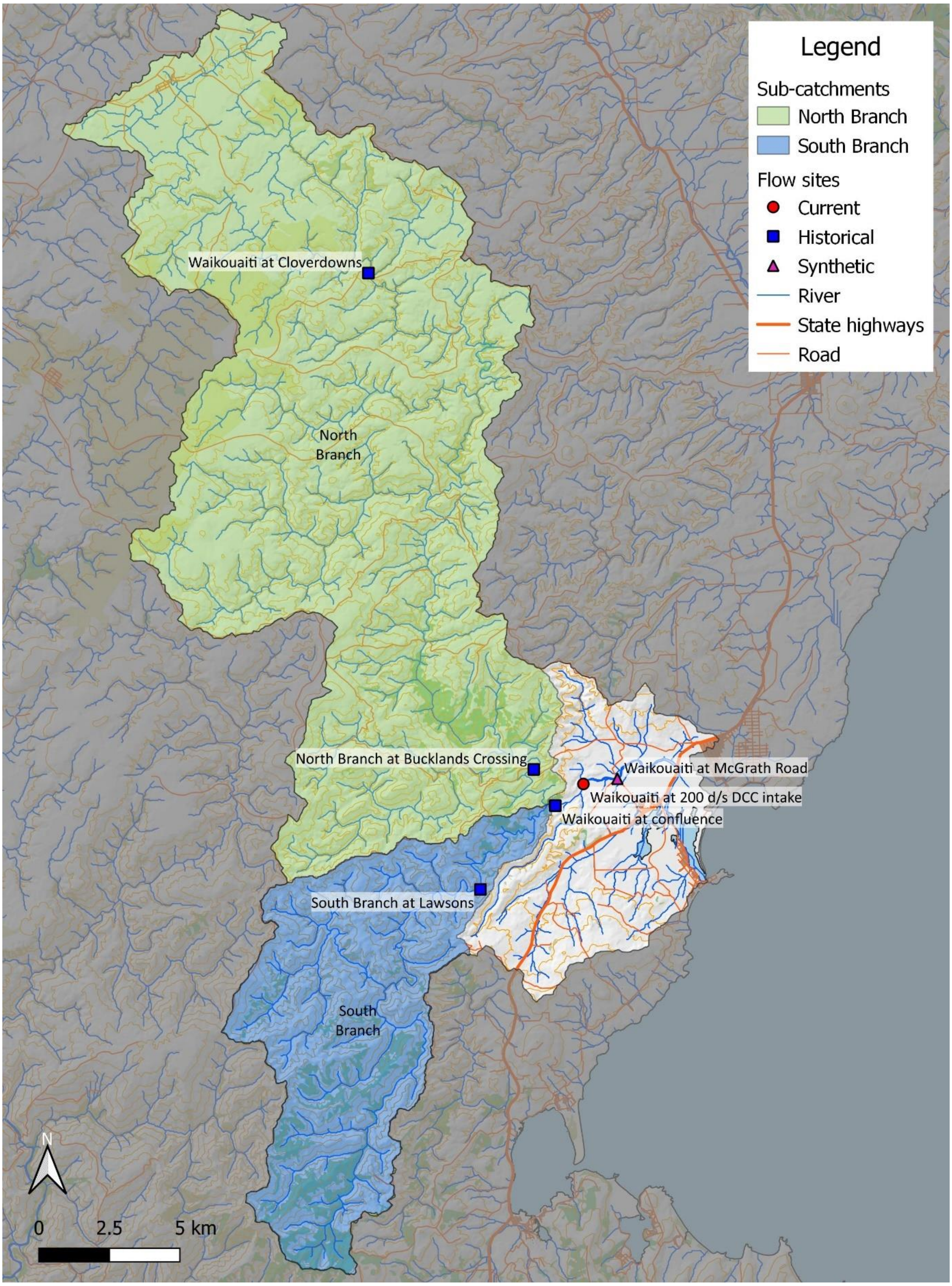

Figure 1 Map of the Waikouaiticatchment and flow recorder sites.

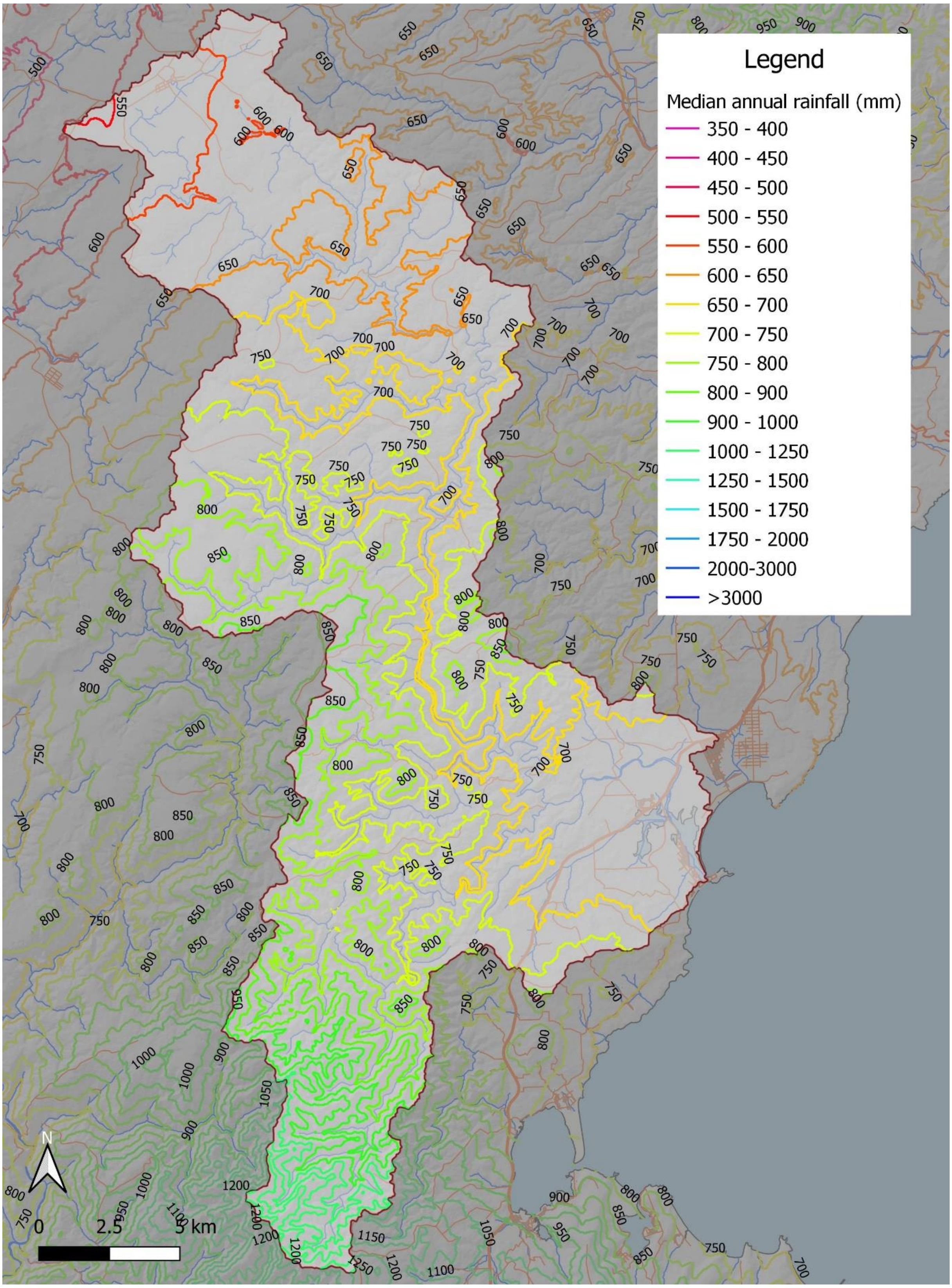

Figure 2 Distribution of rainfall (annual median rainfall) in the Waikouaiti catchment.

2.1.3. Vegetation and land use

The majority of the catchment of the North Branch of the Waikouaiti River consists of agricultural grasslands (low-producing grassland and high-producing exotic grassland), although some areas of tall tussock grassland remain, particularly at higher altitudes. There is an area of indigenous forest and mānuka/kānuka in the North Branch catchment upstream of Bucklands Crossing (Figure 3). Exotic forestry is particularly evident in the eastern portion of the South Branch catchment, with other small areas near Waikouaiti (Figure 3). The upper reaches of the South Branch are in the Silver Peaks Scenic Reserve, which consists of indigenous hardwoods and mānuka/kanuka, while the lower reaches of the South Branch flow through low producing grasslands (Figure 3). The lower catchment below the confluence of the North and South Branches is dominated by high producing exotic grassland (Figure 3).

The Waikouaiti estuary supports the largest remnant saltmarsh system in Otago and is listed in the RPW as a scarce wetland type containing glasswort and jointed rush (Schedule 9 of the RPW).

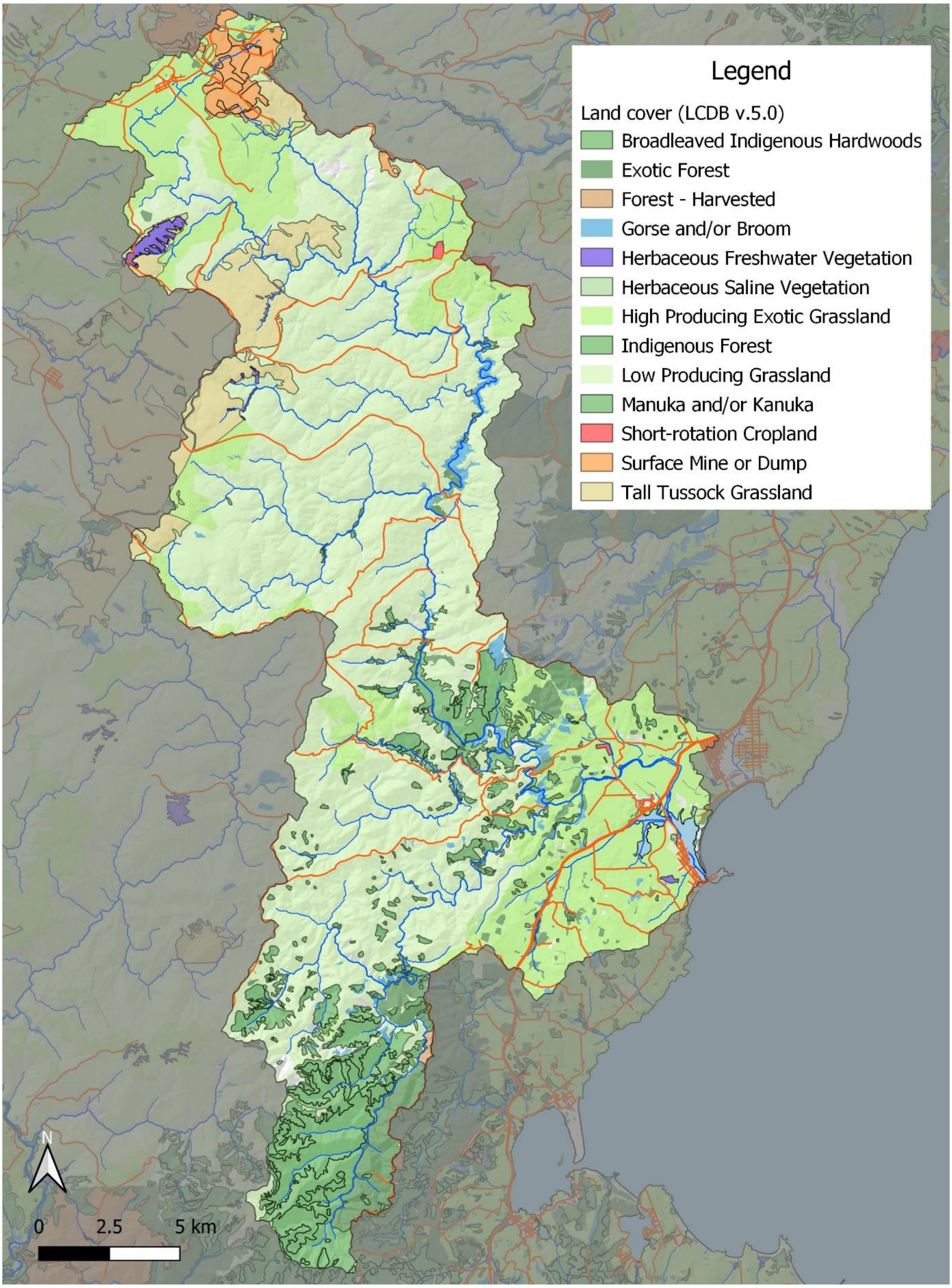

Figure 3 Land cover in the Waikouaiti catchment based on the Land Cover Database Version 5.0.

2.1.4. Estuary

Waikouaiti Estuary is a 229ha shallow, intertidal dominated estuary (SIDE) that discharges via one permanently open (but restricted) tidal mouth to the Pacific Ocean via a broad embayment at Karitane. It has a single narrow tidal opening that is occasionally restricted, a central river channel, and two main arms (Merton Arm and East Arm; Stevens & Robertson 2017).

Broad-scale monitoring in 2016 by Stevens & Robertson (2017) found that saltmarsh was present across 80.3ha (45%) of the intertidal estuary area, while 2% of the intertidal estuary area (1.7ha) supported sea grass (*Zostera muelleri*) growth in muddy sand substrate in the main river channel of the central estuary. The modification and loss of estuary saltmarsh and a densely vegetated buffer have been historically significant, and ongoing pressures were evident in these areas. Fine sediment issues were evident in the relatively sheltered Merton and East Arms, and eutrophication issues have been previously apparent in these same locations. Dense opportunistic macroalgal growths were apparent in the main estuary channel. The combined results of broad-scale monitoring in 2016 placed the estuary in a “moderate” state overall in relation to ecological health (Stevens & Robertson 2017).

Fine-scale benthic monitoring in the Waikouaiti Estuary in 2016 (Robertson et al. 2017) showed that there were areas of very dense growth of macroalgae in the lower estuary, while there were areas of high mud content sediments, low sediment oxygenation at the site in Merton Arm, with the macroinvertebrate community at this site reflecting these conditions (Robertson et al. 2017). This monitoring found no evidence of stratification and total nitrogen and chlorophyll *a* were both less than the eutrophication threshold level, suggesting a low susceptibility to water column phytoplankton blooms in the Waikouaiti Estuary on this occasion.

2.1.5. Surf breaks

The New Zealand Coastal Policy Statement (2010) identifies Karitane as a surf break of national significance (Schedule 1 of the Coastal Policy Statement). There are two popular surf breaks at the mouth of the Waikouaiti Estuary – commonly called the Karitane Bar and Karitane Point.

The Karitane Bar is a right-hand[2] bar break, breaking along the seaward edge of the accumulation of sand at the mouth of the estuary (Figure 4). It is typically surfed at low tide and offers long rides and sometimes hollow waves. Conditions at the Bar may be affected by outflows from the estuary.

The Karitane Point is a heavy reef break located off the point at the end of the rock wall on the true right bank of the estuary mouth (Figure 4). It is a big wave spot that can offer extremely heavy, barrelling waves. It only breaks in large swells (>2 m) and is typically surfed at high tide. It is not likely to be affected by outflows from the estuary except during flood flows.

Figure 4 Surf breaks near the mouth of the Waikouaiti Estuary. Arrows indicate the direction of the breaking wave

[2] Right-hand breaks break from the right to left when viewed from the shore

3. Regulatory setting

3.1. Regional Plan: Water (RPW)

Schedule 2A of the RPW specifies minimum flows and primary allocation for rivers in Otago but does not include a minimum flow for the Waikouaiti River.

