Management Flows for Aquatic Ecosystems in the Teviot River/Te Awa Makarara

February 2024

Otago Regional Council

Otago Regional Council
Private Bag 1954, Dunedin 9054
70 Stafford Street, Dunedin 9016
Phone 03 474 0827
Fax 03 479 0015
Freephone 0800 474 082
www.orc.govt.nz

Report writer:	Dean Olsen, Freshwater Scientist, Otago Regional Council
External reviewer:	Dr Duncan Gray (Senior Scientist – Water Quality and Ecology, Environment Canterbury)
	Jen Dodson (Senior Scientist – hydrology, Environment Canterbury)

Published February 2024

Acknowledgements
The author would like to thank the ORC Environmental Monitoring team for the collection and verification of the hydrological data used in this report and Dr Duncan Gray (Senior Scientist – Water Quality and Ecology, Environment Canterbury) and Jen Dodson (Senior Scientist – hydrology, Environment Canterbury) for their thorough and thoughtful peer-reviews.

Executive summary

The Teviot River/Te Awa Makarara is a small river that rises on the Lammerlaw Range east of Roxburgh before flowing into the Clutha River/Mata-Au downstream of the Roxburgh Dam and opposite Roxburgh township.

The flows of the Teviot River/Te Awa Makarara are highly modified for irrigation and hydroelectric generation. The upper reaches of the Teviot River/Te Awa Makarara and Dismal Swamp were dammed in 1888 for the purpose of gold mining and irrigation and has subsequently been operated as a joint irrigation and hydro-electric power scheme. The current resource consents for hydro-electric generation and irrigation on the Teviot River have residual flow conditions. However, as part of the development of the Land and Water Regional Plan, minimum flows, and allocation limits are to be developed for all catchments in Otago. This report presents hydrological and ecological information to inform water management decision-making in the Teviot catchment.

A regional hydrological model developed for ORC (Friedel *et al*., 2023) estimated the mean flow in the Teviot River/Te Awa Makarara to be 3,395 l/s and the 7-d mean annual low flow to be 703 l/s. The hydrology of the Teviot River is highly modified by Lake Onslow and hydro-electric power generation.

There are nine resource consents for primary water taken from the Teviot catchment (Table 4). Most are held by Pioneer Energy Ltd. and are associated with the operation of the various power schemes along the length of the Teviot River/Te Awa Makarara. Many of these takes are non-consumptive and many are subject to residual flows of between 50 l/s in the lower river and 345 l/s below Lake Onslow.

Limited information is currently available on periphyton communities in the Teviot River/Te Awa Makarara. Pioneer Energy has undertaken periphyton monitoring since 2007 and cover of filamentous green algae has frequently exceeded national guidelines.

A macroinvertebrate sample was collected from the Teviot River/Te Awa Makarara at Bridge Huts Road in 2022. The MCI score on this occasion was indicative of ‘good’ habitat/water quality while the QMCI score was consistent with ‘poor’ habitat/water quality and the ASPM scores (0.385), indicated ‘moderate to severe loss of ecological integrity’.

Five species of indigenous freshwater fish have been recorded from the Teviot catchment – longfin eel, lamprey, common bully, dusky galaxias and Teviot galaxias. Of these, longfin eel (Declining) and lamprey (Nationally Vulnerable) have only been recorded from the lower Teviot River/Te Awa Makarara close to the confluence with the Clutha/Mata-Au. Common bully (Not Threatened) have been recorded from tributaries of Lake Onslow including the Teviot River/Te Awa Makarara North Branch and are likely to be present in the lake itself. Brown trout are widespread in the Teviot catchment while rainbow trout have only been recorded from the lower reaches of the Teviot River/Te Awa Makarara close to the confluence with the Clutha/Mata-Au

Teviot galaxias (Nationally Critical) and Dusky galaxias (Nationally Endangered) have been found in tributaries of the Teviot River/Te Awa Makarara including in tributaries of Lake Onslow.

Brown trout are widespread in the Teviot catchment while rainbow trout have only been recorded from the lower reaches of the Teviot River/Te Awa Makarara close to the confluence with the Clutha/Mata-Au. Little angler effort has been recorded in the Teviot River/Te Awa Makarara. It is considered to be a backcountry fishery while Lake Onslow, receives considerably greater angler effort and is considered to be a regionally significant fishery.

Limited information is available on the water quality and ecological state of the lower Teviot River/Te Awa Makarara. Based on a single macroinvertebrate sample, it would appear that the target states for MCI and QMCI scores are not achieved in the Teviot River/Te Awa Makarara at Bridge Huts Road. Monitoring data collected by Pioneer Energy Ltd. suggests that cover of long filamentous algae exceeds national guidelines in most years.

The highly modified hydrology of the middle and lower reaches of the Teviot River/Te Awa Makarara makes consideration of alternative minimum/residual flows and allocation regimes difficult. The hydrology of the lower river is affected by the presence of three dams and hydro-peaking discharges from the various powerhouses in the catchment. This issue is further complicated by the lack of hydrological monitoring in the lower catchment.

To assist in future assessments of water allocation management in the Teviot catchment, additional hydrological and ecological information is essential and would allow assessment of the ecological state of the lower Teviot River/Te Awa Makarara.

Contents

List of figures

Fort

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.
Hydrological year	The 12-month period between July and June of the following year.
Hydropeaking	The practice of generating hydro-electric power at times when the electricity spot-price is high, with water stored during times when the spot-price is low, and water used to generate electricity when prices are high, resulting in flows downstream of the power station that can fluctuate markedly through the day.
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-day low flow	The lowest seven-day low flow in any hydrological 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.
7-d Mean Annual Low Flow (7-d MALF)	The average of the lowest seven-day low flow (see definition above) for each year of record.
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.
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).
Taking	The taking of water is the process of abstracting water for any purpose and for any period.

1. Introduction

The Teviot River/Te Awa Makarara is a small river that rises at elevations of up to 1,210 m above sea level on the Lammerlaw Range east of Roxburgh before flowing into the Clutha River/Mata-Au downstream of the Roxburgh Dam and opposite Roxburgh township.

The flows of the Teviot River/Te Awa Makarara are highly modified for irrigation and hydroelectric generation. The upper reaches of the Teviot River/Te Awa Makarara and Dismal Swamp were dammed by the Roxburgh Amalgamated Mining Company in 1888 for the purpose of gold mining and irrigation and in 1924 the dam started operating as a joint irrigation and hydro-electric power scheme. The dam was raised three times between 1888 and 1938. In 1982, a new dam was constructed directly in front of the original structure, raising the lake by 5 m and increasing the surface area of the lake from 367 ha to 830 ha. The operating range is 6 m (between 680 m and 686 m above sea level).

Pioneer Energy Ltd. operates five hydro-electric stations on the Teviot River/Te Awa Makarara, with the first station on the dam that forms Lake Onslow, Horseshoe Bend Dam (8.75 km downstream of the dam), with a power station 2.4 km downstream, Marslin Dam (24 km downstream of the dam) which feeds water into Teviot Pond. From here, water flows almost 1 km into the power station, which discharges to the Teviot River/Te Awa Makarara approximately 500 m upstream of the Clutha/Mata-Au.

The Teviot catchment is within the Clutha Mata-Au Freshwater Management Unit (FMU) and the Roxburgh Rohe. Like many waterways within the Roxburgh Rohe, the Teviot catchment has a long history of flow modification, with many of the water takes within the Teviot catchment historically being authorised by deemed permits (also known as mining rights). These permits, often originally issued for mining and later used for irrigation, were not subject to environmental restrictions, such as minimum flows. Therefore, catchments such as the Teviot River/Te Awa Makarara have not been subject to a minimum flow. As part of the development of the Land and Water Regional Plan, minimum flows, and allocation limits are to be developed for all catchments in Otago.

Lake Onslow was identified as the potential site of a pumped hydro-electricity power scheme in 2002 by Professor Earl Bardsley of the University of Waikato. This scheme was identified by the Interim Climate Change Committee as an option to decarbonise electricity generation in New Zealand. The NZ Battery Project was stopped in late 2023 by the incoming government during the second phase of investigations of the scheme. The Lake Onslow pumped-hydro scheme would have involved the construction of a high dam, which would raise the level of Lake Onslow with the potential to add additional storage in the upper Manorburn catchment. This would have flooded a large area of land including regionally significant wetlands. This scheme would have had a storage capacity of 3-8.5 TWh[1]. The installed capacity of the power station would be 1.2 GW (or 1,200 MW). For comparison, this is nearly four times the maximum generation capacity of the nearby Roxburgh Dam, which has an installed capacity of 320 MW.

[1] Terawatt hours is a measure of electrical power. One terawatt hour is equivalent to the energy used by almost 140,000 average New Zealand households in a year.

1.1. Purpose of the report

The purpose of this report is to present information to inform water management decision-making in the Teviot catchment including consideration of available hydrological and ecological information.

2. Background information

2.1. Catchment description

Lake Onslow is fed by several small tributaries that drain the top of the Lammerlaw Range including the North and South Branches of the Teviot River/Te Awa Makarara, Boundary Creek and Fortification Creek. Below Lake Onslow, the Teviot River/Te Awa Makarara flows almost 29 km through a steep gorge before entering the Clutha/Mata-Au opposite the township of Roxburgh. The total area of the Teviot catchment is 321 km^2.

2.1.1. Climate

The climate in most of the Teviot catchment is classified as 'cool-dry' (mean annual temperature <12°C, mean annual effective precipitation ≤500 mm), although some small tributaries of Fortification Creek and the South Branch of the Teviot River/Te Awa Makarara were classed as 'cool-wet' (mean annual temperature <12°C, mean annual effective precipitation 500-1500 mm) (Snelder & Biggs 2002). There is a strong gradient in rainfall within the catchment from the southeastern edge with up to 900 mm of rain falling in the higher elevation areas on the Lammerlaw Range, while the median annual rainfall in the lower elevations in the northwestern part of the catchment is as low as 400-450 mm (Figure 2). The mean annual rainfall at the nearby Roxburgh Aerodrome climate station is 616 mm, with the greatest rainfall in the warmer months (65 mm in November, 71 mm in March) and the lowest rainfall in late winter/early spring (35 mm in August and September; Macara *et al*., 2019).

Mean air temperatures at nearby Roxburgh are 16°C in summer (December-February), with an average of 6.4 days per year with a maximum temperature exceeding 30°C. However, such high temperatures are unlikely to affect the upper Teviot catchment. In contrast, seasonal mean minimum temperatures at Roxburgh drop to 0.2°C in winter (June-July) and there is an average of 58 days per year with a minimum temperature of less than 0°C (Macara *et al*., 2019).