Policy 6.4.2 of the RPW, defines the primary allocation limit as the greater of: (a) That specified in Schedule 2A, but where no limit is specified in Schedule 2A, 50% of the 7-day mean annual low flow; or (b) The sum of consented maximum instantaneous, or consented 7-day, takes of surface water and connected groundwater. Schedule 2A of the RPW does not specify a primary allocation limit for the Waikouaiti catchment, and the 7-d mean annual low flow for the Waikouaiti River is estimated to be 251 l/s (Lu 2023). The consents held by Dunedin City Council to operate the Waikouaiti Community Water Supply Scheme (2006.002.V1 and 2006.075.V1) both have instantaneous maximum rate of take of 60 l/s but cannot be exercised concurrently (Condition 1A of both consents). The current consented maximum instantaneous take in the Waikouaiti catchment is 129.2 l/s (see Section 4.2). Policy 6.4.2 specifies the allocation limit as the greater of (a) 50% of the 7-day mean annual low flow; or (b) the sum of consented maximum instantaneous, or consented 7-day, takes of surface water and connected groundwater. Therefore, the current allocation limit for the Waikouaiti catchment is 129.2 l/s.

3.2. Proposed Land and Water Plan

The ORC has undertaken a full review of the RPW, and the results of this review will be incorporated into a new Land and Water Regional Plan (LWRP). As part of the consultation for the LWRP, objectives have been developed for the Dunedin & Coast Freshwater Management Unit (FMU), which includes the Waikouaiti catchment. The proposed objectives, valid at the time of writing, are presented in Table 1.

Table 1 Baseline state and target attribute states for the state of the environment monitoring sites in the Waikouaiti River at confluence d/s.

Attribute	Baseline State	SOE 10y Trend	SOE 20y Trend	Target 2040
Periphyton Biomass				
Periphyton TN	C			C
Periphyton TP	D (C - D)			C
Ammonia - median	A			A
Ammonia - 95th Percentile	A			A
E.Coli 260	A			A
E.Coli 540	A (A - C)			C
E.Coli median	A			A
E.Coli Q95	A (A - D)			C
DRP-median	A			A
DRP Q95	A			A
MCI	D (D - C)			C
ASPM				
FISH IBI				
Suspended fine sediment	A			A
NNN - median	A			A
NNN - 95th percentile	A			A

4. Hydrology

4.1. Flow statistics

A continuous flow recorder has been installed in the Waikouaiti at 200 d/s DCC intake since September 2014. This site is located approximately 2.8 km upstream of where it enters the Estuary.

Two other long-term hydrological monitoring sites have been established on the mainstem of the Waikouaiti River, including Waikouaiti at Cloverdowns (23 December 1976-28 February 1987), Waikouaiti at confluence (8 February 2010-30 October 2015). A long-term site on the South Branch of the Waikouaiti River at Lawsons was monitored between 5 February 1991 and 5 October 2010 and a long-term site on the North Branch of the Waikouaiti River at Bucklands Crossing was monitored between 30 January 1991 and 3 August 1999.

Lu (2023) used available flow data for the Waikouaiti at 200 d/s DCC intake and water use data to produce a naturalised flow time-series from 22 September 2014– 8 June 2023. The flow statistics based on the analysis of Lu (2023) are summarised in Table 2.

Table 2 Flow statistics for hydrological monitoring sites in the Waikouaiti from Lu (2023) and Dale (2011).

		Flow statistics (l/s)		
		Mean	Median	7d MALF (Jul-Jun)
Waikouaiti at 200 d/s DCC intake	Naturalised flows	2,497	909	251
	Observed flows	2,482	989	234
Waikouaiti at McGrath Road bridge (synthetic)	Simulated observed flows	2,490	906	233
Waikouaiti at downstream confluence	Dale (2011) (natural)	2,855	856	258

Table 3 Low-flow return interval analysis for hydrological monitoring sites in the Waikouaiti at 200 d/s DCC intake from Lu (2023) and Dale (2011).

		Return interval (7-day average)		
		5-year ($Q_{7,5}$)	10-year ($Q_{7,10}$)	20-year ($Q_{7,20}$)
Waikouaiti at 200 d/s DCC intake	Naturalised flows	175	132	-
Waikouaiti at downstream confluence	Dale (2011) (natural)	147	129	119

The average number of events per year exceeding three times the median flow (FRE3) in the Waikouaiti at 200 d/s DCC intake is 6.4 (Lu 2023).

4.2. Water allocation & use

Primary allocation

There are ten resource consents for primary water takes from the Waikouaiti catchment, with a total primary allocation of 129.2 l/s (Table 4). Oceana Gold (New Zealand) Ltd. has six resource consents for water takes from the Waikouaiti catchment as part of their operations at the Macraes gold mine, including for mining and mineral processing operations, post-mining rehabilitation, dewatering of tailings storage facilities and to create a pit lake. For the purposes of this report, these permits are considered to be non-consumptive, and so are not counted in the catchment primary allocation.

Of the remaining four consents, three are for community water supply (Stoneburn Water Supply and Waikouaiti Community Water Supply Scheme, operated by Waitaki District Council and Dunedin City Council, respectively). However, the consents held by Dunedin City Council to operate the Waikouaiti Community Water Supply Scheme (2006.002.V1 and 2006.075.V1) both have instantaneous maximum rate of take of 60 l/s but cannot be exercised concurrently (Condition 1A of both consents). Therefore, the consented allocation in the Waikouaiti catchment is 129.2 l/s.

Available water metering data shows that the average combined rate of take ranged from 36 l/s (January) to 10.5 l/s (July) while the maximum observed combined rate of take from the Waikouaiti River ranged from 91-97 l/s (October-April) to 37-38 l/s (June-July) (Figure 5).

The DCC take is listed in Schedule 1B of the Water Plan as a community take and is not subject to any minimum flow implemented for the Waikouaiti catchment. However, these takes are subject to consent conditions that require the introduction of water conservation measures when flows immediately below these takes fall below 150 l/s from November to April and 350 l/s from May to October and require the taking of water to cease when flows immediately below these takes fall below 60 l/s in November to April and 155 l/s from May to October.

Resource Consent RM13.299.01 requires the maintenance of residual flows of 300 l/s in October, 220 l/s in November and 150 l/s in all other months, with the exception of reasonable stock drinking water.

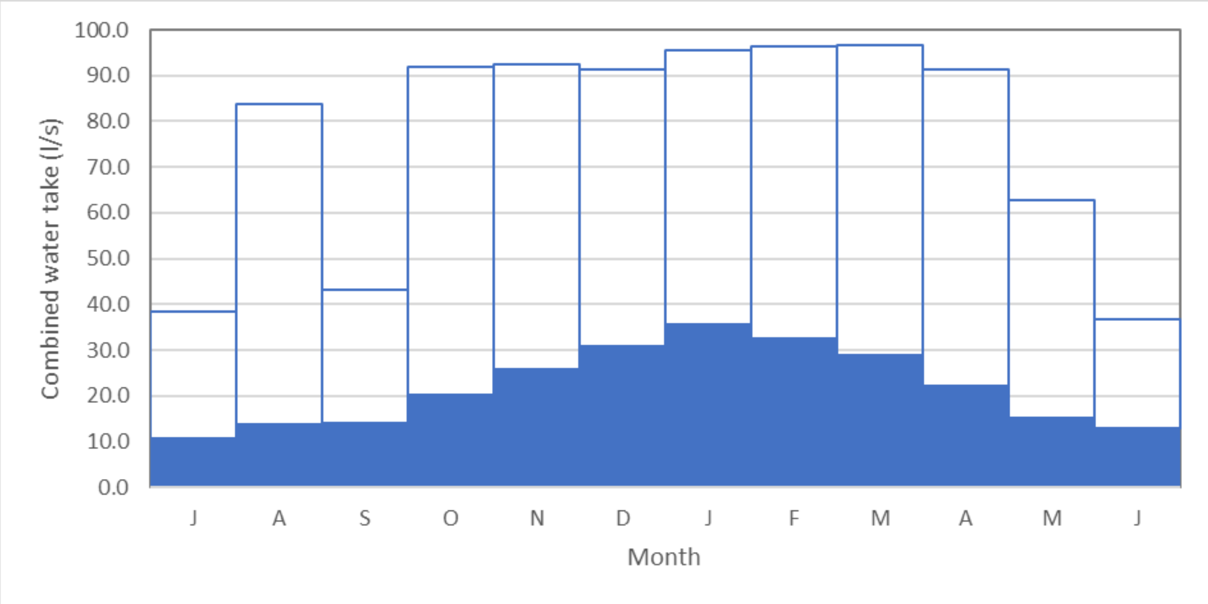

Figure 5 Average (blue bars) and maximum (blue outline) combined rate of take from the Waikouaiti River (based on available water metering data: WM0837, WM1140, WM1483).

Supplementary allocation

There is one resource consent for supplementary water takes in the first supplementary allocation block from the Waikouaiti River held by Waitaki District Council for the operation of the Stoneburn Water Supply. The maximum rate of take of this permit is 0.5 l/s.

Table 4 Active resource consents for primary takes in the Waikouaiti catchment.

Consent #	Max. instant. Take (l/s)	Daily volume (m^3/d)	Monthly volume (m^3/m)	Annual volume (m^3/y)	Waterway	Purpose
RM17.121.01	4.2	360	10,800		North Branch	Rural water supply
2006.002.V1 2006.075.V1	60	3,500			Waikouaiti River	Community water supply
RM13.299.01	65	5,240	153,965	957,900	Waikouaiti River	Irrigation, dairy shed and stockwater use.
96810.V3					Frasers West Pit	Mining operations and post mining rehabilitation
2007.522		300			Golden Bar Pit	
2008.237	100				Frasers Pit	Mine dewatering
RM10.351.46.V1						Creation of pit lakes
RM10.351.48.V2	200				Frasers Pit, Innes Mills Pit, Southern Pit, Round Hill Pit and Golden Point Pit	Mine dewatering
RM20.167.02					Frasers West Pit	Mine dewatering

Table 5 Active resource consents in the first supplementary block (min flow 229 l/s) in the Waikouaiti catchment.

Consent #	Max. instant. Take (l/s)	Monthly volume (m^3/m)	Annual volume (m^3/y)	Waterway	Purpose
RM17.121.02	0.5			North Branch	Rural water supply

5. Water temperature

Water temperature is a fundamental factor affecting all aspects of stream systems. It can directly affect fish populations by influencing survival, growth, spawning, egg development and migration. It can also affect fish populations indirectly, through effects on physicochemical conditions and food supplies (Olsen et al., 2012). Of all the fish in the Waikouaiti catchment, brown trout (*Salmo trutta*) will likely be the most sensitive to high water temperatures. Their thermal requirements are relatively well understood, and Todd *et al*. (2008) calculated acute and chronic thermal criteria for this species. The objective of acute criteria is to protect species from the lethal effects of short-lived high temperatures. In this case, acute criteria are applied as the highest two-hour average water temperature measured within 24-hours (Todd et al., 2008). In contrast, chronic criteria intend to protect species from the sub-lethal effects of prolonged periods of elevated temperatures. In this study, chronic criteria are expressed as the maximum weekly average temperature (Todd et al., 2008).

Water temperatures in the South Branch at Lawsons exceeded acute thermal criteria for many indigenous species present (Table 6) as well as acute and chronic thermal criteria brown trout over the period for which water temperature data was available (Table 7; Figure 6, Figure 7). Similarly, water temperatures in the Waikouaiti at 200 m upstream of the DCC Intake exceeded acute thermal criteria for many indigenous species present as well as for acute and chronic thermal criteria brown trout over the period for which water temperature data was available (Table 7; Figure 6, Figure 7).

These data suggest that the thermal environment of the Waikouaiti can be unsuitable for some of the indigenous species present and for brown trout at times.

Table 6 Thermal criteria used in these assessments. These criteria are based on the upland criteria of Todd et al. (2008) and Olsen et al. (2012).

Common name	Scientific name	Acute criteria (°C)	Chronic criteria (°C)
Shortfin eel	*Anguilla australis*	26	30
Longfin eel	*Anguilla dieffenbachii*	23	28
Common bully	*Gobiomorphus cotidianus*	22	24
Inanga	*Galaxias maculatus*	-	22
Common mayfly	*Deleatidium*	21	-
Net-spinning caddis fly	*Aoteapsyche*	24	-
Sand-cased caddis fly	*Pycnocentria*	23	-
Shrimp	*Paratya curvirostris*	24	-
Amphipod	*Paracalliope fluviatillis*	22	-

Table 7 Number of exceedances of thermal criteria in the South Branch at Lawsons and the mainstem of the Waikouaiti 200 m d/s DCC Intake.

Site	Thermal criteria	Number of exceedances (per year)		Years with no exceedances	Years with exceedances (% of years)
		Mean	Max		
South Branch at Lawsons (5 March 2004 – 4 October 2010)	Brown trout acute (>24.6°C)	3.4	13	4	43%
	Deleatidium acute (21°C)	19.3	57	2	71%
	Common bully (22°C)	14.9	41	3	57%
	Longfin eel, *Pycnocentria* acute (23°C)	9.7	28	3	57%
	Aoteapsyche acute (24°C)	6.0	20	3	57%
	Shortfin eel (26°C)	0.6	4	6	14%
	Brown trout chronic (>19.6°C)	4.6	16	3	57%
Waikouaiti 200 m d/s DCC intake (14 February 2020 – 4 September 2023)	Brown trout acute (>24.6°C)	0.2	1	3	40%
	Deleatidium acute (21°C)	10.0	27	1	80%
	Common bully (22°C)	4.4	12	2	60%
	Longfin eel, *Pycnocentria* acute (23°C)	1.8	5	2	60%
	Aoteapsyche acute (24°C)	0.4	1	2	60%
	Shortfin eel (26°C)	0.0	0	5	0%
	Brown trout chronic (>19.6°C)	5.4	24	2	60%

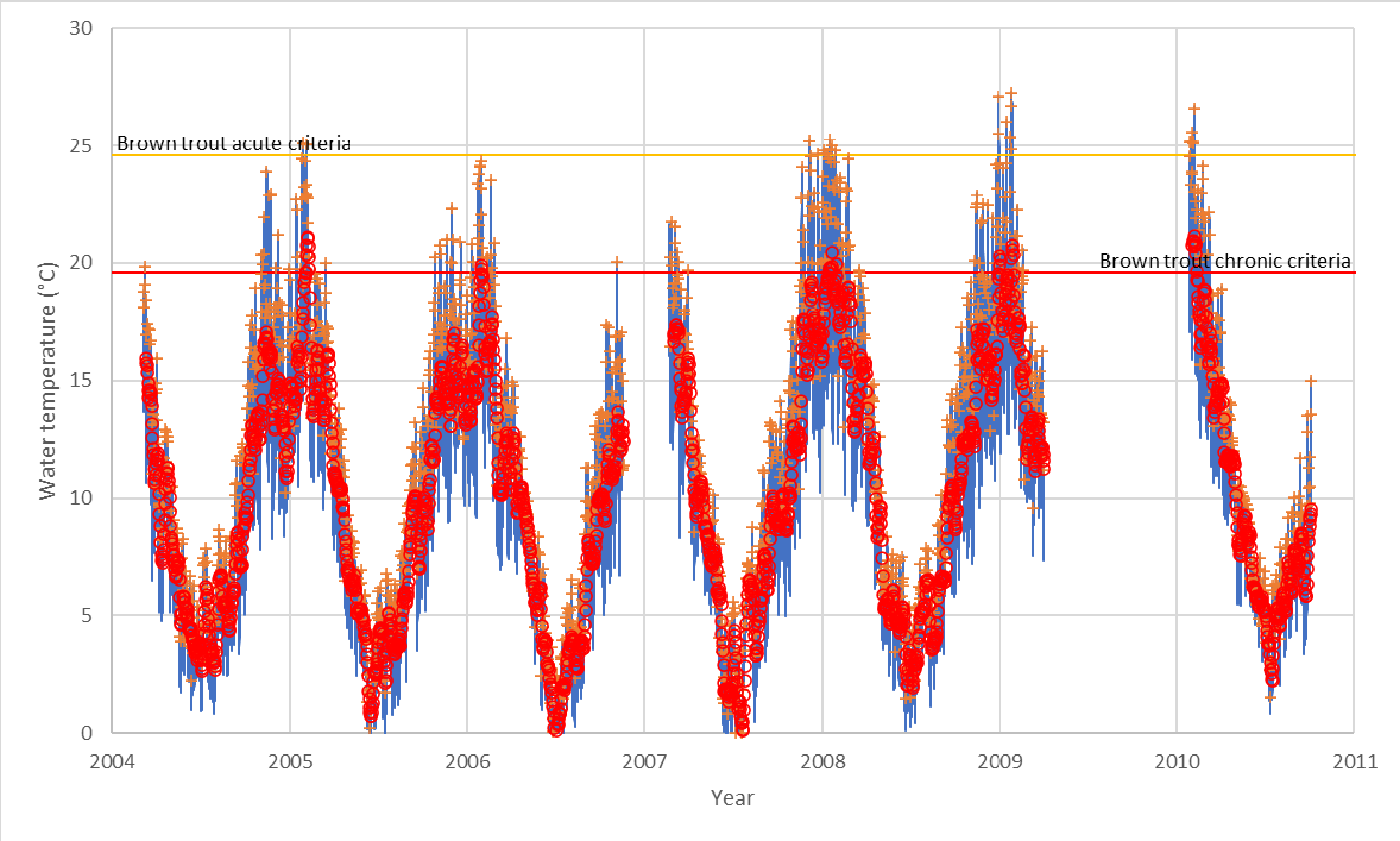

Figure 6 Water temperature in the South Branch of the Waikouaiti River between March 2004 and October 2010. Orange crosses are the maximum 2-h average water temperature for comparison with acute thermal criteria. Red circles are the seven-day average of mean daily temperatures for comparison with chronic thermal criteria.