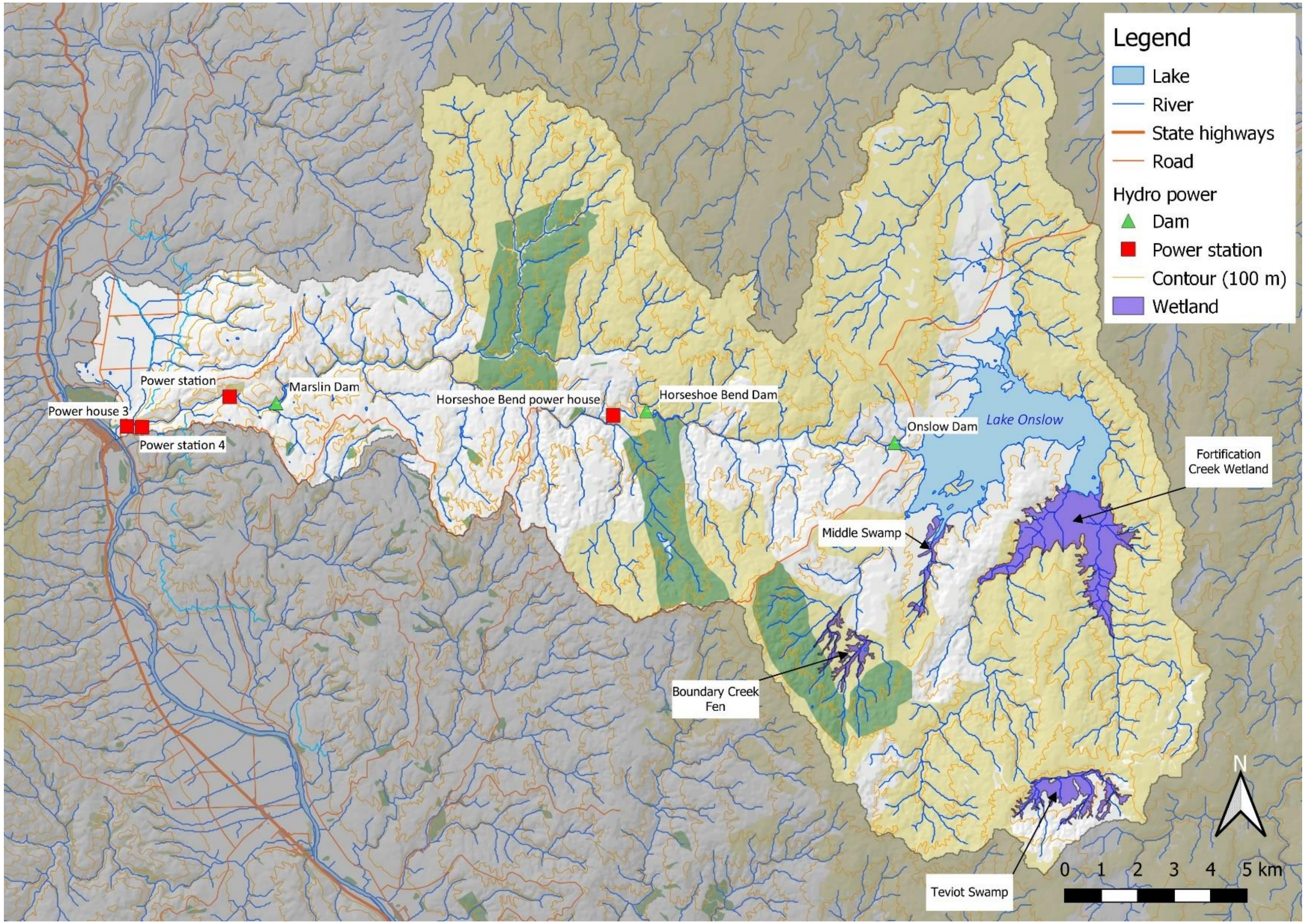

Figure 1 Map of the Teviot catchment.

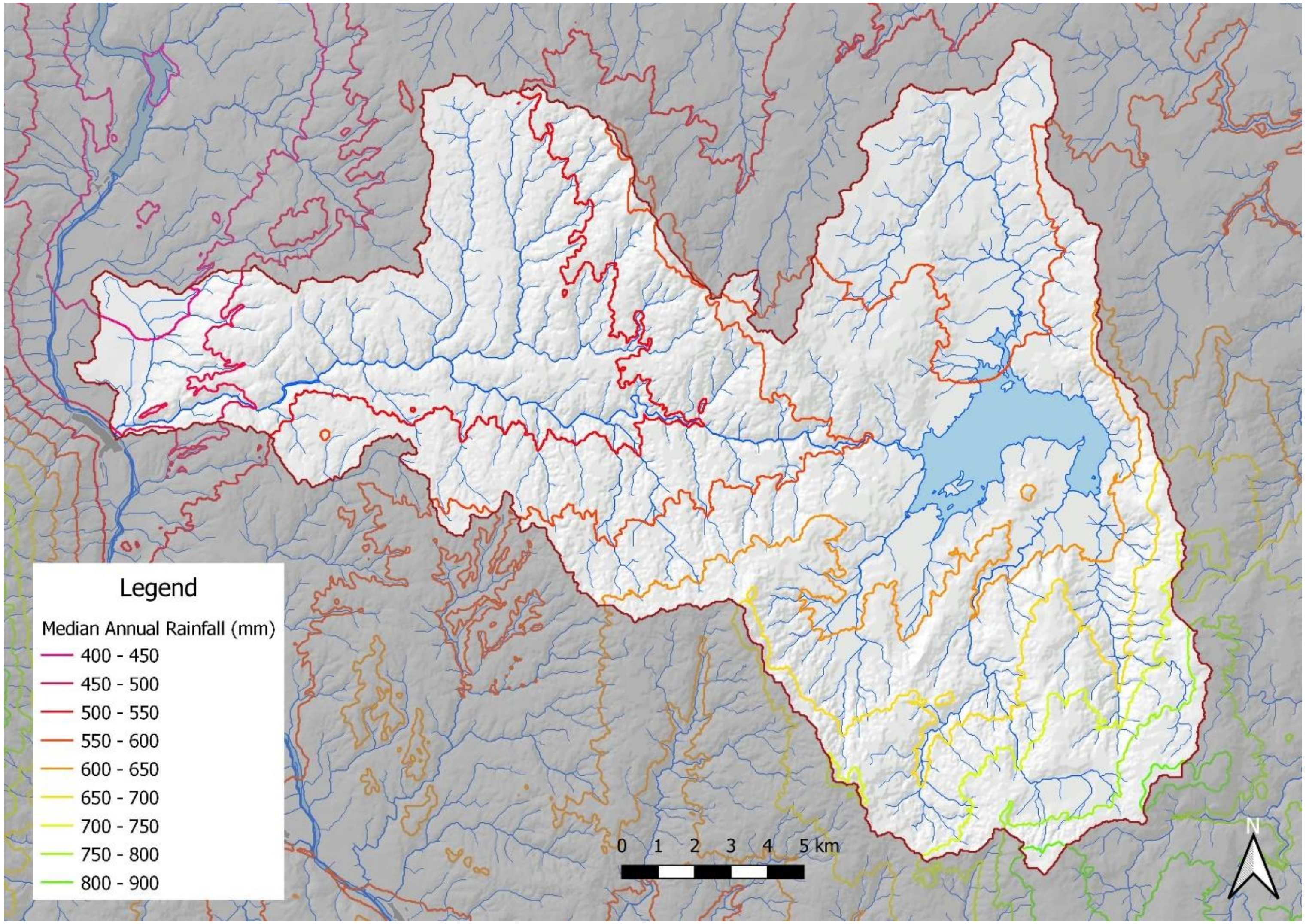

Figure 2 Distribution of rainfall (annual median rainfall) in the Teviot catchment. From GrowOtago (Otago Regional Council (2004).

2.1.2. Geological setting

The Teviot catchment is underlaid by schist (Caples terrane) with small deposits of recent quaternary gravels with organic soils associated with wetlands in the vicinity of Lake Onslow (Turnbull, 2000).

2.1.3. Vegetation and land use

The vegetation of the upper Teviot catchment is mostly tall tussock grassland, and high-producing pasture, while there are also some substantial areas of exotic forestry in the Pinelheugh Creek, Luncheon Creek Right Branch and in the upper reaches of Boundary Creek (Figure 3). Orchards and cropping dominate land use the flats close to the Clutha/Mata-Au in the lower Teviot catchment (Figure 3).

The upper Teviot catchment, upstream of Lake Onslow, has three regionally significant wetlands (as mapped in Map F27 of the RPW). The first, Fortification Creek Wetland Management Area is a fen that represents approximately half of the original extent of this wetland (47%) and is highly natural (98%) (Ausseil *et al*. 2008).

Middle Swamp is an area of bog extending from the shores of Lake Onslow up an unnamed tributary towards Wattys Knob, which represents approximately 32% of the original extent of this wetland but is highly natural (100%; Ausseil *et al*. 2008). .

Boundary Creek Fen is an area of wetland consisting of red tussock and *Sphagnum* moss in the upper part of the Boundary Creek catchment. It represents approximately 47% of the original extent of this wetland but is highly natural (100%; Ausseil *et al*. 2008).

In addition to these wetlands that are identified as Regionally Significant (Schedule 9 of the RPW), any wetland at elevations higher than 800 m above sea level is considered to be a Regionally Significant Wetland (Policy 10.4.1A). In the Teviot catchment, this includes Teviot Swamp, an area of wetland in the upper reaches of the Teviot River/Te Awa Makarara South Branch.

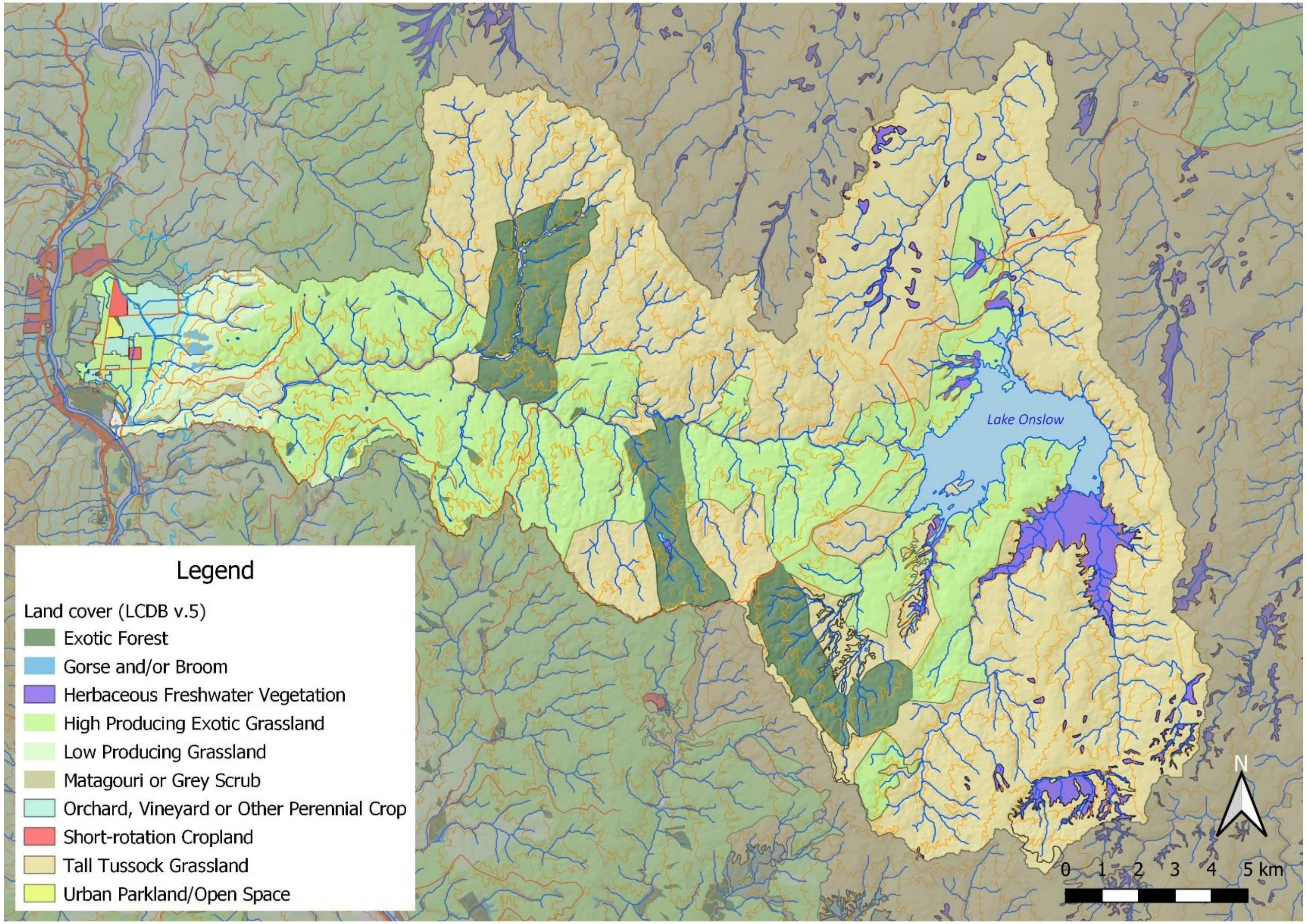

Figure 3 Land cover in the Teviot catchment based on the land cover database (version 5).

3. Regulatory setting

3.1. Regional Plan: Water (RPW)

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 MALF; 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 Teviot catchment, and the Teviot River/Te Awa Makarara's 7-d mean annual low flow at its confluence with the Clutha/Mata-Au is estimated to be 703 l/s (Section 4.4). The net consented allocation in the Teviot catchment is 6,682 l/s[2]. Given that Policy 6.4.2 specifies the allocation limit is the greater of 50% of the 7-day mean annual low flow; or the sum of consented maximum instantaneous, or consented 7-day, takes of surface water and connected groundwater, the current allocation limit for the Teviot catchment is 6,682 l/s.

3.2. Proposed Land and Water Plan

The ORC is undertaking 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 Clutha Mata-Au Freshwater Management Unit (FMU), which is further sub-divided into 5 Rohe: Upper Lakes, Dunstan, Manuherekia, Roxburgh and Lower Clutha. The Teviot River/Te Awa Makarara is within the Roxburgh Rohe. The proposed objectives for the Roxburgh Rohe, valid at the time of writing, are presented in Table 1.

The objectives set out in Table 1 apply to the Teviot catchment. For the sake of brevity, only objectives that apply to flowing water bodies are shown in Table 2.

[2] The sum of the maximum rate of take under 2001.480.V2 (2,832 l/s) and the combined maximum rate of take under RM19.459.01 and 2001.486.V2 (3,850 l/s).

Table 1 Possible environmental outcomes for the values identified in the Roxburgh Rohe and their attributes and target attributes states are from corresponding tables in the National Objectives Framework of the National Policy Statement for Freshwater Management 2022).

Value	Narrative outcome statement	Attribute	Target attribute state
Ecosystem health – (all biophysical components)	Freshwater bodies within the Roxburgh rohe 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. This is achieved where the target attribute state for each biophysical component (as set in table) are reached.		
		Periphyton - mg chl-*a*/m^2	B
		Fish - Fish index of biotic integrity (F-IBI)	B
		Macroinvertebrates - Macroinvertebrate Community Index (MCI) score; Quantitative Macroinvertebrate Community Index (QMCI) score	B
		Macroinvertebrates - Macroinvertebrate Average Score Per Metric (ASPM)	B
EH – Water quality		Ammonia (toxicity) mg NH_4-N/L (milligrams ammoniacal-nitrogen per litre)	A
		Nitrate (toxicity) - mg NO_3 – N/L (milligrams nitrate-nitrogen per litre)	A
		Suspended fine sediment - Visual clarity (metres)	B
		Dissolved oxygen - mg/L (milligrams per litre)	A
		Dissolved reactive phosphorus - DRP mg/L (milligrams per litre)	A
EH - Habitat		Deposited fine sediment - % fine sediment cover	A
EH – Ecological processes		Ecosystem metabolism (both gross primary production and ecosystem respiration) - grams of dissolved oxygen per square metre per day	B
EH – Water quantity		Under development – awaiting national guidance	Not applicable
Human contact	Water bodies within the Roxburgh rohe are clean and safe for human contact activities**.**	*Escherichia coli* (*E. coli*) – *E. coli*/100 mL	A
		Cyanobacteria (planktonic) - Biovolume mm^3/L	A
		E. coli (primary contact sites) – 95th percentile of *E. coli*/100 mL	A
		Phytoplankton mg chl-*a*/ m^3	B
		Suspended fine sediment - Visual clarity (metres)	A

Table 1 Possible environmental outcomes for the values identified in the Roxburgh Rohe and their attributes and target attributes states are from corresponding tables in the National Objectives Framework of the National Policy Statement for Freshwater Management 2022).

Fishing	For parts of the Roxburgh rohe valued for fishing, the numbers of fish are sufficient and safe to eat.	Key attributes include those identified for Ecosystem Health (all biophysical components) and Human Contact	See target attribute states for ecosystem health and human contact above
Animal drinking water	Water from water bodies within the Roxburgh rohe is safe for the reasonable drinking water needs of stock and domestic animals.	Key attributes include those identified for Ecosystem Health (all biophysical components) and Human Contact	See target attribute states for ecosystem health and human contact above
Cultivation and production of food and beverages and fibre	After the health and wellbeing of water bodies and freshwater ecosystems and human health needs are provided for, water bodies within the Roxburgh rohe can provide a suitable supply of water for the cultivation and production of food, beverages and fibre.		
Commercial and industrial use	After the health and wellbeing of water bodies and freshwater ecosystems and human health needs are provided for, water bodies within the Roxburgh rohe can still provide a suitable supply of water for commercial and industrial activities.		
Drinking water supply	Source water from waterbodies within the Roxburgh rohe is safe and reliable for the drinking water supply needs of the community.	Key attributes include those identified for Ecosystem Health (all biophysical components) and Human Contact	See target attribute states for ecosystem health and human contact above
		Source water (after treatment) capable of meeting NZ Drinking water standards	
Natural form and character	Water bodies and riparian margins within the Roxburgh rohe can behave in a way that is	Key attributes include those identified for Ecosystem Health (all biophysical components) and Human Contact	See target attribute states for ecosystem health

	consistent with their natural form and character.		and human contact above
		Other attributes under development	Not applicable

Table 1 Possible environmental outcomes for the values identified in the Roxburgh Rohe and their attributes and target attributes states are from corresponding tables in the National Objectives Framework of the National Policy Statement for Freshwater Management 2022).

Threatened species	The Roxburgh rohe supports self-sustaining populations of threatened species.	Under development (Possible attributes based on presence, abundance, survival, recovery, habitat conditions)	Not applicable
Wetlands	Wetlands within the Roxburgh rohe are resilient and support a diversity of habitats.	Under development	Not applicable
Hydro-electric power generation	After the health and wellbeing of water bodies and freshwater ecosystems and human health needs are provided for, water bodies within the Roxburgh rohe can support low impact hydro-electric generation.		