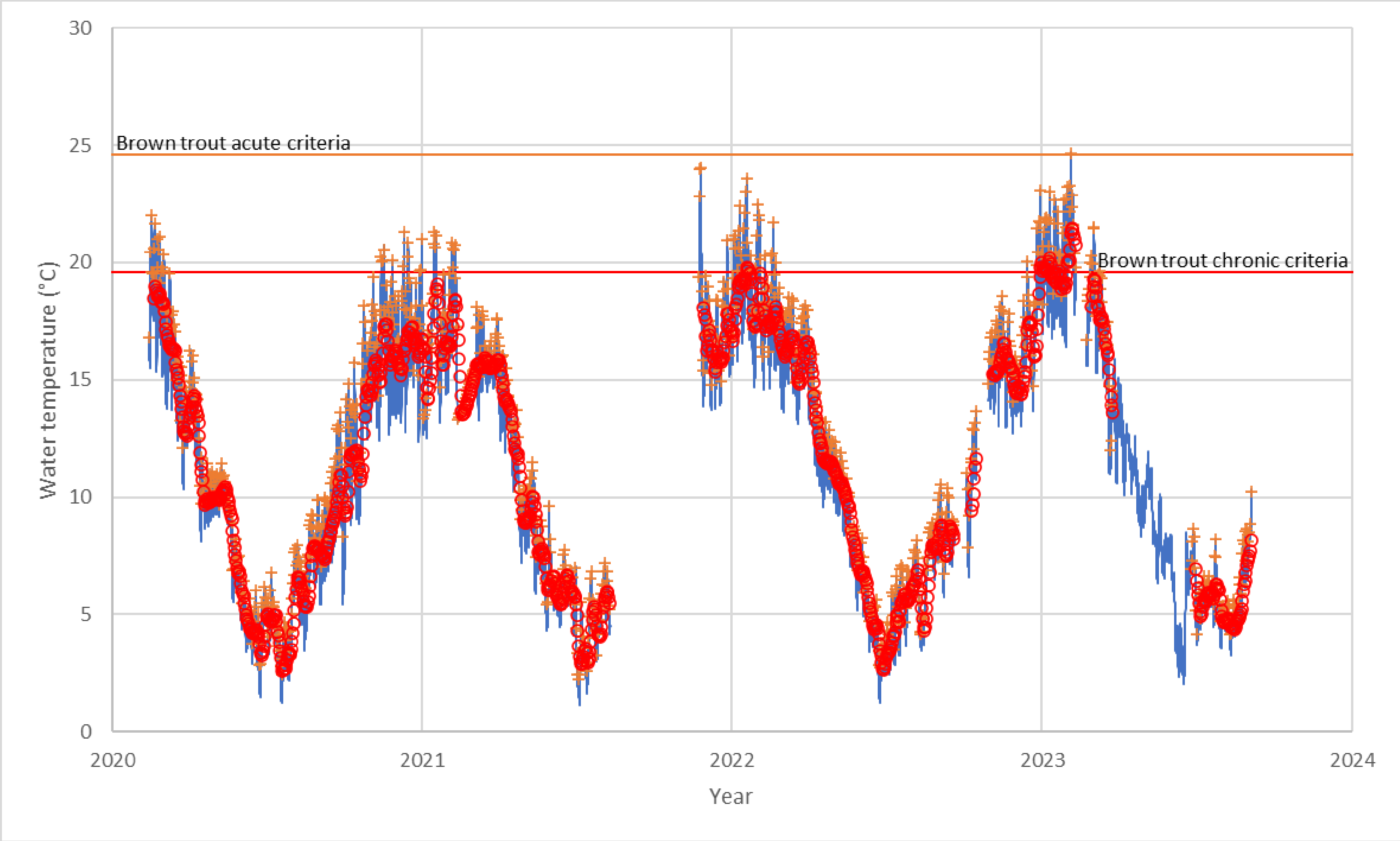

Figure 7 Water temperature in the Waikouaiti at 200 m d/s DCC intake between February 2020 and September 2023. Orange crosses are the maximum 2-h average water temperature for comparison with acute thermal criteria. Red circles are the seven-day average of mean daily temperatures for comparison with chronic thermal criteria.

6. The aquatic ecosystem of the Waikouaiti catchment

6.1. Periphyton

The periphyton community forms the slimy coating on the surface of stones and other freshwater substrates and can include various types and forms. Periphyton is an integral part of the food web of many rivers; it captures energy from the sun and converts it, via photosynthesis, to energy sources available to macroinvertebrates, which feed on it. These, in turn, are fed on by other invertebrates and fish.

However, periphyton can form nuisance blooms that can detrimentally affect other instream values, such as aesthetics, biodiversity, recreation (swimming and angling), water-takes (irrigation, stock/drinking water and industrial) and water quality. Some types of cyanobacteria may produce toxins that pose a health risk to humans and animals. These include toxins that affect the nervous system (neurotoxins), liver (hepatotoxins), and dermatotoxins that can cause severe skin irritation.

The presence of potentially toxic cyanobacteria is undesirable as it can affect the suitability of a waterway for drinking, recreation (swimming), dogs, stock drinking water and food-gathering (by affecting palatability or through accumulation of toxins in organs such as the liver). Cyanobacteria-produced neurotoxins have been implicated in the deaths of numerous dogs in New Zealand (Hamill, 2001; Wood et al., 2007).

There is limited information on the periphyton community of the Waikouaiti River. Information on periphyton composition (based on microscopic examination of rock scrapings) was collected annually between 2001 and 2018 at Orbells Crossing (also known as McGrath Road bridge). Periphyton composition was variable, with little consistency in the dominant periphyton taxa observed. Dominant taxa included the filamentous green algae *Mougeotia* and *Spirogyra*, and the diatoms *Didymosphenia*, *Fragilaria*, *Gomphoneis* and *Synedra*.

6.2. Macroinvertebrates

Macroinvertebrates are an important part of stream food webs, linking primary producers (periphyton and terrestrial leaf litter) to higher trophic levels (fish and birds). Macroinvertebrates have long been used as indicators of ecosystem health and, conversely, the impacts of pollutants (e.g. Hilsenhoff 1977, 1987; Stark 1985). The Macroinvertebrate Community Index and its variants have been widely used in New Zealand to assess the effects of nutrients and sediment (Wagenhoff et al. 2016).

In State of the Environment (SoE) monitoring, the macroinvertebrate communities in the Waikouaiti at McGrath Road/Orbells Crossing collected annually between 2001 and 2016 were dominated by the mudsnail *Potamopyrgus*, amphipod *Paracalliope*, riffle beetles (Elmidae), chironomid midges (Orthocladiinae) and oligochaete worms. Macroinvertebrates were collected from the Waikouaiti at ds confluence in 2017, 2018 and 2022, with similar species dominant at this site as at the Orbells Crossing site.

In addition, kōura/freshwater crayfish (*Paranephrops zealandicus*), freshwater shrimp (*Paratya*), kākahi/freshwater mussel have been recorded from the Waikouaiti catchment. Of these, kōura and kākahi are both classified as at risk – declining (Grainger et al. 2018).

MCI scores for the Waikouaiti at Confluence d/s site between 2014 and 2022 (Range: 83-105, median = 91, N=6) and ASPM scores (Range: 0.24-0.29, median = 0.27, N=6) put this site in C-band of the NOF (Figure 8a & c) while SQMCI scores (Range: 3.22-4.15, median = 3.77, N=6) put this site in D-band of the NOF (Figure 8b).

Historical MCI (Range: 81-102, median = 86, N=7), SQMCI (Range: 1.45-5.01, median = 4.18, N=7), and ASPM scores (Range: 0.17-0.44, median = 0.25, N=7) for Orbells Crossing site put this site in D-band of the NOF (Figure 8a-c).

Trends in macroinvertebrate metrics were not considered for either site due to the relatively limited number of sampling occasions at each.

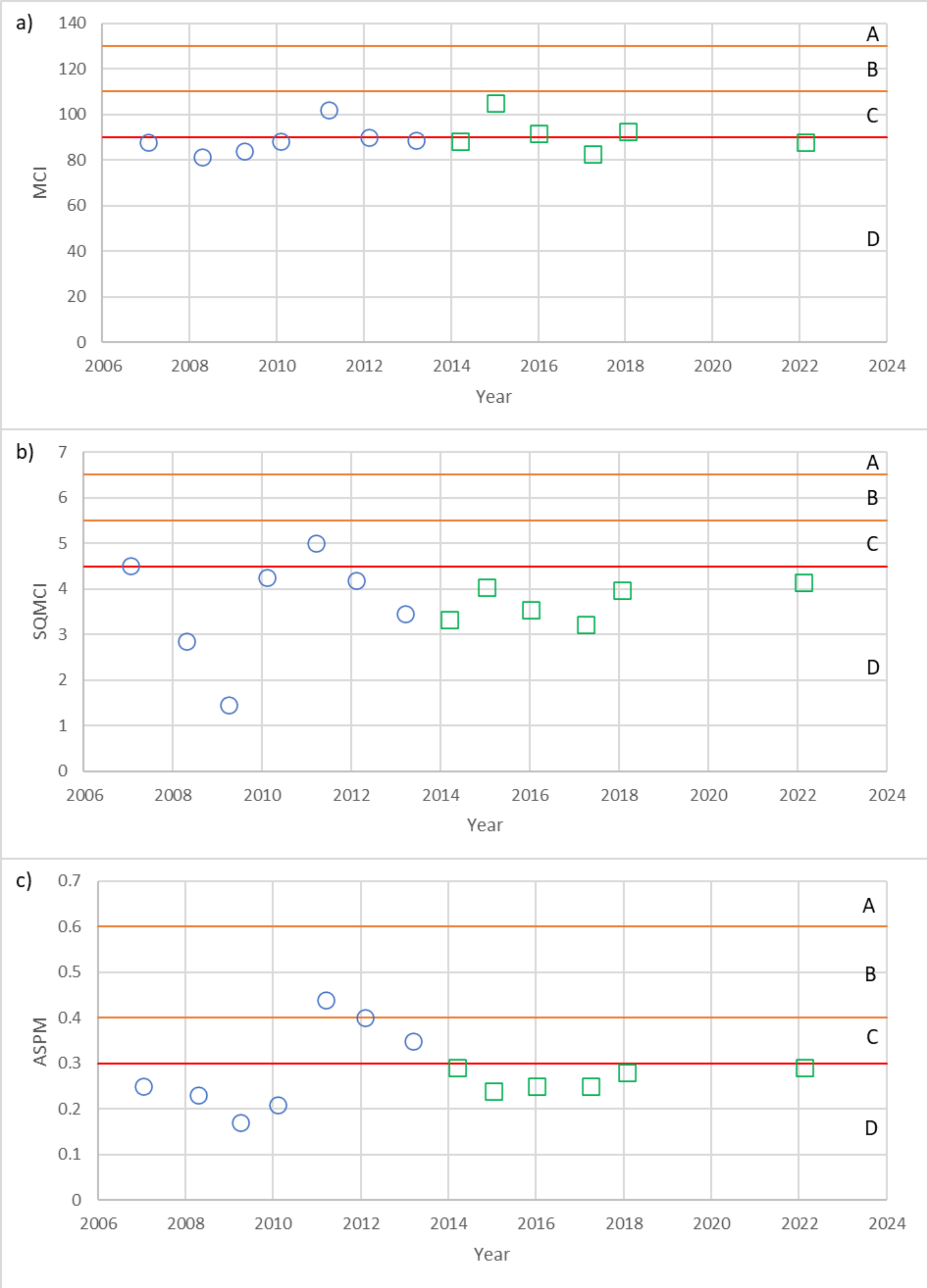

Figure 8 Macroinvertebrate indices for two biomonitoring sites in the Waikouaiti River; Orbells Crossing (2007-2013; blue circles) and d/s confluence (2014-2022; green squares). a) Macroinvertebrate community index (MCI), b) semi-quantitative MCI (SQMCI) and c) average score per metric (ASPM). Each plot includes thresholds for attribute states based on Tables 14 and 15 of the National Objectives Framework.

6.3. Fish

6.3.1. Indigenous fish

Fifteen species of indigenous freshwater fish have been recorded from the Waikouaiti catchment, (Table 9). This represents a high level of indigenous biodiversity, and the species present include several species that are at risk or threatened – longfin eel, bluegill bully, kōaro and inaka/inanga are classified as at risk – declining, while lamprey and Taieri flathead galaxias are classified as threatened – nationally vulnerable (Dunn et al. 2017).

Shortfin eels have been recorded from the North Branch and tributaries of the Merton Arm of the Waikouaiti Estuary, while longfin eels have been recorded from throughout the catchment (Figure 9). Torrentfish, lamprey, common smelt and black flounder have been recorded from the lower reaches (Figure 9).

Upland bully are widespread in the Waikouaiti catchment, while common bully have been recorded as far upstream as Bucklands Crossing, and bluegill, redfin and giant bullies have been recorded in the lower catchment close to the estuary (Figure 9).

Four species of galaxiid have been recorded from the Waikouaiti catchment. Inanka/Inanga have been recorded in the lower reaches of the mainstem of the Waikouaiti River and in tributaries, while flathead galaxias have been recorded from many tributaries in the upper catchment (including Back Creek, Garden Bush Creek, Murphys Creek, Poley Creek) as well as the mainstem of the upper North Branch and Tommy Flat Creek (Figure 9). Kōaro have been recorded from the South Branch, Toll Bar Creek and the upper North Branch (Figure 9). Banded kokopu have been recorded from the mainstem near Orbells Crossing (Figure 9).

6.3.2. Introduced fish

Brown trout are widespread within the Waikouaiti catchment (Figure 9). The Waikouaiti supports a locally important sport fishery (Otago Fish & Game Council 2022). Table 8 presents angler effort in the Waikouaiti, recorded during National Angler Surveys conducted in 1994/95, 2007/08 and 2014/15. Overall angler usage is relatively low, with angling effort occurring throughout the fishing season (October to April; Unwin, 2016).

Table 8 Angler effort on the Waikouaiti based on the National Angler Survey (Unwin, 2016)

	National Angler Survey			
Catchment	**1994/95**	**2001/02**	**2007/08**	**2014/15**
Waikouaiti	2,630 ± 700	1,360 ± 850	1,240 ± 580	630 ± 230

Table 9 Fish species recorded from the Waikouaiti catchment.

Family	Common name	Species	Threat classification
Anguillidae	Shortfin eel	*Anguilla australis*	Not threatened
	Longfin eel	*Anguilla dieffenbachii*	Declining
Eleotridae	Upland bully	*Gobiomorphus breviceps*	Not threatened
	Common bully	*Gobiomorphus cotidianus*	Not threatened
	Bluegill bully	*Gobiomorphus hubbs*	Declining
	Redfin bully	*Gobiomorphus huttoni*	Not threatened
	Giant bully	*Gobiomorphus gobioides*	Naturally uncommon
Galaxidae	Kōaro	*Galaxias brevipinnis*	Declining
	Flathead galaxias	*Galaxias depressiceps*	Nationally vulnerable
	Banded kōkopu	*Galaxias fasciatus*	Not threatened
	Inaka/Inanga	*Galaxias maculatus*	Declining
Geotriidae	Lamprey	*Geotria australis*	Nationally vulnerable
Retropinnidae	Smelt	*Retropinna retropinna*	Not threatened
Cheimarrichthyidae	Torrentfish	*Cheimarrichthys fosteri*	Declining
Pleuronectidae	Black flounder	*Rhombosolea retiaria*	Not threatened
Salmonidae	Brown trout	*Salmo trutta*	Introduced and naturalised

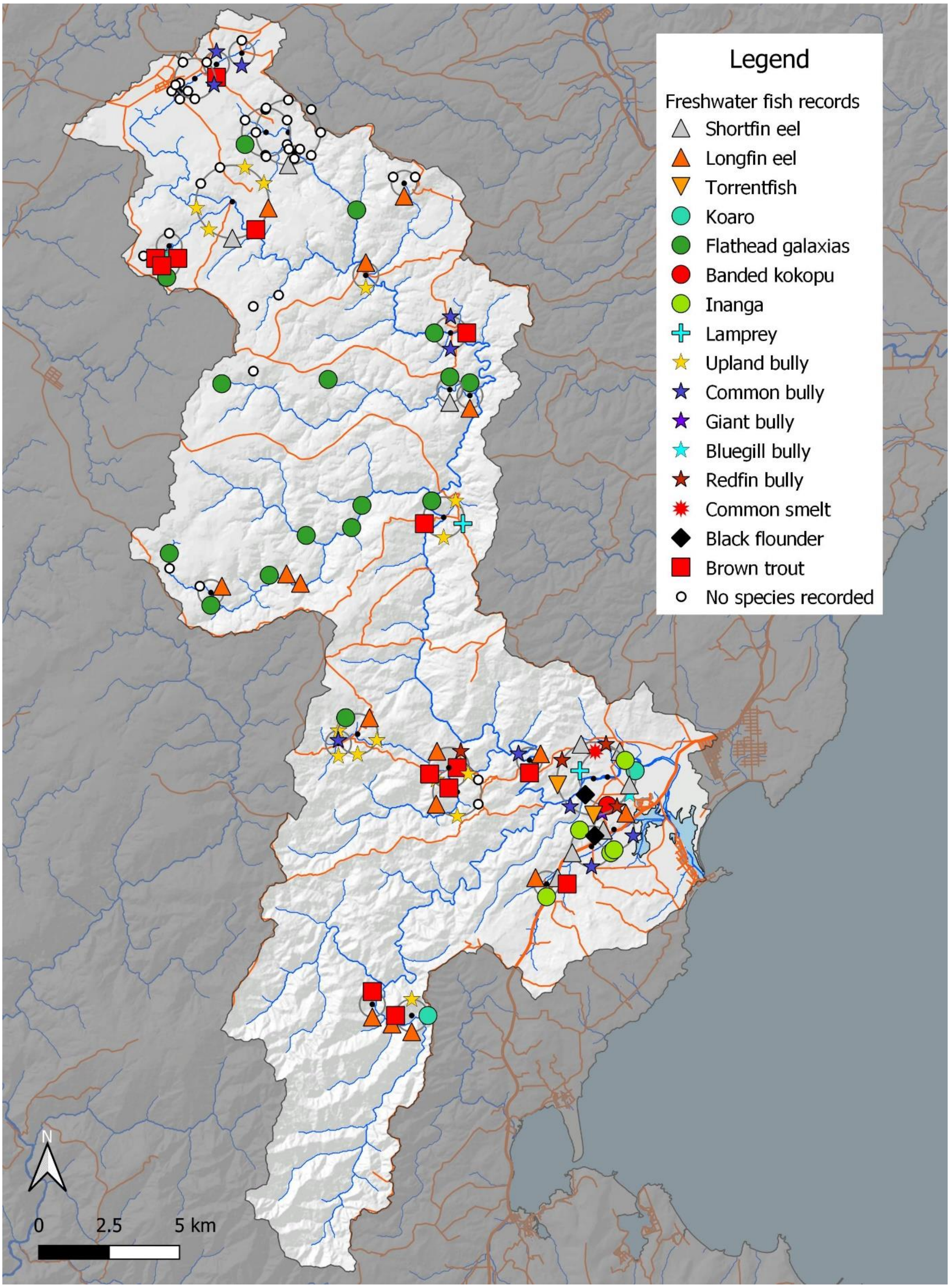

Figure 9 Distribution of fish species within the Waikouaiti catchment. From records in the New Zealand Freshwater Fish Database (downloaded 10 October 2023).

6.4. Current ecological state

Schedule 2A of the RPW does not currently include a minimum flow and/or allocation limit for the Waikouaiti catchment. However, the three main consumptive takes are subject to residual flows. The two takes operated by the DCC require that water conservation measures are introduced if flows fall below 150 l/s (November-April) and 350 l/s (May-October) and require the taking of water to cease when flows immediately below these takes fall below 60 l/s (November-April) and 155 l/s (May-October). The other major take (RM13.299.01) requires the maintenance of residual flows of 300 l/s in October, 220 l/s in November and 150 l/s in all other months, except for reasonable stock drinking water.

At the time of writing, the proposed objectives for the Dunedin & Coast FMU include the following narrative objectives: *"Freshwater bodies within the Dunedin & Coast FMU support healthy ecosystems with thriving habitats for a range of indigenous species, and the life stages of those species, that would be expected to occur naturally"* and *"This is achieved where the target attribute state for each biophysical component (as set in table) are reached.".* The table referred to is presented in Table 10 below.

6.4.1. Ecosystem health

In addition to the ecosystem health and human contact values identified in Table 10, the proposed objectives for fishing, animal drinking water, cultivation and production of food and beverages and fibre, commercial and industrial use, and drinking water supply are measured by the target attribute states for ecosystem health and human contact presented in Table 10. Attributes for natural form and character and threatened species within the Dunedin & Coast FMU are under development, so at the time of writing, it is not possible to consider the current state of the Waikouaiti catchment relative to these attributes.

Table 10 presents the current attribute state for the Waikouaiti at Confluence d/s monitoring site. It compares the current state to the proposed target attribute state for the Dunedin & Coast FMU. Attributes for Ecosystem Health – Aquatic life exceeds the target states for macroinvertebrate attributes (Table 10). Periphyton biomass was not able to be compared to the proposed target attribute state for this site.

6.4.2. Water quality

All water quality parameters considered were in A-band at the Waikouaiti at Confluence d/s monitoring site (Table 10).

Table 10 Comparison of the current attribute state in the Waikouaiti at Confluence d/s based on Ozanne, Borges & Levy (2023).

Attribute	Baseline State	Target 2040	Current state
Periphyton Biomass			
Periphyton TN	C	C	
Periphyton TP	D (C - D)	C	
Ammonia - median	A	A	A
Ammonia - 95th Percentile	A	A	A
E. coli % exceeding 260 cfu/100 mL	A	A	A
E. coli % exceeding 540 cfu/100 mL	A (A - C)	C	A
E. coli median	A	A	A
E. coli Q95	A (A - D)	C	A
DRP-median	A	A	A
DRP Q95	A	A	A
MCI	D (D - C)	C	C*
ASPM			
FISH IBI			A
Suspended fine sediment	A	A	A
NNN - median	A	A	A
NNN - 95th percentile	A	A	A

* = 5-year median based on 2015-2018, 2022

7. Instream Habitat Assessment

7.1. Instream habitat modelling in Waikouaiti

Instream habitat modelling is a method that can be used to consider the effects of changes in flow on instream values, such as physical habitat, water temperature, water quality and sediment processes. The strength of instream habitat modelling lies in its ability to quantify habitat loss caused by changes in the flow regime, which helps evaluate alternative flow proposals. However, it is essential to consider all factors that may affect the organism(s) of interest, such as food, shelter and living space, and to select appropriate habitat-suitability curves, for an assessment to be credible. Habitat modelling does consider several other factors, including the disturbance and mortality caused by flooding and biological interactions (such as predation), which can significantly influence the distribution of aquatic species.

Instream habitat modelling requires detailed hydraulic data, and knowledge of the ecosystem and the stream biota's physical requirements. The basic premise of habitat methods is that if there is no suitable physical habitat for a given species, it cannot exist (Jowett & Wilding 2003). However, if the physical habitat is available for that species, it may or may not be present, depending on other factors not directly related to flow, or flow-related factors which have operated in the past (e.g. floods). In other words, habitat methods can set the outer envelope of suitable living conditions for the target biota (Jowett 2005).

Instream habitat is defined as Reach Area Weighted Suitability (RAWS), a measure of the total area of suitable habitat per metre of stream length. It is expressed as square metres per metre (m^2/m). Another metric, the reach-averaged Combined Suitability Index (CSI), measures the average habitat quality provided at a particular flow. CSI is useful when considering the effects of changes in flow regime on periphyton where it is not the overall population response that is of interest (such as for fish), but the percentage cover across the riverbed (such as periphyton).

7.1.1. Habitat preferences and suitability curves

Habitat suitability curves (HSC) for a range of organisms present in the Waikouaiti catchment were modelled (Table 11) to understand the full range of potential effects of flow regime changes in the Waikouaiti – from changes in the cover and type of periphyton, to changes in the availability of macroinvertebrate prey, to changes in the habitat for fish and birds.

The food producing habitat HSC is an overseas HSC describing macroinvertebrates most productive habitat conditions (riffles and shallow runs). The mudsnail *Potamopyrgus* is among the most abundant and widespread aquatic macroinvertebrate in New Zealand. It is abundant in the lower reaches of the Waikouaiti River (Section 6.2) and was included in this analysis for this reason. Chironomid midge larvae (Orthocladiinae) also widespread and can be particularly abundant in lowland waterways and following periods of stable flow when periphyton biomass is high. Riffle beetles (Elmidae) are also a widespread taxon, which can be abundant in the Waikouaiti River (Section 6.2).

Flathead galaxias were not considered in this analysis, as they have been recorded from tributaries and upper reaches of the Waikouaiti but have not been recorded from the modelled reach.

Table 11 Habitat suitability curves used in instream habitat modelling in the Waikouaiti.

Group	HSC name	HSC source
Macroinvertebrates	Food producing	Waters (1976)
	Mudsnail (*Potamopyrgus*)	Jowett (Waitaki)
	Chironomid midge (Orthocladiinae)	Jowett (Waitaki)
	Riffle beetle (Elmidae)	Jowett (Waitaki)
Indigenous fish	Longfin eel (>300 mm)	Jowett & Richardson (2008)
	Torrentfish	Jowett & Richardson (2008)
	Upland bully	Jowett & Richardson (2008)
	Common bully	Jowett & Richardson (2008)
	Bluegill bully	Jowett & Richardson (2008)
	Redfin bully	Jowett & Richardson (2008)
	Inaka/Inanga	Jowett & Richardson (2008)
	Lamprey	Jowett & Richardson (2008)
Sports fish	Brown trout adult	Hayes & Jowett (1994)
	Brown trout yearling	Raleigh *et al.* (1986)
	Brown trout spawning	Shirvell & Dungey (1983)

Figure 10 presents the predicted physical characteristics of the survey reach of the Waikouaiti River based on instream habitat modelling.

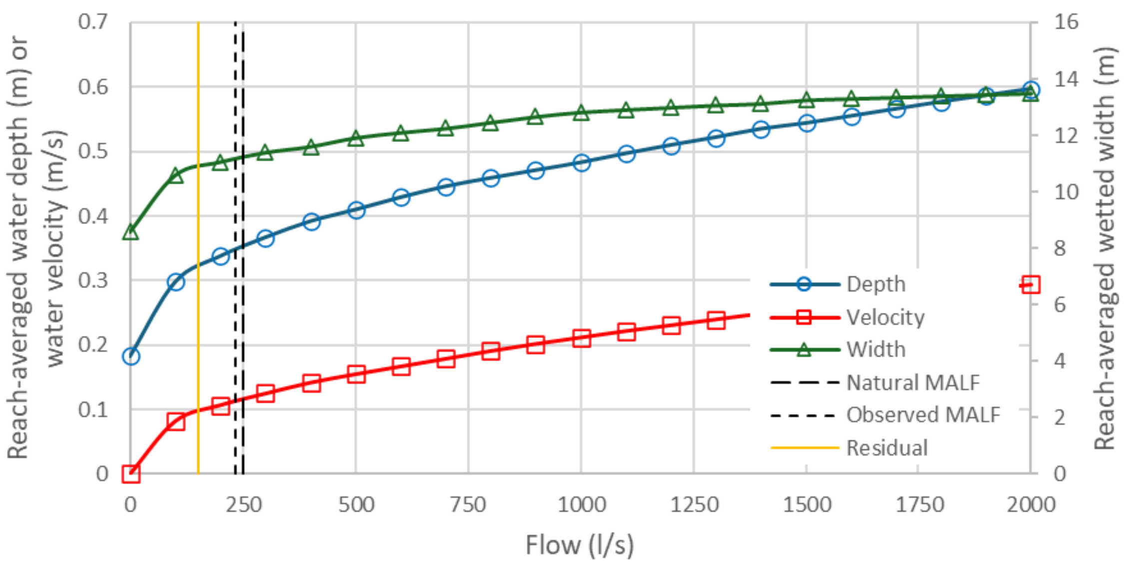

Figure 10 Variation in physical characteristics relative to flow in the survey reach of the Waikouaiti.

7.2. Macroinvertebrates

Food-producing habitat and habitat for orthoclad midges increased with flow across the modelled flow range, while habitat for mudsnails and riffle beetles increased with increasing flows at low flows but were relatively stable once flows were above 500 l/s (Figure 11). Flows required to achieve different habitat retention levels for each macroinvertebrate taxa are presented in Table 12.