4. Hydrology

4.1. Catchment description

The headwaters of the Teviot River/Te Awa Makarara arise as low-gradient streams at high altitudes (>1,210 m a.s.l) on the Lammerlaw Range before flowing into a steep gorge before entering the Clutha/Mata-Au opposite the township of Roxburgh (

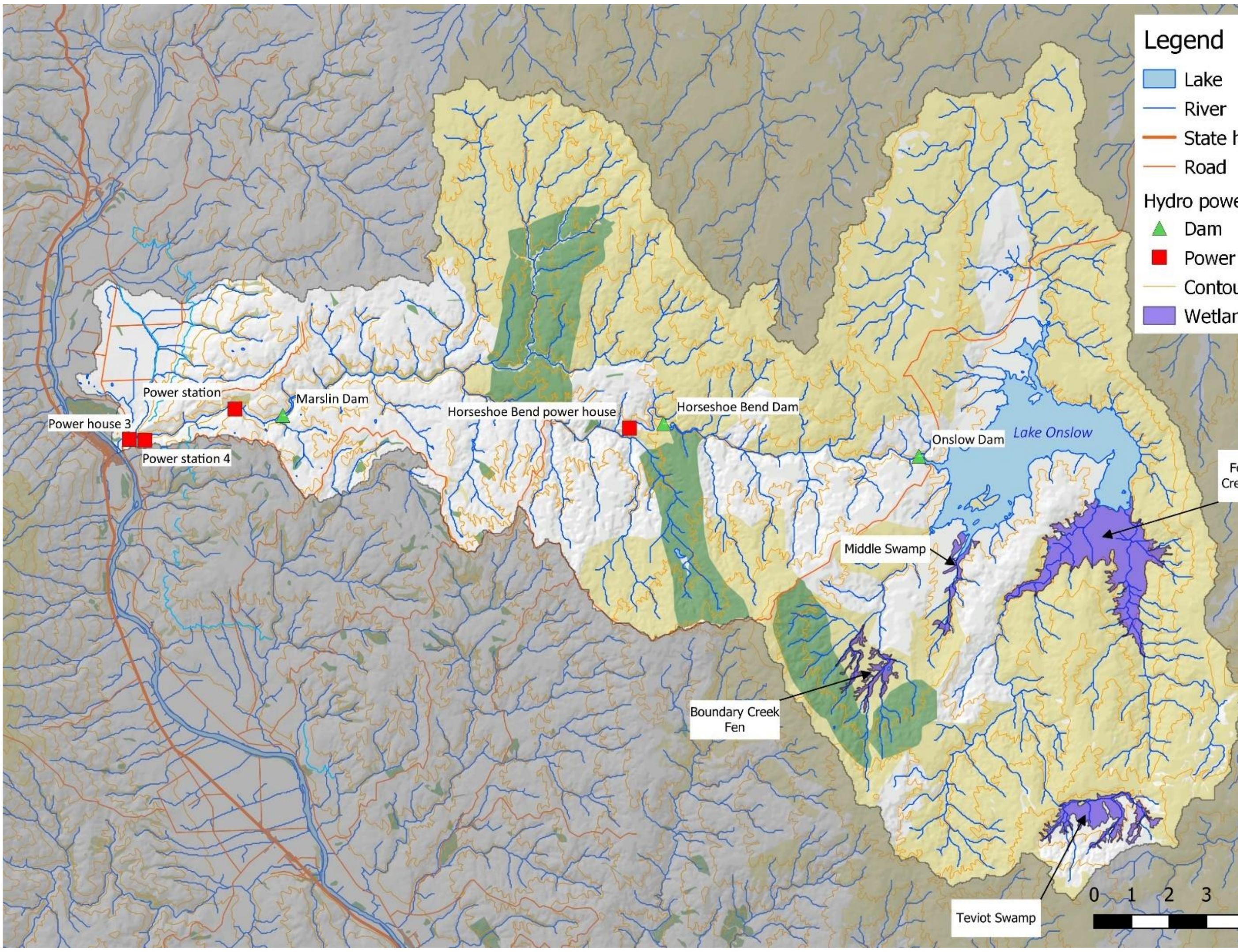

Figure 1). Given the strong rainfall gradient in the catchment (Figure 2) and tussock vegetation cover (Figure 3), water yields in high-altitude areas are expected to be much higher than in low-altitude areas.

Flows in the Teviot River/Te Awa Makarara are modified by water stored in Lake Onslow for the purposes of hydro-electric generation (Section 4.2) and irrigation (Section 4.3).

4.2. Hydro-electric Power Generation

The hydrology of the mainstem of the Teviot River/Te Awa Makarara is modified by the operation of six hydro-electric power stations as well as Lake Onslow. The hydrology of the tributaries of Lake Onslow is natural with major inflows from the Teviot River/Te Awa Makarara North Branch (12.3 km) and South Branch (10.4 km), Boundary Creek (6.6 km), Fortification Creek (6.5 km) (Table 2). A 7.5 km long reach (26%) between the outflow from Lake Onslow to the top of the reservoir formed by Horseshoe Bend Dam is subject to a residual flow of 345 l/s, with up to 6,000 l/s discharged from the dam for the purpose of hydro-electric power generation. The Teviot Irrigation Company also holds consent to take and discharge up to 2,832 l/s from Lake Onslow to the Teviot River/Te Awa Makarara for the purpose of augmenting flows for irrigation.

Pioneer Energy Ltd. has consent to take up to 6,000 l/s from Horseshoe Bend Dam which is discharged from a powerhouse (4.3 MW) approximately 2.4 km downstream (Table 2). The reach between Horseshoe Bend Dam and the powerhouse has a residual flow of 305 l/s, while the reach between the powerhouse and the top of the water impounded by Marslin Dam is subject to hydropeaking[3] (Table 2; Figure 4, Figure 5).

Below Marslin Dam, Pioneer Energy Ltd. has consent to take up to 6,232 l/s from Marslin Dam some of this is discharged from the Kowhai power station (2 MW) approximately 1.5 km downstream, while the remainder is discharged to the Michelle power station (1.6 MW) which discharges to Teviot Pond (293 m a.s.l.) via a race. Water from Teviot Pond passes into the George (1 MW), Teviot Bridge (1.125 MW) and Ellis (6.8 MW) Powerhouses.

4.3. Irrigation

The Teviot Irrigation Company (TIC) discharges up to 2,832 l/s from Lake Onslow to the Teviot River/Te Awa Makarara and up to 2,491 l/s is taken from a weir on the lower river immediately downstream of the Kowhai Powerhouse to supply the TIC scheme. From the TIC intake weir, water passes through a tunnel into a race that feeds the Ewings Race, which carries it almost 14 km south along the true left of the Clutha/Mata-Au to Onslow Downs, a station located opposite Ettrick. Some of the water diverted from the TIC weir flows on to Teviot Pond, and is siphoned under the Teviot River/Te Awa Makarara in two pipelines (high pressure and low pressure) before feeding a series of open races and pipelines that flow up to 8.5 km to the north to the Roxburgh East area (Figure 6).

Table 2 Description of distinct hydrological reaches in the Teviot River/Te Awa Makarara affected by hydro-electric power generation activities

[3] The practice of generating hydro-electric power at times when the electricity spot-price is high, with water stored during times when the spot-price is low, and water used to generate electricity when prices are high, resulting in flows downstream of the power station that fluctuate markedly through the day.

Reach	Description	Length (km)
Upper reaches (Boundary Creek, Fortification Creek,Teviot River/Te Awa Makarara North Branch, Teviot River/Te Awa Makarara South Branch)	Natural	36
LAKE ONSLOW		8.0
Lake Onslow to Horseshoe Bend Dam	Take of up to 6,000 l/s, residual flow (345 l/s)	7.5
HORSESHOE BEND DAM		1.3
Horseshoe Bend Dam to powerhouse	Take of up to 6,000 l/s, residual flow (305 l/s)	2.4
Horseshoe Bend powerhouse to Marslin Dam	Hydro-peaking, residual flow (305 l/s)	11
MARSLIN DAM		1.8
Marslin Dam to Kowhai powerhouse	Take of up to 6,232 l/s, residual flow (50 l/s)	1.5
Teviot Irrigation Company Weir to lower power Stations (Teviot Bridge & Ellis)	Take of up to 1,359 l/s, residual flow (50 l/s)	3.2
Downstream lower discharge point to Clutha confluence	Hydro-peaking (discharge of up to 6,800 l/s)	0.5

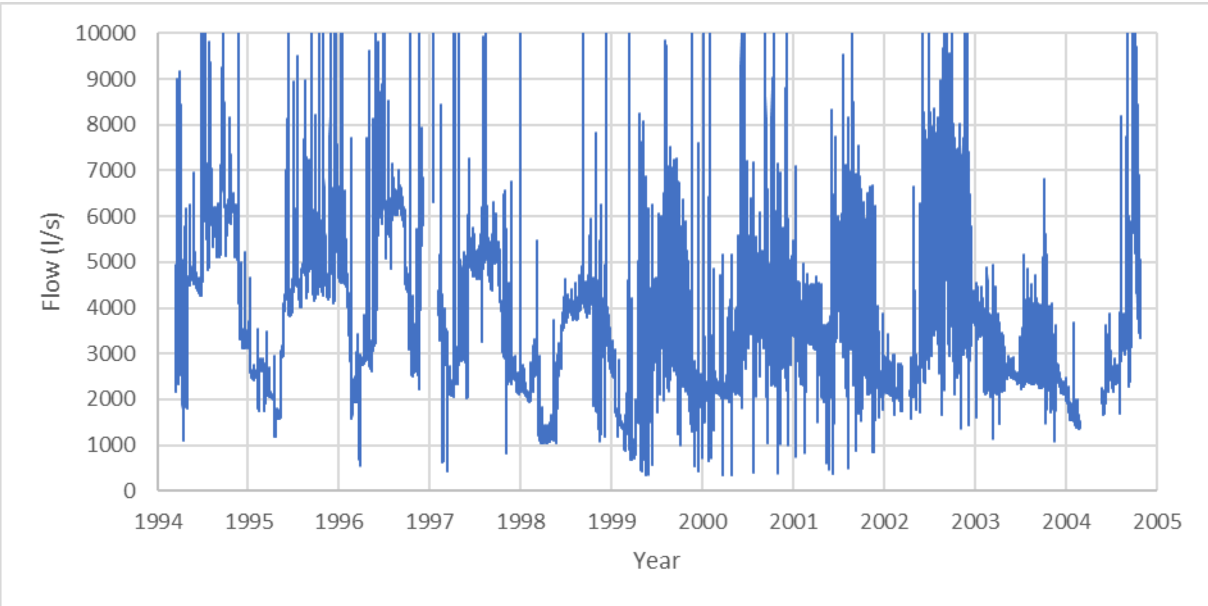

Figure 4 Observed flows in the Teviot River/Te Awa Makarara at Bridge Huts Road between March 1994 and October 2004.