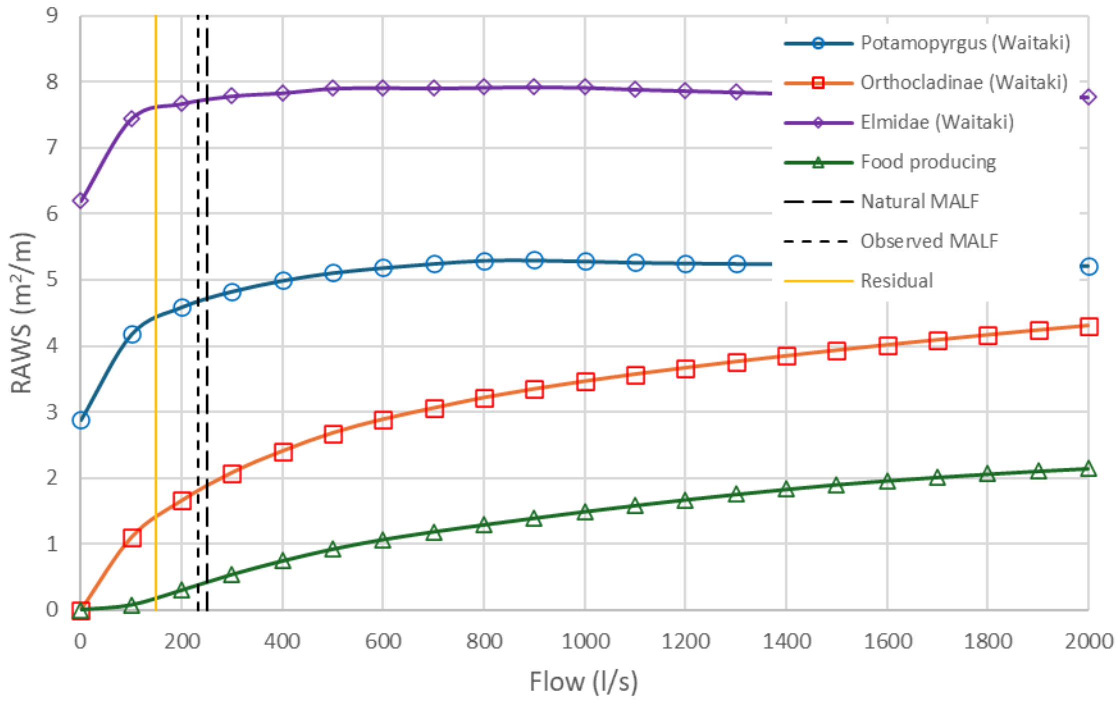

Figure 11 Variation in instream habitat for common macroinvertebrates relative to flow in the survey reach of the Waikouaiti.

Table 12 Flow requirements for macroinvertebrate habitat in the Waikouaiti. Flows required for the various habitat retention values are given relative to the naturalised 7dMALF (i.e., flows predicted in the absence of any abstraction).

Species	Optimum flow (l/s)	Flow at which % habitat retention occurs (l/s)				Habitat retention at 150 l/s (%)
		60%	70%	80%	90%	
Food producing habitat	>2,000	179	197	215	233	45%
Mudsnail (*Potamopyrgus)*	900	-	32	68	115	93%
Chironomid midge (Orthocladiinae)	>2,000	104	138	171	206	74%
Riffle beetle (Elmidae)	900	-	-	-	61	98%

7.3. Indigenous fish

Both HSC predict that habitat for tuna/longfin eel (<300 mm) is predicted to gradually increase with increasing flows across the modelled flow range, while habitat for larger tuna/longfin eels (>300 mm) increase with increasing flow up to 800-900 l/s, while habitat is predicted to stabilise (based on Jowett & Richardson (2008 or decline (based on Jellyman et al. 2003) as flows increase further (Figure 12). Juvenile lamprey habitat increased with increasing flow up to 1,600 l/s, before levelling out at higher flows (Figure 12).

Habitat for upland bully decreased with increasing flow across the flow range (Figure 13). Habitat for bluegill bully is predicted to increase with increasing flow up to 800 l/s before gradually declining at higher flows (Figure 13). Habitat for common bully is predicted to increase with increasing flow to 300 l/s, before declining at higher flows (Figure 13). Habitat for redfin bully is predicted to be highest at 100-200 l/s but decline as flows rise (Figure 13).

Habitat for inaka/inanga is predicted to increase steeply with increasing flow to 300 l/s and decline at higher flows (Figure 14). Torrentfish habitat is predicted to increase with increasing flow to flows of 1,400 l/s before gradually dropping as flows increase further (Figure 14).

Flows required to achieve different levels of habitat retention for indigenous fish species are presented in Table 13.

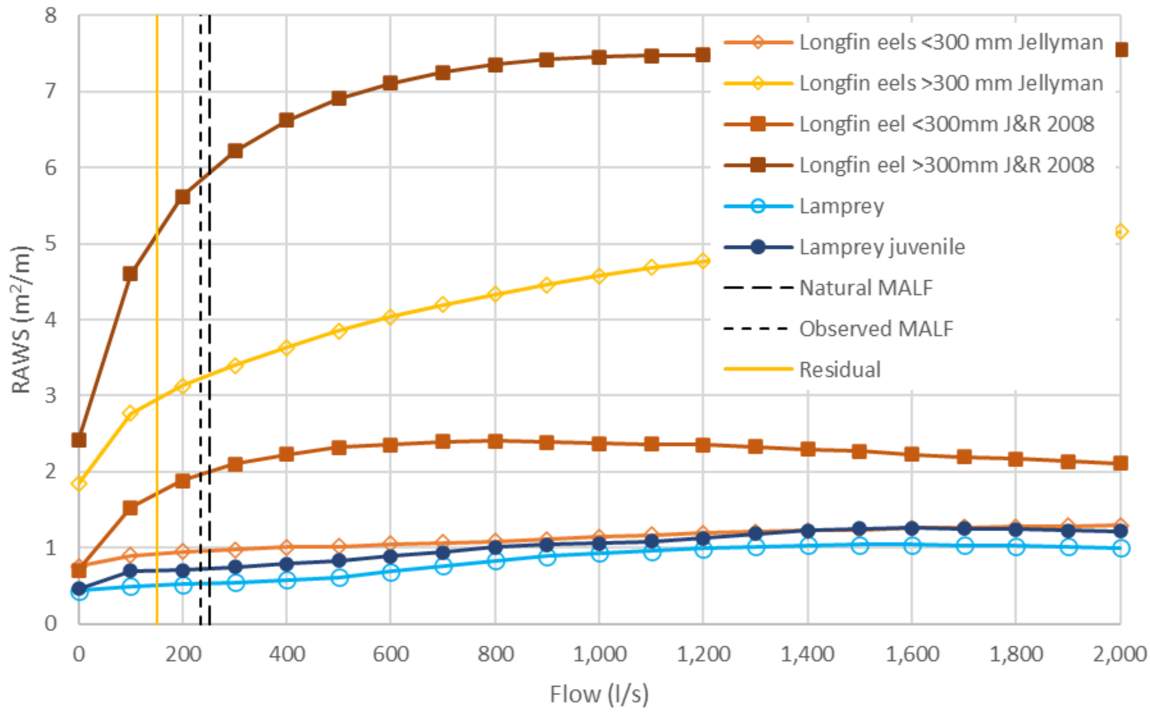

Figure 12 Variation in instream habitat for longfin eel size-classes and lamprey relative to flow in the survey reach of the Waikouaiti.

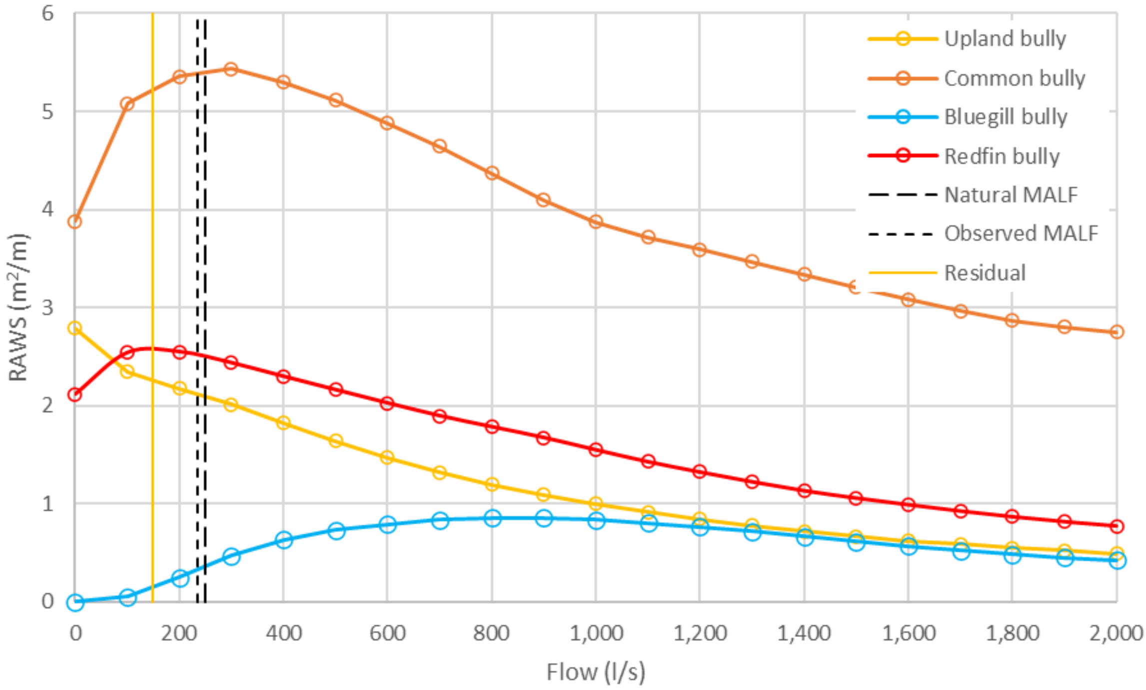

Figure 13 Variation in instream habitat for bully species size-classes relative to flow in the survey reach of the Waikouaiti.

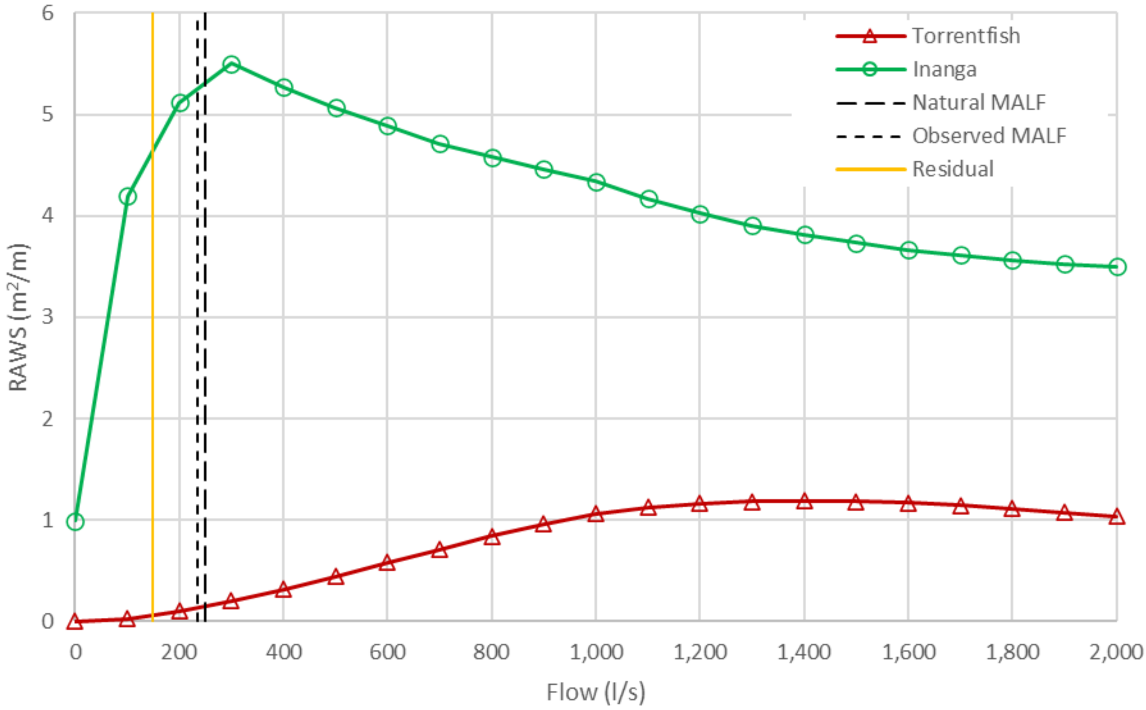

Figure 14 Variation in instream habitat for torrentfish and inaka/inanga species relative to flow in the survey reach of the Waikouaiti.

Table 13 Flow requirements for indigenous fish habitat in the Waikouaiti. Flows required for the various habitat retention values are given relative to the naturalised 7dMALF (i.e., flows predicted in the absence of any abstraction).

Species	Optimum flow (l/s)	Flow at which % habitat retention occurs (l/s)				Habitat retention at 150 l/s
		60%	70%	80%	90%	
Tuna/longfin eel <300 mm (Jellyman et al. 2003)	>2000	-	-	13	79	96%
Tuna/longfin eel >300 mm (Jellyman et al. 2003)	>2000	13	48	83	146	90%
Tuna/longfin eel <300 mm (Jowett & Richardson 2008)	800	60	84	119	175	86%
Tuna/longfin eel >300 mm (Jowett & Richardson 2008)	>2000	52	79	113	171	86%
Torrentfish	1400	184	203	218	234	43%
Upland bully	<100	-	-	-	-	108%
Common bully	300	-	-	36	81	97%
Bluegill bully	800	183	201	218	234	42%
Redfin bully	200	-	-	-	30	102%
Inaka/inanga	300	68	85	105	163	88%
Kanakana/lamprey	1600	-	-	-	85	95%
Kanakana/lamprey juvenile	1600	-	20	51	82	96%

7.4. Sports fish

Habitat for brown trout adults is predicted to increase with flow across the modelled range, while habitat for brown trout fry to 15 cm increased with increasing flows to 1,200-1,300 l/s before decreasing gradually as flows increase (Figure 15). Habitat for brown trout yearlings increased rapidly with increasing flow to reach a maximum at 700-800 l/s and slowly declined at higher flows (Figure 15). Flows required to achieve different levels of habitat retention for each of these species/life-stages are presented in Table 14.

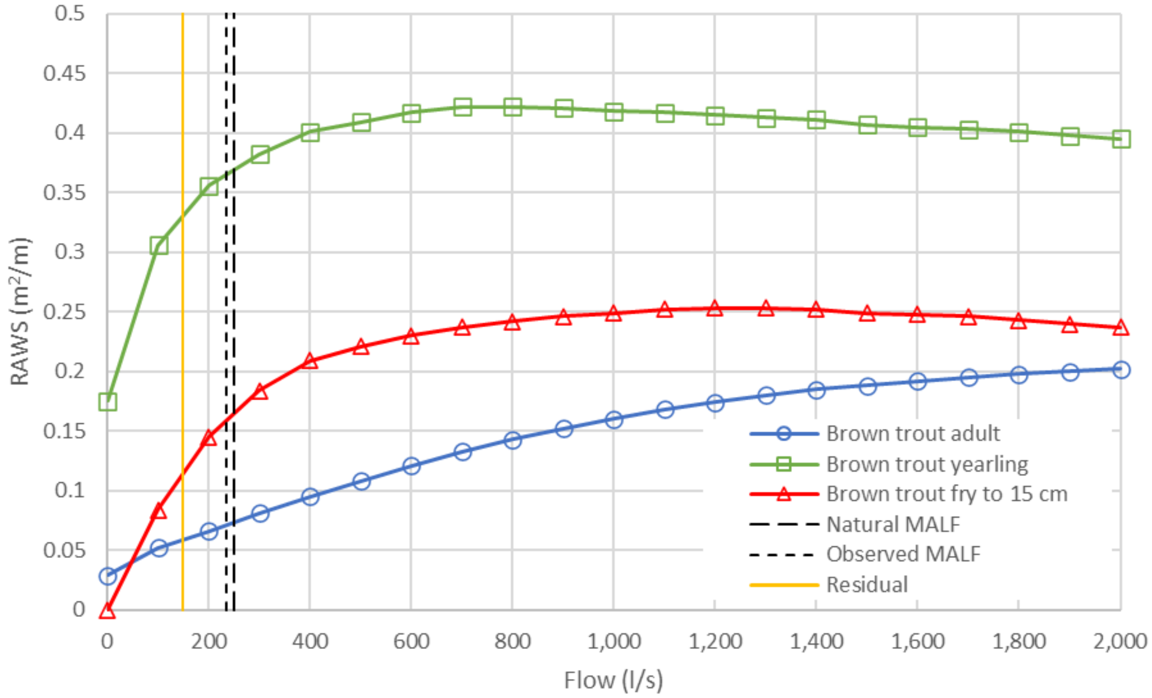

Figure 15 Variation in instream habitat for sportsfish relative to flow in the survey reach of the Waikouaiti.