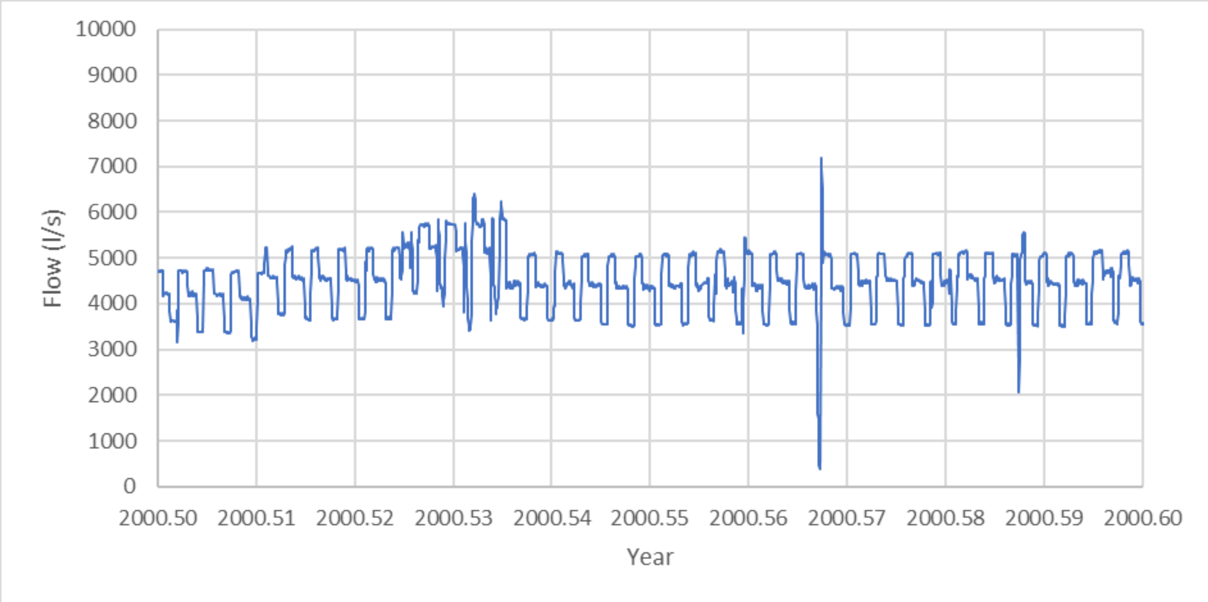

Figure 5 Observed flows in the Teviot River/Te Awa Makarara at Bridge Huts Road between 1 July and 7 August 2000.

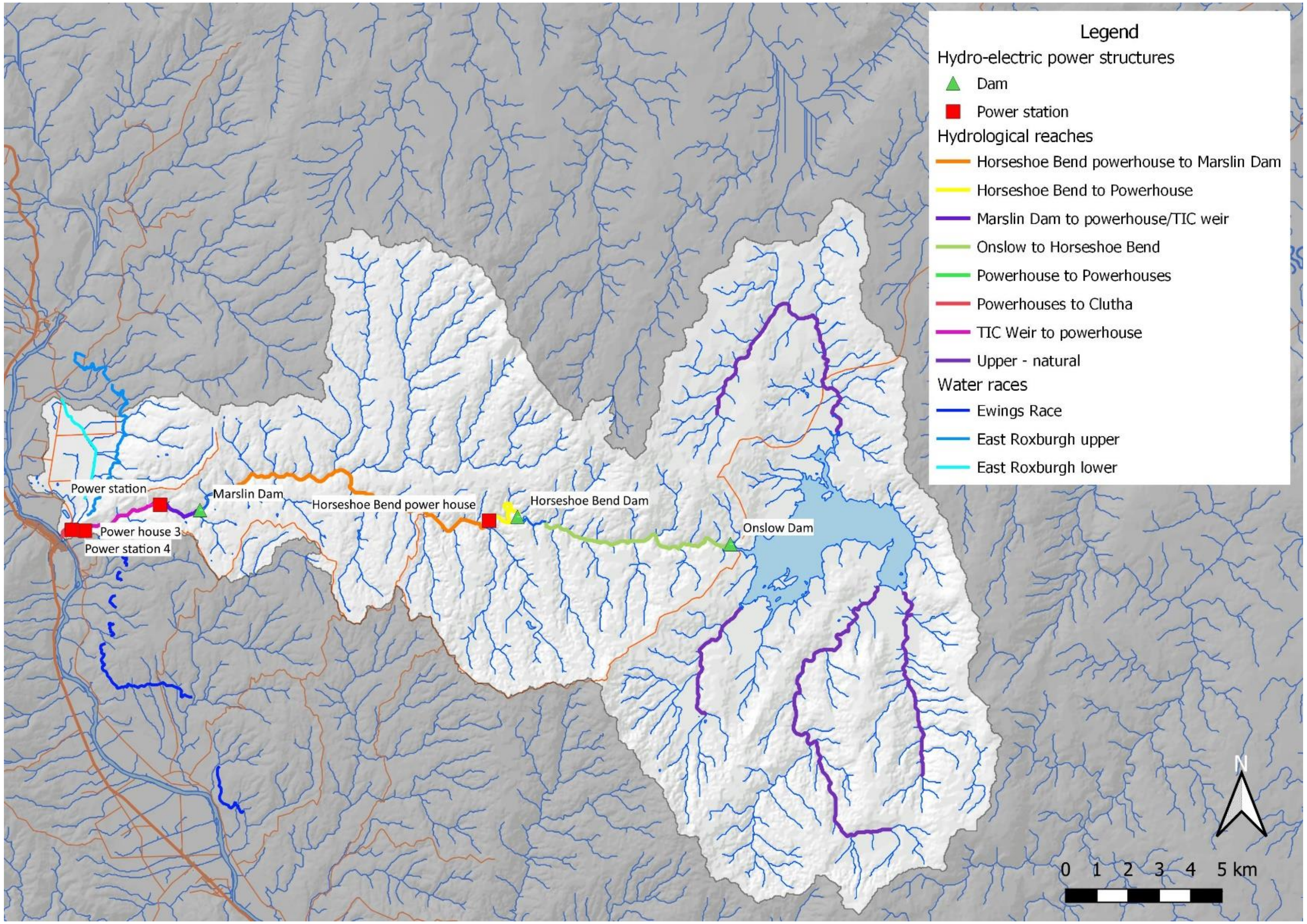

Figure 6 **Hydrological reaches within the mainstem of the Teviot River/Te Awa Makarara showing the different effects of the operation of hydro-electric power schemes and irrigation takes along with the Teviot Irrigation Company race.**

4.4. Flow statistics

A continuous flow recorder was installed in the Teviot River/Te Awa Makarara at Bridge Huts Road between 16 March 1994 and 27 October 2004. The flow statistics for the Teviot River/Te Awa Makarara at the Clutha/Mata-Au confluence were estimated based on a regional hydrological model developed by Friedel *et al*. (2023) are summarised in Table 3 along with summary statistics for observed flows at the Bridge Huts Road hydrological site.

Table 3 Flow statistics for hydrological sites in the Teviot River/Te Awa Makarara from a regional hydrological model developed by Friedel et al. (2023)

Site	Type	Flow statistics (l/s)		
		Mean	Median	7d MALF
Teviot at Bridge Huts Road	Observed flows (16 March 1994- 27 October 2004)	3,881	3.677	1,867
Teviot at Clutha/Mata-Au confluence	Modelled natural flows	3,395	-	703

Observed flows in the Teviot River/Te Awa Makarara over the period 1994-2004 were highest between July and October (Figure 7).

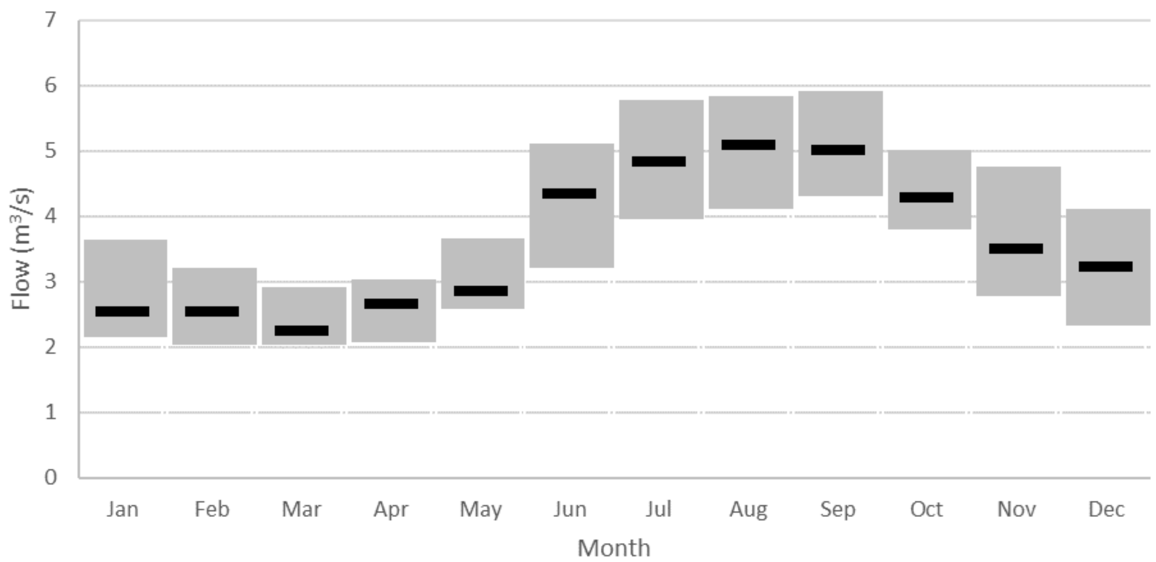

Figure 7 Seasonal variation in flows in the Teviot River/Te Awa Makarara at Bridge Huts Road (16 March 1994- 27 October 2004). Grey bars are inter-quartile range. Horizontal black lines are monthly medians.

Flow events exceeding three times the median flow are generally considered large enough to reduce periphyton biomass and cover and are referred to as flushing flows. The observed frequency of such events (FRE3) in the Teviot River/Te Awa Makarara over the period 16 March 1994- 27 October 2004 was an average of 1 event per year. Given the high degree of hydrological modification downstream of Onslow Dam, including flow augmentation during periods of naturally low flows and flow fluctuations associated with hydropeaking, it is difficult to determine what frequency of flushing flows would be required to reduce periphyton biomass in the Teviot River/Te Awa Makarara. Current conditions on a resource consent held by Pioneer Energy Ltd. (2001.477) provide for the release of flushing flows in response to monitoring on the recommendation of the freshwater ecologist undertaking the monitoring (see Section 5.1).

4.4.1. Water allocation & use

Primary allocation

There are nine resource consents for primary water taken from the Teviot catchment (Table 4). Most are held by Pioneer Energy Ltd. and are associated with the operation of the various power schemes along the length of the Teviot River/Te Awa Makarara (see Section 4.2)

Table 4 Active surface water take consents in the Teviot catchment.

Consent number	Consent holder	Expiry	Instant	Monthly volume	Annual Volume	Residual flow	Purpose
RM21.273.01*	Teviot Irrigation Company Ltd	21/06/2027	2,832				Flow augmentation for irrigation
2001.476.V4*	Pioneer Energy Ltd	1/04/2041	6,000			345 l/s	Hydroelectric power generation and flow augmentation
97322*	Pioneer Energy Ltd	15/09/2032	6,000			305 l/s	To maintain residual flow
97324.V1*	Pioneer Energy Ltd		1,000				To take water for compensation flows from the lake formed
97326.V1*	Pioneer Energy Ltd	15/09/2032	6,000				Dam dewatering
2001.481.V1*	Pioneer Energy Ltd	1/04/2041	3,400				Hydroelectric power generation and dam dewatering
2001.480.V2	Pioneer Energy Ltd	1/04/2041	2,832			50 l/s	Hydroelectric power generation and flow augmentation for irrigation
RM19.459.01	Pioneer Energy Limited and Teviot Irrigation Company Limited	1/04/2041	3,850	10,311,840	121,746,240	50 l/s	Hydroelectric power generation and flow augmentation for irrigation
2001.486.V2	Pioneer Energy Limited	1/04/2041	2,491				Flow augmentation for hydroelectric power generation and irrigation

* = Non-consumptive

5. The aquatic ecosystem of the Teviot catchment

5.1. Periphyton

The periphyton community forms the slimy coating on the surface of stones and other substrates in freshwaters. It can include a range of different 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 (e.g. Hamill, 2001; Wood *et al*., 2007). These include toxins that affect the nervous system (neurotoxins), liver (hepatotoxins), and dermatotoxins that can cause severe skin irritation.

Limited information is currently available on periphyton communities in the Teviot River/Te Awa Makarara. Pioneer Energy has undertaken periphyton monitoring since 2007, as part of Consent Monitoring for Resource Consent 2001.477 (Dungey, 2023). The maximum cover of filamentous green algae reported has ranged from 3% to 87%, with the maximum annual cover exceeding 30% in eleven out of sixteen monitoring seasons (Dungey, 2023). National guidelines for cover of long filamentous algae for protection of aesthetics/recreation and trout habitat and angling is 30% cover by long filaments (>2 cm).

Monitoring by Pioneer Energy has found that the cyanobacteria *Nostoc* was consistently present at sites in the Teviot River/Te Awa Makarara, along with the filamentous green algae *Microspora*, *Spirogyra*, *Rhizoclonium* and the filamentous diatom *Melosira*.

5.2. 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 (MCI) and its variants (e.g. semi-quantitative MCI; SQMCI) have been widely used in New Zealand to assess the effects of nutrients and sediment (Wagenhoff *et al*. 2016).

A macroinvertebrate sample was collected from the Teviot River/Te Awa Makarara at Bridge Huts Road in 2022. The MCI score (109.6) was indicative of 'good' habitat/water quality while the QMCI score (3.99) was consistent with 'poor' habitat/water quality (based on the criteria of Stark & Maxted, 2004). The ASPM scores (0.385), indicated 'moderate to severe loss of ecological integrity' (based on Table 15 of the NPSFM 2020). On this occasion, the macroinvertebrate community was numerically dominated by the mudsnail *Potamopyrgus,* with oligochaete worms, chironomid midges (Orthocladiinae) and the purse-cased caddis fly *Oxyethira* also among the most abundant taxa at this site. The net-spinning caddis fly *Aoteapsyche*, mayfly *Austroclima* and the spiral-cased caddis fly *Helicopsyche* were also abundant in this sample.

5.3. Fish

5.3.1. Indigenous fish

Five species of indigenous freshwater fish have been recorded from the Teviot catchment – longfin eel, lamprey, common bully, dusky galaxias and Teviot galaxias (Figure 8; Table 5). Of these, longfin eel (Declining; Dunn *et al*., 2018) and lamprey (Nationally Vulnerable; Dunn *et al*., 2018) have only been recorded from the lower Teviot River/Te Awa Makarara close to the confluence with the Clutha/Mata-Au (Figure 8). Common bully (Not Threatened; Dunn *et al*., 2018) have been recorded from tributaries of Lake Onslow including the Teviot River/Te Awa Makarara North Branch and are likely to be present in the lake itself (Figure 8).

Teviot galaxias are classified as Nationally Critical (Dunn *et al*., 2018), the highest threat status in New Zealand. They have been found in tributaries of the Teviot River/Te Awa Makarara including Old Hut Creek, unnamed tributaries on the true left of the Teviot River/Te Awa Makarara upstream of the Horseshoe Bend Power Station and in two small unnamed tributaries of Lake Onslow (Figure 8).

Dusky galaxias are classified as Nationally Endangered (Dunn *et al*., 2018), the second highest threat status in New Zealand. They have been found in tributaries of the Teviot River/Te Awa Makarara including Old Hut Creek, the upper reaches of Pinelheugh Creek, the Right Branch of Luncheon Creek and in the Teviot River/Te Awa Makarara South Branch upstream of Lake Onslow (Figure 8).

5.3.2. Introduced fish

Brown trout are widespread in the Teviot catchment while rainbow trout have only been recorded from the lower reaches of the Teviot River/Te Awa Makarara close to the confluence with the Clutha/Mata-Au (Figure 8).

Little angler effort has been recorded in the Teviot River/Te Awa Makarara in the National Angler Surveys conducted in 1994/95, 2007/08 and 2014/15 (Table 6). It is considered to be a backcountry fishery, while Lake Onslow, which receives considerably greater angler effort (Table 6) is considered to be a regionally significant fishery (Otago Fish & Game Council, 2015).

Table 5 Fish species recorded from the Teviot catchment.

Family	Common name	Species	Threat classification	Subcatchments
Anguillidae	Longfin eel	*Anguilla dieffenbachii*	Declining	Lower Teviot
Eleotridae	Common bully	*Gobiomorphus cotidianus*	Not threatened	Tributaries of Lake Onslow, Lake Onslow
Galaxiidae	Dusky galaxias	*Galaxias pullus*	Nationally Endangered	Teviot River/Te Awa Makarara South Branch, Old Hut Creek, Pinelheugh Creek
	Teviot galaxias	*Galaxias* sp. T	Nationally Critical	Minor tributaries of Lake Onslow
Geotriidae	Lamprey	*Geotria australis*	Nationally Vulnerable	Lower Teviot
Salmonidae	Brown trout	*Salmo trutta*	Introduced and naturalised	Widespread in catchment
	Rainbow trout	*Oncorhynchus mykiss*	Introduced and naturalised	Lower Teviot

Table 6 Angler effort on the Teviot River/Te Awa Makarara and Lake Onslow based on the National Angler Survey (Unwin, 2016)

	NAS (angler days)			
Waterway	2014/15	2007/08	2001/02	1994/95
Teviot River/Te Awa Makarara	190 ± 120	100 ± 80	330 ± 200	160 ± 70
Lake Onslow	1,420 ± 410	3,130 ± 780	3,450 ± 570	2,720 ± 490

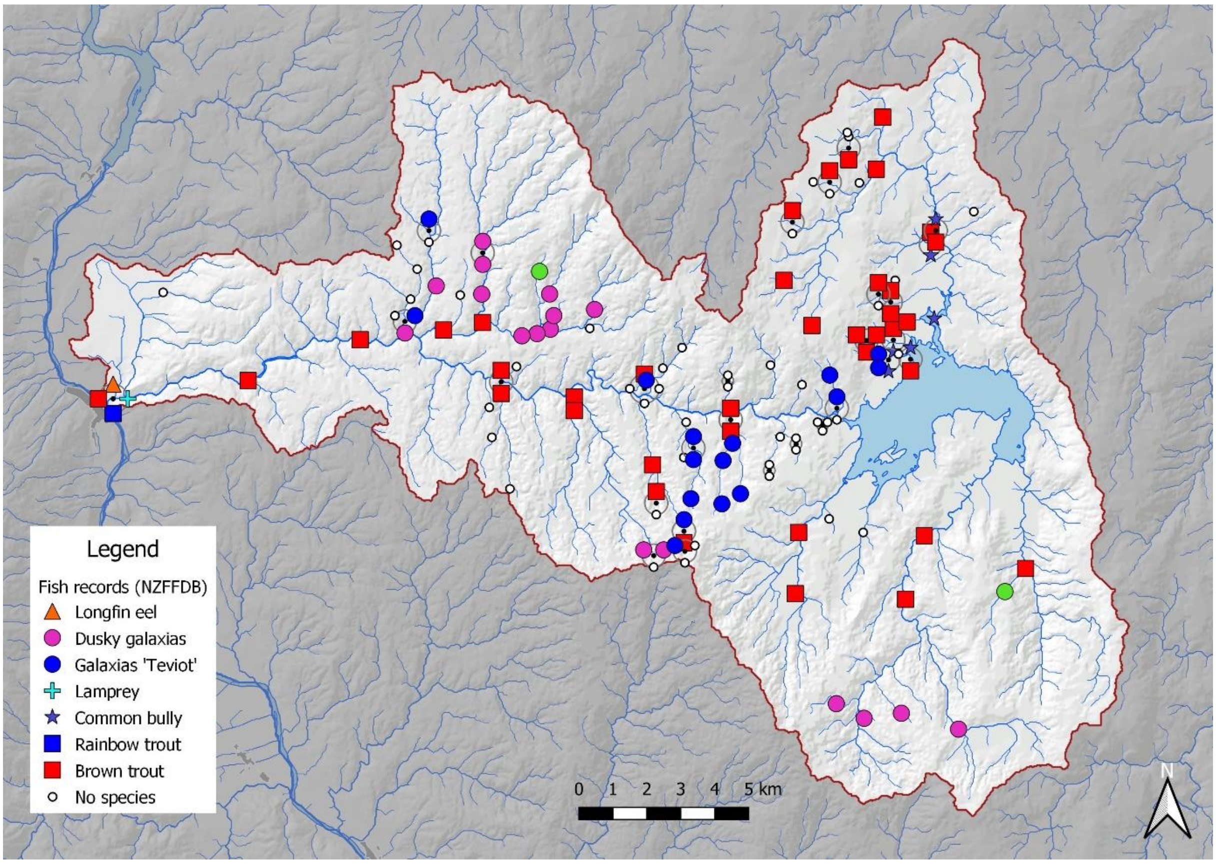

Figure 8 Fish distribution in the Teviot River/Te Awa Makarara catchment catchment based on records in the New Zealand Freshwater Fish Database (downloaded 5 October 2023). Records have been condensed by removing duplicate records for a particular area for simplicity.

5.4. Current ecological state

The current state of the Teviot River/Te Awa Makarara reflects the combined effects of heavy allocation pressure, hydro-electric power schemes which have been in place for many years. Therefore, comparison of the current state of the Teviot River/Te Awa Makarara with objectives for the Roxburgh Rohe provide insight into whether current conditions are consistent with the objectives proposed in the Land & Water Regional Plan.