Table 14 Flow requirements for sportsfish habitat in the Waikouaiti. Flows required for the various habitat retention values are given relative to the naturalised 7dMALF (i.e., flows predicted in the absence of any abstraction).

Species	Optimum flow (l/s)	Flow at which % habitat retention occurs (l/s)				Habitat retention at 150 l/s
		60%	70%	80%	90%	
Brown trout adult	>2,000	66	98	149	202	80%
Brown trout fry to 15 cm	700-800	124	152	179	209	69%
Brown trout yearling	1,200-1,600	36	64	92	153	90%

7.5. Summary of instream habitat assessments

The objective when setting a minimum flow is to protect instream values from the adverse effects of water abstraction. In doing this, consideration must be given to the National Policy Statement for Freshwater Management (NPSFM) and LWRP objectives for the Dunedin &Coast FMU outlined in Table 1. In the Waikouaiti catchment, these considerations intersect with consideration of the Waikouaiti Estuary.

Flows of 68-206 l/s were predicted to retain 80% of the habitat for the most abundant macroinvertebrate taxa in the lower Waikouaiti River, while the current residual flow is predicted to maintain 74-93% of the habitat at the naturalised MALF (Table 15). Generalised habitat for macroinvertebrates (as measured by the Food Producing HSC) increased with increasing flows up to at least 2,000 l/s, with a flow of 215 l/s predicted to achieve 80% habitat retention, while the residual flow of 150 l/s is predicted to retain 45% of habitat at the naturalised MALF (Table 15).

Habitat for tuna/longfin eels (>300 mm) increased with increasing flows up to 1,000 l/s, while predicted habitat for small longfin eels differs between the two HSC used, with the Jellyman et al (2003) curves predict that habitat will increase across the modelled flow range, while the Jowett & Richardson (2008) predict that habitat increased with increasing flows up to 700 l/s before gradually decreasing. The current residual flow is predicted to retain 86-96% of the habitat for longfin eels at the naturalised MALF (Table 15).

Bluegill bully and torrentfish are among the most flow-demanding indigenous fish species in the Waikouaiti catchment, with optimum flows of 800 l/s and 1,400 l/s, respectively. A flow of 218 l/s is predicted to provide 80% habitat retention for both species in the Waikouaiti River while the current residual flow is predicted to retain 42-43% of the habitat for these species when compared to the naturalised MALF (Table 15). The optimum flow for upland bully habitat was below 100 l/s, while optimum flow for redfin bully habitat was at 200 l/s. Flows of less than 100 l/s were predicted to retain 80% of the habitat for common, redfin and upland bullies available at the naturalised MALF retention. The current residual flow retains 97% (common bully) and 108% (upland bully) of the habitat for at the naturalised MALF (Table 15).

Flows of 105 l/s would provide 80% habitat retention for inaka/inanga while the current minimum flow retains 88% of the habitat for this species at the naturalised MALF (Table 15). Habitat for juvenile kanakana/lamprey was predicted to rise with increasing flows up to 1,600 l/s, although flows of less than 100 l/s were predicted to retain 80% of the habitat available at the naturalised MALF while the current residual flow retains 95-96% of the habitat available at the naturalised MALF (Table 15).

Given that the Waikouaiti supports a highly valued locally significant fishery (Otago Fish & Game Council 2015), an appropriate management objective for trout may be to maintain 70% to 80% of habitat for adult brown trout which would equate to flows of between 98 and 149 l/s of the habitat for the various life-stages of trout relative to naturalised flows (Table 15). The current minimum flow of 150 l/s is predicted to retain 80% of the habitat for adult brown trout relative to the naturalised MALF (Table 15).

Table 15 Flow requirements for habitat objectives in the Waikouaiti River. Flows required for the various habitat retention values are given relative to the naturalised 7dMALF (i.e., flows predicted in the absence of any abstraction).

Value	Season	Significance	Level of habitat retention	Flow to maintain suggested level of habitat retention (l/s)	Habitat retention at 150 l/s
Food producing	All year	Life-supporting capacity, indigenous biodiversity	80% relative to naturalised	215	45%
Potamopyrgus	All year	Life-supporting capacity, indigenous biodiversity	80% relative to naturalised	<100	93%
Chironomid midge	All year	Life-supporting capacity, indigenous biodiversity	80% relative to naturalised	171	74%
Riffle beetle (Elmidae)	All year	Life-supporting capacity, indigenous biodiversity	80% relative to naturalised	-	98%
Tuna/longfin eel	All year	Life-supporting capacity, indigenous biodiversity, mahika kai, at risk (declining)	80% relative to naturalised	<120	86-96%
			90% relative to naturalised	<175	
Torrentfish	All year	Life-supporting capacity, indigenous biodiversity, at risk (declining)	80% relative to naturalised	218	43%
Kanakana/lamprey	All year	Threatened (nationally vulnerable), life-supporting capacity, indigenous biodiversity, mahika kai	80% relative to naturalised	<100	95-96%
			90% relative to naturalised	<100	
Upland bully	All year	Life-supporting capacity, indigenous biodiversity	80% relative to naturalised	-	108%
Common bully	All year	Life-supporting capacity, indigenous biodiversity	80% relative to naturalised	<100	97%
Bluegill bully	All year	Life-supporting capacity, indigenous biodiversity, at risk (declining)	80% relative to naturalised	218	42%
Redfin bully	All year	Life-supporting capacity, indigenous biodiversity, at risk (declining)	80% relative to naturalised	-	102%
Inaka/inanga	All year	Life-supporting capacity, indigenous biodiversity, mahika kai, at risk (declining)	80% relative to naturalised	105	88%
Brown trout adult	All year	Locally significant fishery	70% relative to naturalised	98	80%
			80% relative to naturalised	149	
Juvenile trout	All year	Locally significant fishery	70% relative to naturalised	64-98	69-90%
			80% relative to naturalised	152-179	
			Maintain existing	150	

7.6. Consideration of the Waikouaiti Estuary

The minimum flow in the Waikouaiti River has the potential to interact with habitat and/or water quality in the Waikouaiti Estuary; an increase in the minimum flow and/or reduction in abstraction from the Waikouaiti may be beneficial for habitat and/or water quality outcomes in the Waikouaiti Estuary. However, addressing habitat and/or water quality issues in the Waikouaiti Estuary will require an integrated approach targeting sediment loads as well as any potential changes to the minimum flow/allocation regime in the Waikouaiti catchment.

The hydrological analysis summarised in Table 2 estimated the naturalised 7-d MALF in the Waikouaiti at confluence d/s is 251 l/s, while the observed 7-d MALF is 234 l/s. The reduction in flows from naturalised to those observed is unlikely to appreciably change the hydraulic conditions within the Waikouaiti Estuary (MetOcean Solutions Ltd 2016).

Minimum flows typically apply for a relatively short proportion of the irrigation season - synthetic flows in the Waikouaiti have dropped to 150 l/s on about 4 % of occasions. Raising the minimum flow would increase the length of time that the river was at the minimum flow: minimum flows of 175 l/s, 200 l/s and 225 l/s would be reached at approximately 5% 7% and 7% of occasions[3]. This illustrates the limited impact a change to the minimum flow alone would have on conditions in the Waikouaiti Estuary.

[3] Based on observed flows in the Waikouaiti at 200 m d/s DCC intake minus the WM1140 between 12 December 2015 and 17 September 2023

8. Assessment of alternative minimum flow & allocation scenarios in the Waikouaiti catchment

Four minimum flows were considered, representing different proportions of the 7-day MALF, and five allocation limits including the current residual flow (150 l/s) and an allocation limit of 50% of MALF based on Policy 6.4.2 (Table 16). Simulations were run from 1 July 2015 to 20 March 2023 to consider the hydrological effects of the various combinations of minimum flow/allocation. The simulations used naturalised flows estimated by adding measured water take (based on water metering data for the DCC take in the Waikouaiti catchment) back onto the observed flows in the Waikouaiti River 200 m d/s DCC intake.

Table 16 Minimum flow and allocation limits considered in this analysis.

Minimum flow		Allocation limit		Description
Option	% 7-d MALF	Option	% 7-d MALF	
150 l/s primary	60%	129.2 l/s	51%	Current minimum flow (60% of MALF), current actual allocation (51% MALF)
		108 l/s	43%	Current minimum flow (60% of MALF), current combined maximum observed rates of take[4].
		97 l/s	39%	Current minimum flow (60% of MALF), maximum observed cumulative rate of take[5].
		75 l/s	30%	Current minimum flow (60% of MALF), allocation at 30% MALF
		50 l/s	20%	Current minimum flow (60% of MALF), allocation at 20% MALF
175 l/s primary	70%	129.2 l/s	51%	Minimum flow at 70% of MALF, current actual allocation (51%% MALF)
		108 l/s	43%	Minimum flow at 70% of MALF current combined maximum observed rates of take[4]
		97 l/s	39%	Minimum flow at 70% of MALF, maximum observed cumulative rate of take[5]
		75 l/s	30%	Minimum flow at 70% of MALF, allocation at 30% MALF
		50 l/s	20%	Minimum flow at 70% of MALF, allocation at 20% MALF
200 l/s primary	80%	129.2 l/s	51%	Minimum flow at 80% of MALF, current actual allocation (127% MALF)
		108 l/s	43%	Minimum flow at 80% of MALF, current combined maximum observed rates of take[4]
		97 l/s	39%	Minimum flow at 80% of MALF, maximum observed cumulative rate of take[5]
		75 l/s	30%	Minimum flow at 80% of MALF, allocation at 30% MALF
		50 l/s	20%	Minimum flow at 80% of MALF, allocation at 20% MALF
225 l/s primary	90%	129.2 l/s	51%	Minimum flow at 90% of MALF, current actual allocation (127% MALF)
		108 l/s	43%	Minimum flow at 90% of MALF, current combined maximum observed rates of take[4].
		97 l/s	39%	Minimum flow at 90% of MALF, maximum observed cumulative rate of take[5]
		75 l/s	30%	Minimum flow at 90% of MALF, allocation at 30% MALF
		50 l/s	20%	Minimum flow at 90% of MALF, allocation at 20% MALF

[4] The sum of the maximum observed rate of take for each consent
[5] The maximum of the observed combined rate of take at any point in time

The degree of hydrological alteration from each minimum flow/allocation scenario was assessed using the Dundee Hydrological Regime Assessment Method (DHRAM) (Black et al. 2005). This method involves the calculation of 32 parameters relating to the seasonality of flows, magnitude and duration of annual extremes (high and low flow events), timing of annual extremes, frequency and duration of high and low pulses and the rate and frequency of change in flow (Black et al. 2005). The results of these simulations are presented in Table 18.

Table 17 DHRAM classes used in the assessment of alternative minimum flow/allocation

Class	Points range	Description
1	0	Un-impacted condition
2	1-4	Low risk of impact
3	5-10	Moderate risk of impact
4	11-20	High risk of impact
5	21-30	Severely impacted condition

Observed flows in the Waikouaiti at DCC intake 200 m d/s are unimpacted relative to naturalised flows (Table 18). All scenarios considered were assessed as resulting in unimpacted hydrology relative to naturalised flows (Table 18; Figure 16, Figure 17, Figure 18 and Figure 19).

Table 18 Comparison of the hydrological effects of different minimum flow/allocation limit combinations in the Waikouaiti.

Min flow	Allocation	Monthly		Min/max means		Date/timing		Pulse count /duration		Rate of change		Risk grade
		CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	
Observed flows		0	0	0	0	0	0	0	0	0	0	Unimpacted
150	129.2	0	0	0	0	0	0	0	0	0	0	Unimpacted
	108	0	0	0	0	0	0	0	0	0	0	Unimpacted
	97	0	0	0	0	0	0	0	0	0	0	Unimpacted
	75	0	0	0	0	0	0	0	0	0	0	Unimpacted
	50	0	0	0	0	0	0	0	0	0	0	Unimpacted
175	129.2	0	0	0	0	0	0	0	0	0	0	Unimpacted
	108	0	0	0	0	0	0	0	0	0	0	Unimpacted
	97	0	0	0	0	0	0	0	0	0	0	Unimpacted
	75	0	0	0	0	0	0	0	0	0	0	Unimpacted
	50	0	0	0	0	0	0	0	0	0	0	Unimpacted
200	129.2	0	0	0	0	0	0	0	0	0	0	Unimpacted
	108	0	0	0	0	0	0	0	0	0	0	Unimpacted
	97	0	0	0	0	0	0	0	0	0	0	Unimpacted
	75	0	0	0	0	0	0	0	0	0	0	Unimpacted
	50	0	0	0	0	0	0	0	0	0	0	Unimpacted
225	129.2	0	0	0	0	0	0	0	0	0	0	Unimpacted
	108	0	0	0	0	0	0	0	0	0	0	Unimpacted
	97	0	0	0	0	0	0	0	0	0	0	Unimpacted
	75	0	0	0	0	0	0	0	0	0	0	Unimpacted
	50	0	0	0	0	0	0	0	0	0	0	Unimpacted

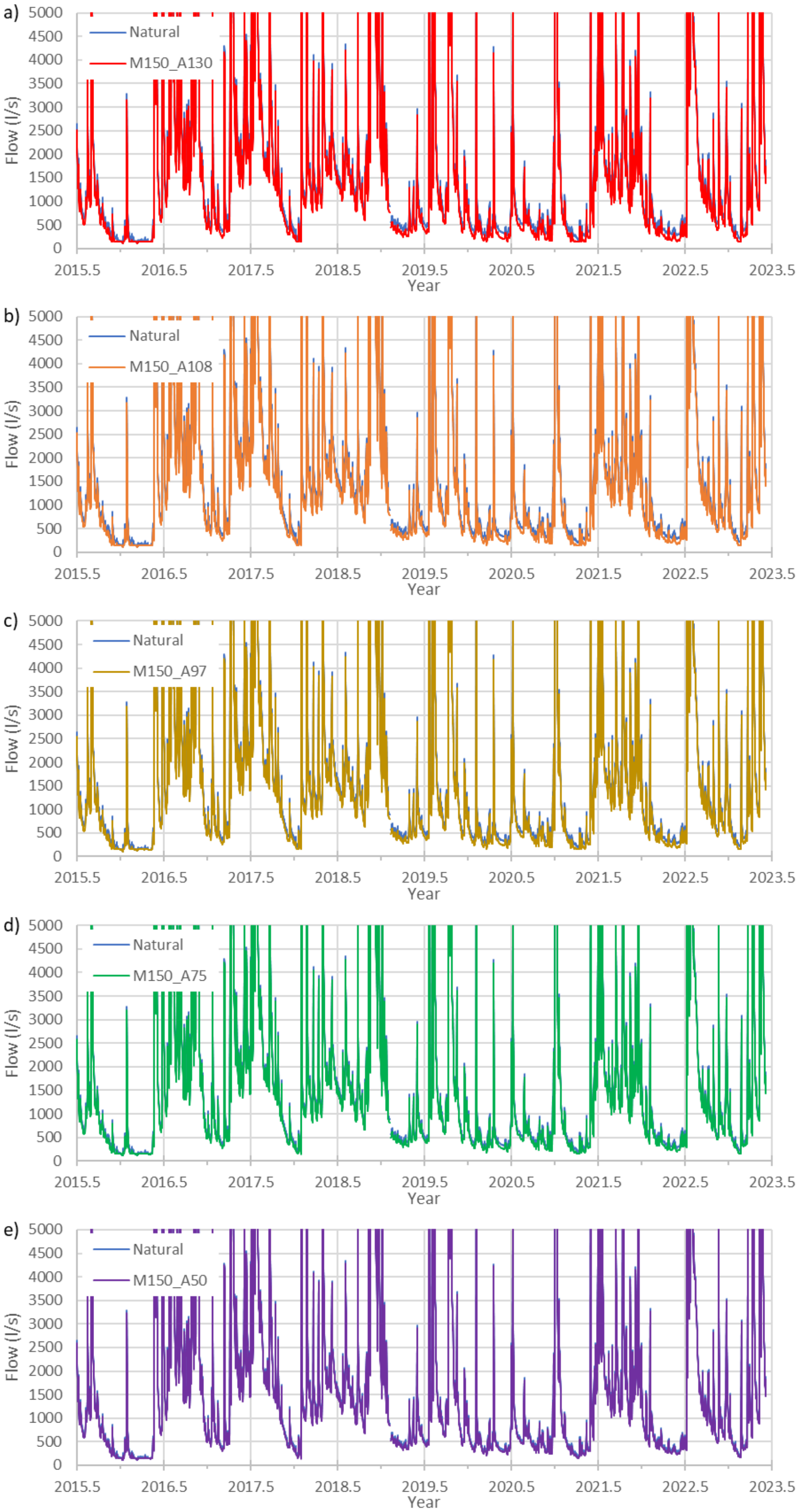

Figure 16 Hydrographs of allocation scenarios with a minimum flow of 150 l/s. a) Current allocation limit 130 l/s, b) allocation limit of 108 l/s, c) allocation limit of 97 l/s, d) allocation limit of 75 l/s, e) allocation limit of 50 l/s.