At the time of writing, the proposed objectives for the Roxburgh Rohe include the following narrative objectives: *"Freshwater bodies within the Roxburgh Rohe 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 7 below.

5.4.1. Ecosystem health

In addition to the ecosystem health and human contact values identified in Table 7, the proposed objectives for fishing, animal drinking water, cultivation and production of food and beverages and fibre, commercial and industrial use, drinking water supply are measured by the target attribute states for ecosystem health and human contact presented in Table 7. Attributes for natural form and character and threatened species within the Roxburgh Rohe are under development, so it was not possible to consider the current state of the Teviot catchment relative to these attributes at the time of writing.

Table 7 presents the limited information available on the current attribute state for the Teviot River/Te Awa Makarara at Bridge Huts Road and compares the current state to the proposed target attribute state for the Roxburgh Rohe. It should be noted here that this is based on single samples from the Teviot River/Te Awa Makarara in 2022, while macroinvertebrate attributes are typically assessed based on 5-year medians. However, taking the limitations of available information, it would appear that the target states for MCI and SQMCI scores are not achieved in the Teviot River/Te Awa Makarara at Bridge Huts Road (Table 7). Macroinvertebrate community composition is affected by a range of factors including periphyton composition and biomass, predation by salmonids, water physicochemistry (e.g., water temperature, dissolved oxygen) and habitat characteristics (e.g., substrate composition, fine sediment cover). In this case, the low macroinvertebrate scores observed in the Teviot River/Te Awa Makarara reflect the abundance of tolerant taxa at this site (including the mudsnail *Potamopyrgus*, oligochaete worms and chironomid midges). These taxa are consistent with high cover by filamentous algae (Dungey, 2023)

5.4.2. Water quality

Water quality in the Teviot at Bridge Huts Road is very good (A-band) for most attributes based on the data for the limited number of parameters available (Table 7). The two exceptions are suspended fine sediment (visual clarity; D-band) and *E. coli* (B-band). In the case of suspended fine sediment, Table 8 of the National Objectives Framework lists “naturally highly coloured brown-water streams” within naturally occurring processes that may exempt a site from the national bottom line. In the case of the Teviot River/Te Awa Makarara, dissolved organic substances from wetland areas upstream will absorb short wavelengths light (blue-ultraviolet), making the water appear red or yellow. The absorbance by such substances will reduce the transmission of light through the water, thereby reducing underwater visibility. On this basis, the Teviot River/Te Awa Makarara is considered to be a “naturally highly coloured brown-water stream” and is therefore exempt from the national bottom line for suspended fine sediment.

The 95th percentile of observed *E. coli* concentrations (B-band) exceed the target attribute states (A-band). The 95th percentile of *E. coli* concentrations is a measure of the magnitude of the highest observed concentrations, which are typically expected to occur during high flow events as a result of overland flow. As such, they are not expected to be affected by minimum flows and/or allocation limits, particularly in the Teviot catchment where most of the area irrigated using flows from the Teviot River/Te Awa Makarara is outside the catchment.

Table 7 Comparison of the current attribute state in the Teviot River/Te Awa Makarara at Bridge Huts Road. Values based on Ozanne, Borges & Levy (2023). Attribute states are from corresponding tables in the National Objectives Framework of the National Policy Statement for Freshwater Management 2022).

Value	Attribute	Target attribute state	Current attribute state
			Teviot at Bridge Huts Rd
Ecosystem health – (all biophysical components)			
	Periphyton - mg chl-*a*/m^2	B	Not able to be determined
	Fish - Fish index of biotic integrity (F-IBI)	B	Not able to be determined
	Macroinvertebrates - (MCI) score	B	C Mean: 109.6 (2022)
	Macroinvertebrates - (QMCI) score	B	D Mean: 3.99 (2022)
	Macroinvertebrates - (ASPM)	B	C Mean: 0.385 (2022)
EH – Water quality	Ammonia (toxicity) mg NH_4-N/L	A	A Median: 0.001 95^{th} percent: 0.008
	Nitrate (toxicity) - mg NO_3 – N/L	A	A Median: 0.004 95^{th} percent: 0.018
	Suspended fine sediment - Visual clarity (m)	B	D* (1.21 m)
	Dissolved oxygen - mg/L	A	Not able to be determined
	Dissolved reactive phosphorus - DRP mg/L	A	A Median: 0.0011 95^{th} percent: 0.0037
EH - Habitat	Deposited fine sediment - % cover	A	Not able to be determined
EH – Ecological processes	Ecosystem metabolism (both gross primary production and ecosystem respiration)	B	Not able to be determined
Human contact	*Escherichia coli* (*E. coli*) – *E. coli*/100 mL	A	B Median: 28 95^{th} percent: 562 % >260: 13% % >540: 4%
	E. coli (primary contact sites) – 95^{th} percentile	A	B 95^{th} percent: 562
	Suspended fine sediment - Visual clarity (m)	A	D* (1.21 m)

* Sites in the Teviot catchment have naturally low visual clarity due to dissolved organic matter and are not expected to meet the national bottom line.

6. New Zealand Battery Project

Lake Onslow was identified as the potential site of a pumped hydro-electricity power scheme in 2002 by Professor Earl Bardsley of the University of Waikato. Pumped hydro-electric power schemes involve water being pumped from a lower reservoir or river up into an upper reservoir during periods of low power prices, with this water stored until periods of low electricity supply/high prices, when water flows from the upper reservoir to power generators before flowing into the lower reservoir/river. In the case of the proposed Lake Onslow scheme, the lower reservoir would be either Lake Roxburgh or the Clutha/Mata-Au, while the upper reservoir would be an expanded Lake Onslow.

This scheme was identified by the Interim Climate Change Committee as an option to decarbonise electricity generation in New Zealand, particularly to address the 'dry year problem', when existing hydro-electric power catchments (particularly the Waiau, Clutha/Mata-Au and Waitaki catchments) receive insufficient rainfall or snow and water levels in storage lakes run low (as occurred in 1992, 2001, 2003 and 2008).

The NZ Battery Project was stopped in late 2023 by the incoming government during the second phase of investigations of the scheme. Phase 1 evaluated long-term, large-scale renewable energy storage options, including pumped hydro and a range of other dry year storage solutions. This included detailed investigations of the feasibility of pumped hydro at Lake Onslow (including geotechnical investigations) and comparison to feasibility studies of other options. Phase 2 included a detailed business case and would have developed preferred option or options.

Various options regarding the Lake Onslow pumped-hydro scheme would have involved the construction of a high dam, which would have raised the level of Lake Onslow (with the maximum water level dependent on the storage option chosen). This area has the potential to accommodate a scheme with a storage capacity of between 3 and 8.5 TWh[4], although the maximum storage capacity of the scheme is likely to have been between 3 TWh (maximum water level: 745 m) and 5 TWh (maximum water level: 765 m). These scenarios would have inundated up to 5,900 ha (3 TWh option) or 7,100 ha (5 TWh option).

The installed capacity of the power station would be 1.2 GW (or 1,200 MW). For comparison, this is nearly four times the maximum generation capacity of the nearby Roxburgh Dam, which has an installed capacity of 320 MW.

[4] Terawatt hours is a measure of electrical power. One terawatt hour is equivalent to the energy used by almost 140,000 average New Zealand households in a year.

7. Alternative minimum flows and allocation limits

The highly modified hydrology of the middle and lower reaches of the Teviot River/Te Awa Makarara complicates the comparisons of alternative minimum/residual flows and allocation regimes with natural flows. The hydrology of the lower river is affected by the presence of Lake Onslow in the upper catchment and hydro-peaking discharges from the Teviot Hydroelectric Power Scheme. This is further complicated by the lack of hydrological monitoring in the lower catchment.

Given the inter-connectedness of Lake Onslow and the various power stations downstream, along with the Teviot Irrigation Company takes, the operation of these schemes and the residual flows specified in the various consents are the key determinants of flows in the Teviot River. Residual flows in the Teviot River/Te Awa Makarara range from 345 l/s (resource consent 2001.476.V4; 49% of MALF) immediately downstream of Lake Onslow, 305 l/s (resource consent 97322; 43% of MALF) between Horseshoe Bend and Marslin Dam to 50 l/s downstream of Marslin Dam (resource consents 2001.480.V2 and RM19.459.01; 7% of MALF). The 50 l/s residual flow downstream of the Marslin Dam was determined by an independent commissioner to have a no more than minor effect on instream values in the lower Teviot, based on the steep, bedrock and boulder channel and limited fish species present (brown trout being the only fish species recorded in this section). The permits associated with the Horseshoe Bend hydro-electric scheme expire on 15 September 2032, while those associated with the Marslin Dam and associated power stations expire on 1 April 2041.

Applying the default minimum flow and allocation values from Hayes et al. (2021) to the Teviot River would result in a minimum flow of 633 l/s (90% of the 7-d MALF) and allocation limit of 141 l/s (20% of the 7-d MALF).

7.1. Potential effects of climate change in the Teviot catchment

The potential effects of future climate change are subject to considerable variation depending on future emission scenarios. This assessment is based on the assessment of Macara *et al*. (2019) using two scenarios (RCP4.5 and RCP8.5[5]) for the period 2031-2050.

The probability, magnitude, and duration of low flow events in the Teviot catchment is expected to be similar to what is currently experienced (Table 8). The predicted changes in the hydrology of the Teviot River/Te Awa Makarara resulting from climate change include slightly higher mean annual flow and higher flood magnitudes. While such changes could be expected to enhance flushing of fine sediments and periphyton (Table 8), which is expected to be a positive ecological effect, particularly on the macroinvertebrate community of the Teviot River/Te Awa Makarara, such effects are likely to be dampened by the operation of Lake Onslow and downstream power schemes. Thus, the potential positive effects associated with climate change may not eventuate.

[5] Future climate change projections are considered under four emission scenarios, called Representative Concentration Pathways (RCPs) by the IPCC. RCP 4.5 is a mid-range scenario where greenhouse gas concentrations stabilise by 2100, while RCP8.5 is a “business as usual” scenario with greenhouse gas emissions continuing at current rates.

Table 8 Potential effects of climate change on the Teviot 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 Teviot River	Potential ecological consequences
Temperature	• Increased mean temperatures (0.8-0.9°C) • Increased annual mean maximum temperature (1.1-1.2°C) • Increase in number of hot days (>30°C) (increase by 6.1-6.4 days per annum) • Reduced frost days (-8.6 - -10.2 fewer frost days per annum)	• Increased evapotranspiration • Faster flow recession • Increased irrigation demand	• Higher water temperatures, reduced suitability for sensitive species • Faster accrual of periphyton biomass
Rainfall	• Increase in annual mean rainfall (3-4%) • Similar summer mean rainfall (+2-0%) • Increased winter rainfall (+6-10%) • Similar risk of low rainfall events • Little change in heavy rain days (>25 mm; +0.4- +0.5 days per annum) • Increase in peak rainfall intensity	• Similar or slightly reduced likelihood and/or magnitude of low flow events • Potential increase in magnitude of high flow events (but any benefits of this may be reduced by operation of Lake Onslow)	• Enhanced flushing of sediment and periphyton(but any benefits of this may be reduced by operation of Lake Onslow)
Snow	• Reduction in snow days, especially in upper catchment (-1 - -5 days)	• Reduced snowpack • Earlier and/or shorter spring snowmelt • Larger winter floods	• Enhanced flushing of sediment and periphyton (but any benefits of this may be reduced by operation of Lake Onslow)
Hydrology	• Little change in Q95 flow (-5- +5%) • Increase in mean flow (up to 5-10% increase) • Increased mean annual flood	• Low flows similar magnitude to existing • Irrigation demand may slightly decrease • Increased frequency and/or magnitude of flushing flows • Reliability for irrigators similar or slightly higher than present	• Enhanced flushing of sediment and periphyton

8. Conclusions

The Teviot River/Te Awa Makarara is a small river that rises on the Lammerlaw Range east of Roxburgh before flowing into the Clutha River/Mata-Au downstream of the Roxburgh Dam and opposite Roxburgh township.

The flows of the Teviot River/Te Awa Makarara are highly modified for irrigation and hydroelectric generation. The upper reaches of the Teviot River/Te Awa Makarara and Dismal Swamp were dammed in 1888 for the purpose of gold mining and irrigation and has subsequently been operated as a joint irrigation and hydro-electric power scheme. The current resource consents for hydro-electric generation and irrigation on the Teviot River have residual flow conditions. However, as part of the development of the Land and Water Regional Plan, minimum flows, and allocation limits are to be developed for all catchments in Otago. This report presents hydrological and ecological information to inform water management decision-making in the Teviot catchment.

Flow statistics for hydrological sites in the Teviot River/Te Awa Makarara from the regional hydrological model developed for ORC (Friedel *et al.* 2023):

Site	Type	Flow statistics (l/s)		
		Mean	Median	7d MALF (Jul-Jun)
Teviot at Bridge Huts Road	Observed flows (16 March 1994-27 October 2004)	3,881	3.677	1,867
Teviot at Clutha/Mata-Au confluence	Modelled natural flows	3,395	-	703

There are nine resource consents for primary water taken from the Teviot catchment (Table 4). Most are held by Pioneer Energy Ltd. and are associated with the operation of the various power schemes along the length of the Teviot River/Te Awa Makarara. Many of these takes are non-consumptive and many are subject to residual flows of between 50 l/s in the lower river and 345 l/s below Lake Onslow.

Limited information is currently available on periphyton communities in the Teviot River/Te Awa Makarara. Pioneer Energy has undertaken periphyton monitoring since 2007. The maximum cover of filamentous green algae reported has ranged from 3% to 87%, with the maximum annual cover exceeding the national guideline for cover by long filamentous algae (30%) in eleven out of sixteen monitoring seasons. Based on the available information, the Teviot River/Te Awa Makarara is unlikely to meet the national bottom line for periphyton biomass.

A macroinvertebrate sample was collected from the Teviot River/Te Awa Makarara at Bridge Huts Road in 2022. The MCI score on this occasion was indicative of 'good' habitat/water quality while the QMCI score was consistent with 'poor' habitat/water quality and the ASPM scores (0.385), indicated 'moderate to severe loss of ecological integrity'. The low scores for this sample is consistent with high cover by filamentous algae and the presence of a varial zone as a result of hydro-peaking.

Five species of indigenous freshwater fish have been recorded from the Teviot catchment – longfin eel, lamprey, common bully, dusky galaxias and Teviot galaxias. Of these, longfin eel (Declining) and lamprey (Nationally Vulnerable) have only been recorded from the lower Teviot River/Te Awa Makarara close to the confluence with the Clutha/Mata-Au. Common bully (Not Threatened) have been recorded from tributaries of Lake Onslow including the Teviot River/Te Awa Makarara North Branch and are likely to be present in the lake itself. Brown trout are widespread in the Teviot catchment while rainbow trout have only been recorded from the lower reaches of the Teviot River/Te Awa Makarara close to the confluence with the Clutha/Mata-Au.

Teviot galaxias (Nationally Critical) and Dusky galaxias (Nationally Endangered) have been found in several tributaries of the Teviot River/Te Awa Makarara including in tributaries of Lake Onslow.

Brown trout are widespread in the Teviot catchment while rainbow trout have only been recorded from the lower reaches of the Teviot River/Te Awa Makarara close to the confluence with the Clutha/Mata-Au. Little angler effort has been recorded in the Teviot River/Te Awa Makarara. It is considered to be a backcountry fishery while Lake Onslow, receives considerably greater angler effort and is considered to be a regionally significant fishery.

Limited information is available on the water quality and ecological state of the lower Teviot River/Te Awa Makarara. Based on a single macroinvertebrate sample, target states for MCI and SQMCI scores are not achieved in the Teviot River/Te Awa Makarara at Bridge Huts Road. Monitoring data collected by Pioneer Energy Ltd. suggests that cover of long filamentous algae exceeds national guidelines in most years.

The highly modified hydrology of the middle and lower reaches of the Teviot River/Te Awa Makarara makes consideration of alternative minimum/residual flows and allocation regimes difficult. The hydrology of the lower river is affected by the presence of three dams and hydro-peaking discharges from the various powerhouses in the catchment. This issue is further complicated by the lack of hydrological monitoring in the lower catchment.

To assist in future assessments of water allocation management in the Teviot catchment, additional hydrological and ecological information is essential and would allow for a complete assessment of the ecological state of the lower Teviot River/Te Awa Makarara.

9. References

Ausseil, A.G., Newsome, P., Johnson, P. (2008) Wetland Mapping in the Otago Region. Landcare Research Contract Report prepared for the Otago Regional Council.

Dungey R (2023). Teviot Algae Monitoring, Report to Pioneer Energy Ltd. 2022-2023 Summer & summary of annual trends and consideration of flushing flows for several summers. Ross Dungey Consulting Ltd. May 2023.

Dunn, N.R.; Allibone, R.M.; Closs, G.P.; Crow, S.K.; David, B.O.; Goodman, J.M.; Griffiths, M.; Jack, D.C.; Ling, N.; Waters, J.M.; Rolfe, J.R. 2018: Conservation status of New Zealand freshwater fishes, 2017. *New Zealand Threat Classification Series 24*. Department of Conservation, Wellington. 11 p.

Friedel, M.J., Stewart, D., Lu, X., Stevenson, P., Manly, H., & Dyer, T. (2023). A simple stacked ensemble machine learning model to predict naturalised hydrology and allocation status across gauged catchments and ungauged reaches of Otago, New Zealand. Otago Regional Council, Dunedin. 61 p. plus appendices

Hamill KD. 2001. Toxicity in benthic freshwater cyanobacteria (blue-green algae): first observations in New Zealand. *New Zealand Journal of Marine and Freshwater Research* **35**: 1057−1059.

Hayes J., Booker, D., Singh, S. & Franklin P. (2021). Default Minimum Flow and Allocation Limits for Otago. Letter to J. Augspuger, Otago Regional Council dated 17 September 2021. Cawthron, Nelson. ID: 2157.

Hilsenhoff, W. L. (1977). Use of Arthropods to Evaluate Water Quality of Streams. Wis. Dep. Nat. Resour. Technical Bulletin, 100.

Hilsenhoff, W.L. (1987). An Improved Biotic Index of Organic Stream Pollution. *Great Lakes Entomologist*, **20**, 31-39.

Macara, GR (2015). The Climate and Weather of Otago. 2nd Edition. NIWA Science and Technology Series 67. 42 p.

Macara G, Woolley J-M, Zammit C, Pearce P, Stuart S, Wadhwa S, Sood A, Collins D (2019). Climate change projections for the Otago Region. NIWA Client Report 2019281WN. Prepared for Otago Regional Council. NIWA, Wellington. 136 p.

Otago Fish and Game Council (2015). Sports Fish & Game Management Plan for the Otago Fish and Game Region 2022-2032. Otago Fish and Game Council, Dunedin. 55 p. plus appendices.

Otago Regional Council (2004). Grow Otago. Climate and Soil Maps. Otago Regional Council, Dunedin. 4x CD-ROMs.

Ozanne, R,, Borges, H., & Levy, A. (2023). State and trends of river, lake, and groundwater quality in Otago – 2017-2022. Otago Regional Council, Dunedin. In preparation

Snelder TH, Biggs BJF. 2002. Multiscale River Environment Classification for Water Resources Management. Journal of the American Water Resources Association 38:1225-1239.

Stark, J.D. (1985). A macroinvertebrate community index of water quality for stony streams. *Water & Soil Miscellaneous Publication* 87. National Water and Soil Conservation Authority, Wellington, New Zealand), 53 p.

Stark JD, Maxted JR (2007). A user guide for the Macroinvertebrate Community Index. Prepared for the Ministry for the Environment. Cawthron Report No.1166. 58 p.

Turnbull, I.M. (compiler) 2000: Geology of the Wakatipu area: scale 1:250,000. Lower Hutt: Institute of Geological & Nuclear Sciences. Institute of Geological & Nuclear Sciences 1:250,000 geological map 18. 72 p. + 1 folded map

Unwin, M. (2016). Angler usage of New Zealand lake and river fisheries: Results from the 2014/15 National Angling Survey. NIWA Client Report 2016021CH, 59 p., plus appendices. Prepared for Fish & Game New Zealand.

Wagenhoff, A., Shearer, K., Clapcott, J. (2016). A review of benthic macroinvertebrate metrics for assessing stream ecosystem health. Prepared for Environment Southland. Cawthron Report No. 2852. 49 p. plus appendices.

Wood, S. A., Selwood, A. I., Rueckert, A., Holland, P. T., Milne, J. R., Smith, K. F., Smits, B., Watts, L., & Cary, C. S. (2007). First report of homoanatoxin-a and associated dog neurotoxicosis in New Zealand. Toxicon, (50), pp. 292–301.