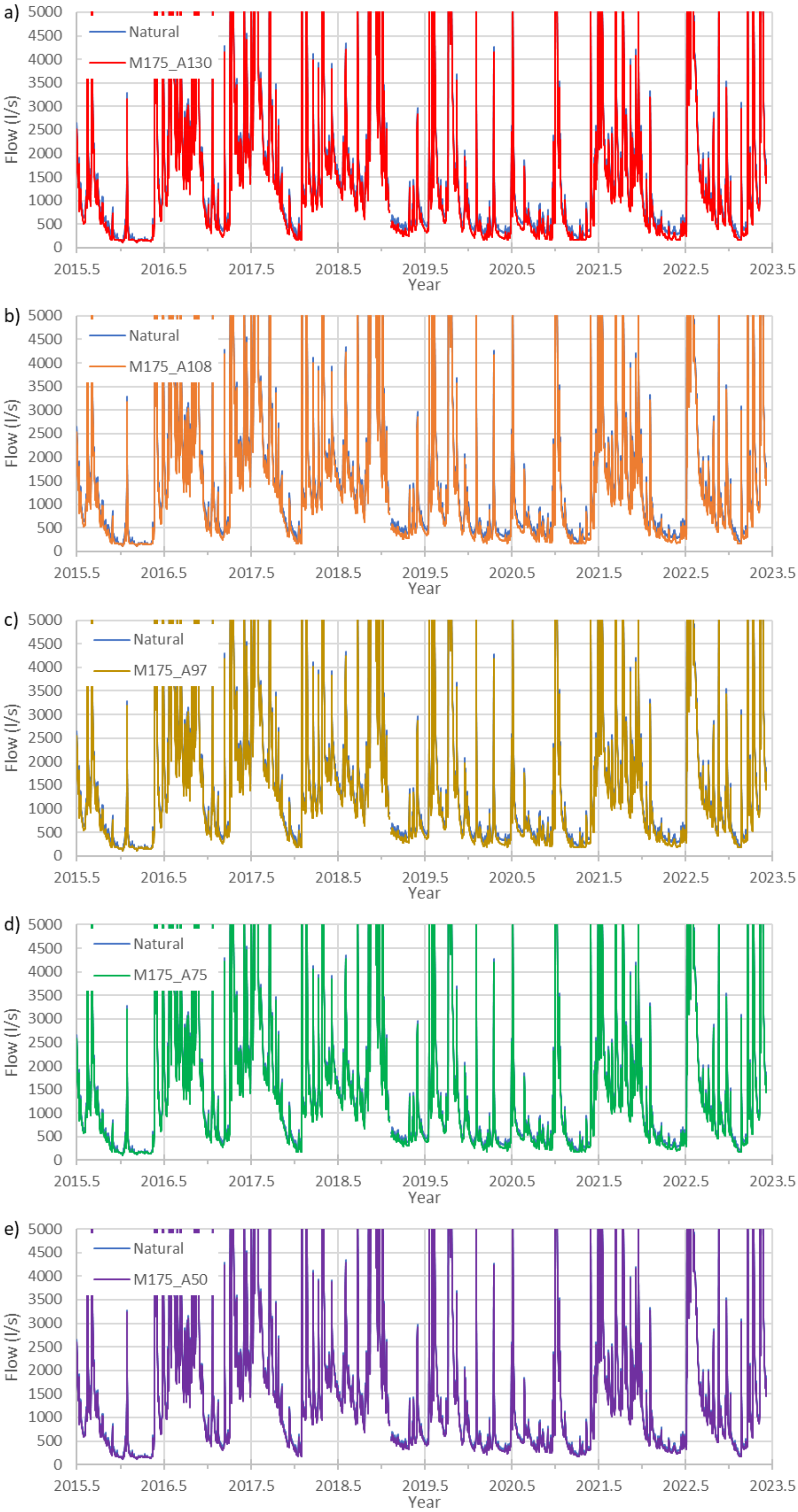

Figure 17 Hydrographs of allocation scenarios with a minimum flow of 175 l/s. a) Current allocation limit 130 l/s, b) allocation limit of 108 l/s, c) allocation limit of 97 l/s, d) allocation limit of 75 l/s, e) allocation limit of 50 l/s.

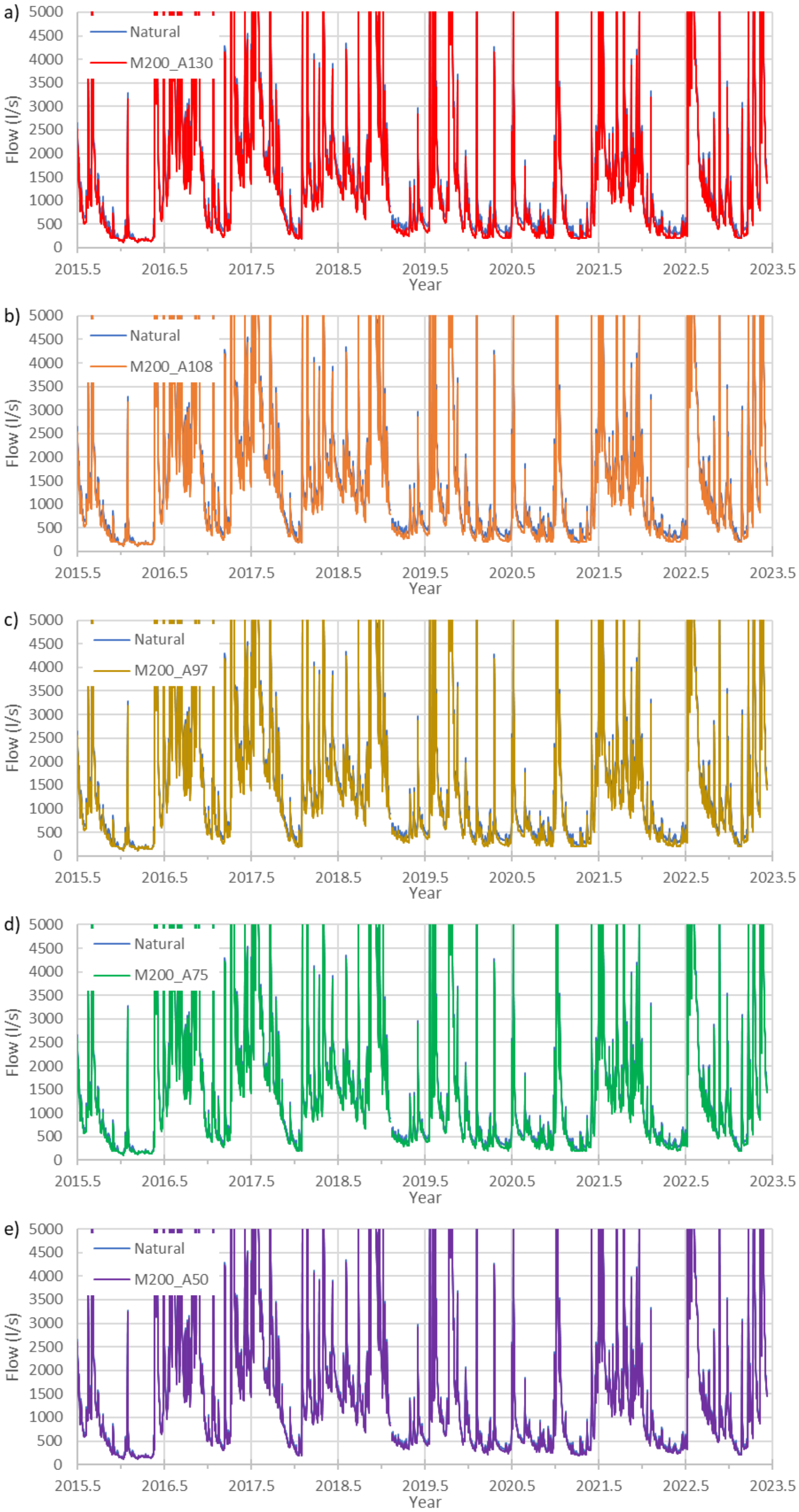

Figure 18 Hydrographs of allocation scenarios with a minimum flow of 200 l/s. a) Current allocation limit 130 l/s, b) allocation limit of 108 l/s, c) allocation limit of 97 l/s, d) allocation limit of 75 l/s, e) allocation limit of 50 l/s.

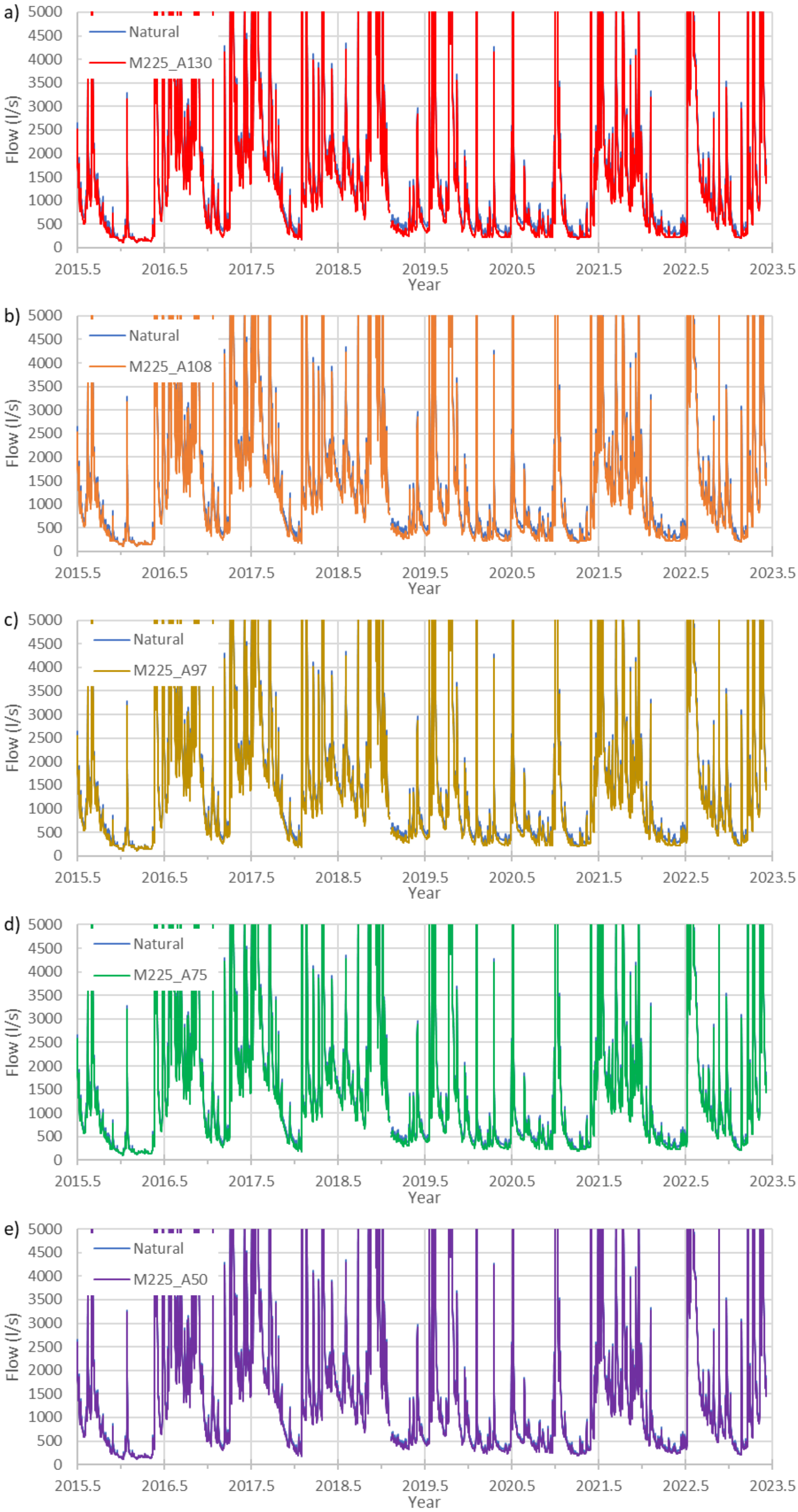

Figure 19 Hydrographs of allocation scenarios with a minimum flow of 225 l/s. a) Current allocation limit 130 l/s, b) allocation limit of 108 l/s, c) allocation limit of 97 l/s, d) allocation limit of 75 l/s, e) allocation limit of 50 l/s.

8.1. Consideration of existing environmental flows & allocation

Schedule 2A of the RPW does not currently specify a minimum flow and/or allocation limit for the Waikouaiti catchment. However, the three main consumptive takes are subject to residual flows. The two takes operated by the DCC require that water conservation measures are introduced if flows fall below 150 l/s (November-April) and 350 l/s (May-October) and require the taking of water to cease when flows immediately below these takes fall below 60 l/s (November-April) and 155 l/s (May-October). The other major take (RM13.299.01) requires the maintenance of residual flows of 300 l/s in October, 220 l/s in November and 150 l/s in all other months, except for reasonable stock drinking water.

The existing residual flow (150 l/s) and current allocation (129.2 l/s) are predicted to result in a hydrograph that is expected to be unimpacted relative to naturalised flows (based on the DHRAM score). MCI scores in the Waikouaiti River meet the target attribute state proposed in the LWRP but QMCI and ASPM scores for the Waikouaiti at 200 m d/s DCC intake monitoring site were below the national bottom line set out in the NPS-FM.

8.2. Potential effects of climate change in the Waikouaiti catchment

The potential effects of future climate change vary considerably depending on future emission scenarios. This assessment is based on the evaluation of Macara et al. (2019) using two scenarios (RCP4.5 and RCP8.5) for 2031-2050.

The projected effects of climate change, such as higher temperatures (and therefore evapotranspiration), and reduced summer rainfall, may increase the probability, magnitude and duration of low flow events in the Waikouaiti catchment (Table 19). Changes associated with climate change may reduce habitat suitability for sensitive species (via increased water temperatures, reduced summer flows) and increase the risk of periphyton proliferations (through increased water temperatures, longer accrual periods). This may affect the baseline state for periphyton biomass (i.e. the periphyton biomass that would be achievable under natural conditions) and therefore the achievability of periphyton objectives in the Waikouaiti catchment.

Table 19 Potential effects of climate change on the Waikouaiti catchment based on the assessment of Macara et al. (2019) using two scenarios (RCP4.5 and RCP8.5) for the period 2031-2050.

Variable	Projected effect	Potential effect on hydrology of Waikouaiti River	Potential ecological consequences
Temperature	• Increased mean temperatures (0.6-0.7°C) • Increased annual mean maximum temperature (0.8-0.9°C) • Small increase in number of hot days (>30°C) (increase by 1-1.3 days per annum) • Reduced frost days (31 fewer frost days per annum)	• Increased evapotranspiration • Faster flow recession • Increased irrigation demand	• Higher water temperatures, reduced suitability for sensitive species • Potential risk of faster accrual of periphyton biomass
Rainfall	• Little change in annual mean rainfall (+2-3%) • Reduced summer mean rainfall (-3 - -5%) • Similar risk of low rainfall events • Small increase (0.4-0.5 days per year) in peak rainfall intensity	• Increased likelihood and/or magnitude of low flow events • Potential increase in magnitude of high flow events	• Small increase in the risk of periphyton biomass reaching nuisance levels
Snow	• No change in snow days		
Hydrology	• Little change (±5%) to increase (5-20%) in low flows (Q95) • Improved reliability for irrigators	• Higher low flows	• Altered habitat suitability for some species

9. Conclusions

The Waikouaiti is a medium-sized river which rises in two branches arising in the ranges between Macraes and the Silver Peaks before combining to flow into the Waikouaiti Estuary, a shallow, intertidal dominated (SIDE) estuary, that is a rich habitat for fish, shellfish, and waterfowl and is an important mahinga kai (food-gathering site). The estuary enters the Pacific Ocean at the seaside town of Karitane. Landcover in the North Branch catchment is dominated by agricultural grasslands, while the South Branch flows through indigenous hardwoods, mānuka/kanuka, and exotic forestry before flowing through low producing grasslands. Below the confluence, the lower catchment is dominated by high producing exotic grassland.

Schedule 2A of the RPW does not currently specify a minimum flow and/or allocation limit for the Waikouaiti catchment. However, the three main consumptive takes are subject to residual flows. The current allocation limit for the Waikouaiti catchment is 129.2 l/s.

This report presents information to inform water management decision-making in the Waikouaiti catchment. This includes hydrological information (including flow naturalisation and flow statistics), data on aquatic values (including the distribution of indigenous fish) and application of instream habitat modelling to guide flow-setting processes, and consideration of the current state of the Waikouaiti compared to the proposed objectives for the Dunedin & Coast FMU set out in the proposed Otago Land and Water Regional Plan.

The flow statistics based on the analysis of Lu (2023) and Dale (2011) are summarised below:

		Flow statistics (l/s)		
		Mean	**Median**	**7d MALF (Jul-Jun)**
Waikouaiti at 200 d/s DCC intake	Naturalised flows	2,497	909	251
	Observed flows	2,482	989	234
Waikouaiti at McGrath Road bridge (synthetic)	Simulated observed flows	2,490	906	233
Waikouaiti at downstream confluence	Dale (2011) (natural)	2,855	856	258

There are ten resource consents for primary water takes from the Waikouaiti catchment, with a total primary allocation of 129.2 l/s. Oceana Gold (New Zealand) Ltd. has six resource consents for water takes from the Waikouaiti catchment as part of their operations at the Macraes gold mine. For the purposes of this report, these permits are considered to be non-consumptive. Of the remaining four consents, three are for community water supply (Stoneburn Water Supply and Waikouaiti Community Water Supply Scheme, operated by Waitaki District Council and Dunedin City Council, respectively). However, the consents held by Dunedin City Council to operate the Waikouaiti Community Water

Supply Scheme (2006.002.V1 and 2006.075.V1) both have instantaneous maximum rate of take of 60 l/s but cannot be exercised concurrently.

There is limited information on the periphyton community of the Waikouaiti River. Information on periphyton composition (collected between 2001 and 2018) suggests that composition was variable, with the filamentous green algae *Mougeotia* and *Spirogyra*, and the diatoms *Didymosphenia*, *Fragilaria*, *Gomphoneis* and *Synedra* among the dominant periphyton taxa observed.

Macroinvertebrate communities in the Waikouaiti were dominated by the mudsnail *Potamopyrgus*, amphipod *Paracalliope*, riffle beetles (Elmidae), chironomid midges (Orthocladiinae) and oligochaete worms. MCI and ASPM scores for the Waikouaiti at Confluence d/s site (2014 and 2022) put this site in C-band of the NOF while SQMCI scores put this site in D-band of the NOF. Historical MCI, SQMCI, and ASPM scores (2007-2013) for Orbells Crossing site put this site in D-band of the NOF (Figure 8a-c).

The Waikouaiti River supports a highly diverse community of indigenous fish with fifteen indigenous fish species recorded. These include several species that are at risk or threatened – longfin eel, torrentfish, bluegill bully, redfin bully, kōaro and inaka/inanga. Giant bully are classified as at risk – naturally uncommon while lamprey and Taieri flathead galaxias are classified as threatened – nationally vulnerable. Brown trout are the only introduced fish species that have been collected from the Waikouaiti catchment. The Waikouaiti supports a locally significant sport fishery.

An instream habitat model developed for the mainstem of the Waikouaiti below the confluence of the North and South Branches has been applied to consider the effects of different flows on the physical characteristics of the Waikouaiti and habitat for periphyton, macroinvertebrates and fish.

The current minimum flow in the Waikouaiti catchment (150 l/s) is predicted to maintain between 74% (chironomid midge) and 98% (riffle beetle (Elmidae)) of habitat for common macroinvertebrate taxa in the lower Waikouaiti River and but is predicted to maintain 45% of general macroinvertebrate habitat (food-producing waters). It is predicted to maintain 42% of the bluegill bully habitat and 43% of habitat for torrentfish compared to the naturalised 7-d MALF. The current minimum flow is predicted to achieve >86% habitat retention for other indigenous species considered and between 69-90% habitat retention for the various brown trout life-stages considered.

Bluegill bully and torrentfish are among the most flow-demanding indigenous fish species in the Waikouaiti catchment and a flow of 218 l/s is expected to provide 80% habitat retention for these species in the Waikouaiti River. Flows of up to 120 l/s were predicted to provide 80% habitat retention for large longfin eels, while flows of up to 175 l/s were predicted to provide 90% habitat retention for large longfin eels. Habitat for kanakana/lamprey was predicted to be highest at low flows. Flows of 111-183 l/s are predicted to provide 80% habitat retention for the brown trout life stages considered.

The existing minimum flow and allocation limit are predicted to result in a hydrograph that is unimpacted relative to naturalised flows (based on the DHRAM score).

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Appendix A

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Otago Regional Council

Flow naturalisation of the Waikouaiti River

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Contents

This document describes how naturalised flow statistics at the current flow recorder on the Waikouaiti River 200m downstream of the DCC intake, and the simulated actual flows at the bridge at McGrath Road were derived.

Daily flow time series data for Waikouaiti River

The daily flow time series data available for analysis are listed in **Table 1** below. The locations of the flow sites and current consents are shown in **Figure 1**. The current consents used for flow naturalisation are listed in **Table A1** in the **Appendix**. (Note: Waikouaiti at 200m d/s DCC Intake is downstream of the confluence of the North and South Branches of the Waikouaiti River.

Table 1: The daily flow time series data available for the analysis above the flow site 200m d/s DCC intake on the Waikouaiti River.

Site	Start	End	Length (year)
Waikouaiti North Branch at Bucklands	30/01/1991	3/08/1999	8.5
Waikouaiti South Branch at Lawsons	5/02/1991	5/10/2010	19.7
Waikouaiti at Cloverdowns	23/12/1976	28/02/1987	10.2
Waikouaiti at Confluence d/s	8/02/2010	30/10/2015	5.7
Waikouaiti at 200m d/s DCC intake	22/09/2014	8/06/2023	8.7

Daily water use time series

Time series data of water use (WU) is used to naturalise the flow of the Waikouaiti river at the flow recorder 200m d/s of the DCC intake. All consents above the flow recorder must first be identified.

Total water use above the flow recorder 200m d/s of the DCC intake

Altogether 43 consents have historically been issued above the flow recorder 200m d/s of the DCC intake on the Waikouaiti River. However, after removing consents which did not affect flow, 20[1] consents are used in the flow naturalisation process (See **Table A1** in the Appendix). As shown in the table, 4 consents are currently active. **Figure 2** shows the total water use (WU) regime above the flow recorder 200m d/s of the DCC intake on the Waikouaiti River. An additional current irrigation consent located downstream of the flow recorder will also be used in a second part of this study (see Table 2 and Figure 3).

[1] 20 consents used in this study are listed in **Table A1** in the **Appendix**. They are the consents left by filtering out:

- Groundwater takes with no effect on the nearby water body (refer to the attribute of *Stream depletion rate*)
- Non-consumptive takes
- Retakes

Figure 1: The location of flow recorders and current consents used in this study on Waikouaiti River.

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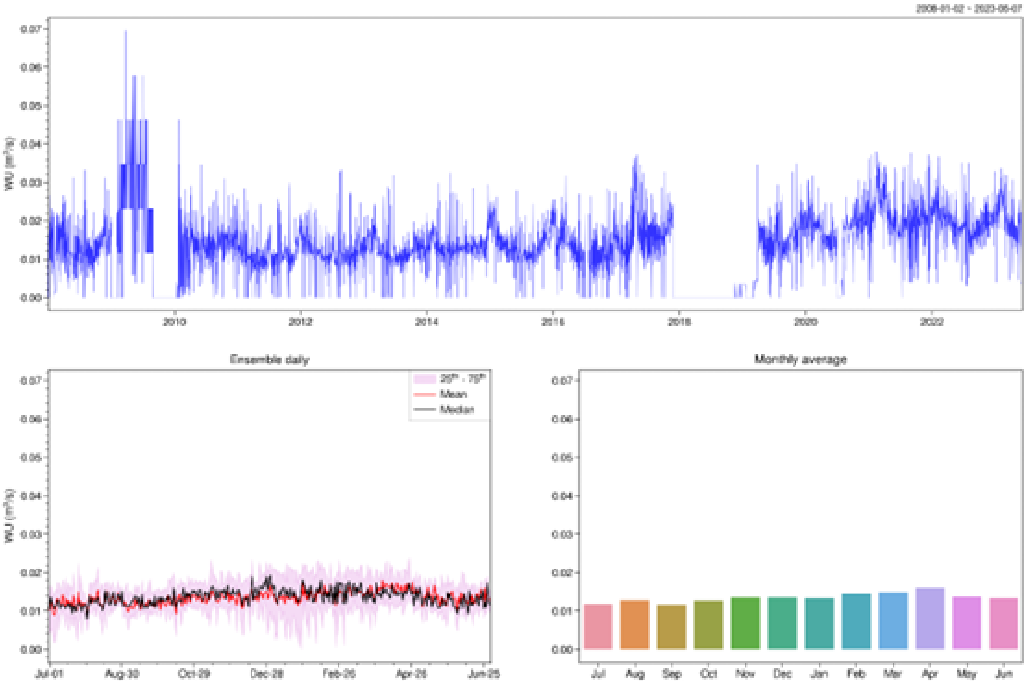

Figure 2: The total water use upstream of the recorder 200m d/s of the DCC intake on the Waikouaiti River.

As shown in **Figure 2**, the water has been used across the whole year since all 4 current consents have been using the water for the purpose of domestic and stock water supply with the largest being the DCC take for Waikouaiti township and surrounding area. The average total WU is 13 L/s.

Flow naturalisation at the flow recorder 200m d/s of the DCC intake

This section describes how the naturalised flow statistics are estimated for the flow recorder 200m d/s of the DCC intake on the Waikouaiti River.

Method

The naturalised flow time series can be estimated by adding the upstream total WU to the observed flow records.

One of the study's key goals is to produce long-term flow statistics, including the naturalised seven-day mean annual flow (7dMALF) and long-term median and mean flows for the flow recorder 200m d/s of the DCC intake on the Waikouaiti River.

Basic flow statistics (Table 2) for the flow recorder 200m d/s of the DCC intake.

Table 2: Naturalised flow statistics for the recorder 200m d/s of the DCC intake on the Waikouaiti River (22/09/2014 - present).

Site	Mean (m^3/s)	Median (m^3/s)	FRE3[2] ($year^{-1}$)	7dMALF (m^3/s) (Jul - Jun)
Waikouaiti at 200m d/s DCC intake (observed)	2.482	0.898	6.4	0.234
Waikouaiti at 200m d/s DCC intake (naturalised)	2.497	0.909	6.4	0.251

Actual flows estimated at the bridge at McGrath Road

Another goal of this study is to estimate the actual flows at the bridge at McGrath Road. **Figure 3** shows the target location and its relative location to the flow recorder at 200m d/s DCC intake. It also shows location of the current irrigation consent between the flow recorder and the McGrath Road bridge.

[2] The frequency of events exceeding three times the median flow value. In this study, an independent event is defined by a minimal event interval of 7 days.

Figure 3. The target location relative to the flow recorder at DCC intake

Method

To simulate actual flows at the bridge at McGrath Road, the naturalised flows at this location need to be estimated first. The area between the DCC flow recorder and the bridge at McGrath Road is small and has insignificant flow contributions to the Waikouaiti River when error is considered. Therefore, the naturalised flows at the target location are assumed to be the same as those at the flow recorder 200m d/s of the DCC Intake. Therefore, the simulated actual flows at the bridge at McGrath Road can be estimated by subtracting the total water use along the Waikouaiti River between the d/s DCC Intake recorder and the bridge at McGrath Road. There is only one take in this area, which is the consent RM13.299.01 (**Figure 3**), with 65 L/s consented (**Table A2** in the **Appendix**). **Figure 4** shows the water use hydrograph for this consent.

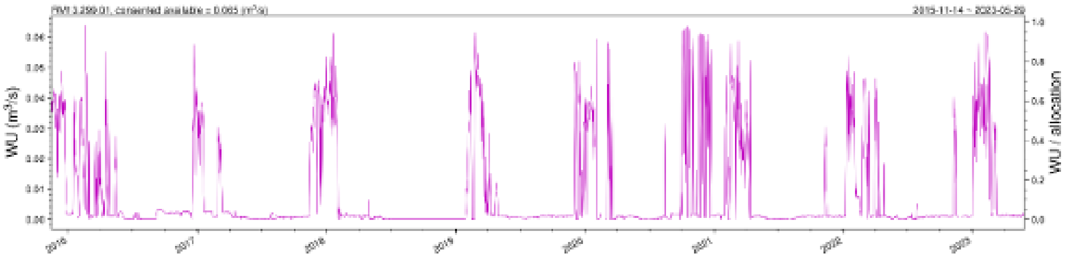

Figure 4. The daily water use for consent RM13.299.01.

Basic flow statistics (Table 3) for the Waikouaiti River at the bridge at McGrath Road.

Table 3: Flow statistics for the simulated actual flows at the target location

Site	Mean (m^3/s)	Median (m^3/s)	FRE3 ($year^{-1}$)	7dMALF (m^3/s) (Jul - Jun)
The bridge at McGrath Road (**Figure 3**)	2.490	0.906	6.4	0.233

Appendix

Table A1. The consents used for flow naturalisation 200m d/s of the DCC intake on the Waikouaiti River.

Consent	Status	Water meter	Allocation type	Category	Consented rate
2006.002.V1	Current	WM0837		Surface Take	60
2006.075.V1	Current	WM0837		Surface Take	60
RM17.121.01	Current	WM1483	Primary	Surface Take	4.2
RM17.121.02	Current	WM1483	Supplementary Block 1	Surface Take	0.5
1453	Expired			Surface Take	
2002.487	Expired			Surface Take	
2417	Expired			Surface Take	
2929	Expired			Surface Take	
3057	Expired			Surface Take	
4147C	Expired			Surface Take	
4208D	Expired			Surface Take	
4212D	Expired			Surface Take	
4216D	Expired			Surface Take	
93218	Expired			Surface Take	
97427	Expired			Surface Take	4.1
96798	Lapsed			Surface Take	
96806	Lapsed			Surface Take	
2004.091	Not Required			Surface Take	
2003.823.V1	Surrendered	WM0186	Primary	Surface Take	19
3427	Surrendered			Surface Take	

Table A2. The consent in the area between 200m d/s DCC intake and the target location (at McGrath Road) along the Waikouaiti River.

Consent	Status	Water meter	Allocation type	Category	Consented rate
RM13.299.01	Current	WM1140		Surface Take	65

The details in data processing can be found in this HTML file**.**