Management Flows for Aquatic Ecosystems in the Pomahaka River

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Foreword

The future development and prosperity of Otago depends on water. However, much of Otago has long been recognised as a water-short area and consequently Otago is constantly at the forefront of water management in New Zealand. In many cases, irrigation particularly in these drier areas is critical to the continued well being of the people and communities who rely on the primary production it supports.

The Regional Policy Statement provides the overall framework for the future management of water in Otago. The Water Plan provides the direction for better utilisation and protection of water so that the values, opportunities and needs of Otago's communities can be reasonably met.

A key thrust of the Water Plan is its emphasis on the progressive implementation of minimum flow regimes for streams and rivers throughout the region. The goal of these minimum flows is to maintain the stream's aquatic ecosystem and natural character during periods of low flow. Furthermore, setting appropriate allocation limits and promoting water use efficiency are integral for ensuring reliable access to the water resource.

In Otago, surface water supplies are heavily allocated. Over-abstraction can result in degradation of a stream's natural values and character. Therefore, careful management is required to keep rates of taking sustainable. The best way forward is to use this valuable water resource to our advantage and to implement allocation limits and minimum flows so that over-abstraction does not occur.

The Pomahaka River has water available for primary allocation, is a regionally significant trout fishery in Otago and it also contains ten species of native fish. Currently, there are six water takes from the catchment that are used to irrigate approximately 120ha. Clearly there is a need to manage the stream for its natural values while allowing access to the water resource for the local community.

Executive summary

The purpose of this report was to investigate the flows required to maintain acceptable habitat for the fish species found in the Pomahaka River.

Low flow return periods such as the 7-day Mean Annual Low Flows (MALF) and 7-day 10 year low flow ($Q_7$10) have been calculated to give an indication of the low flows experienced by the catchment. Rainfall data has also been summarised to give an indication of annual rainfall and seasonal distributions.

Recreational and biodiversity information has been obtained from both Fish and Game Otago and the Department of Conservation. This information has been incorporated into this report along with fisheries and climate data collected by Otago Regional Council.

Instream habitat surveys were carried out in the Pomahaka River and flow requirements for all the resident species assessed by examining the relationships between flow and suitable habitat using instream habitat modelling. Habitat suitability was determined from general habitat suitability curves developed from studies in other rivers.

The Pomahaka River contains a regionally significant trout fishery and it also contains several species of native fish of conservation importance. The habitat information for the lower Pomahaka River showed that maximum habitat for adult brown trout was provided by a flow of 13m^3/s, and the amount of suitable adult trout habitat began to fall when flows fell below 7.5m^3/s. Maximum brown trout fry habitat was provided by a flow of 6m^3/s, with a reduction beginning when flows fell below 2.5 m^3/s. Yearling brown trout required slightly higher flows than fry, with maximum habitat at a flow of about 6.4m^3/s, and a reduction when flows fell below about 2.5m^3/s. Flow requirements of native fish were lower than those of trout, with a flow of 2.5m^3/s providing close to maximum habitat for upland bullies and galaxies species and a reduction in suitable habitat as flows fell below 1m^3/s.

The selection of an appropriate minimum flow depends on the fish species present and the flow management objectives that balance the degree of environmental protection against the value of water for other uses. This report focuses on the natural values of the Pomahaka River which have been taken from Schedule 1A of the Water Plan.

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1. Introduction

The Regional Plan: Water for Otago[1] 2004 (Water Plan) sets out as one of its objectives "to retain flows in rivers sufficient to maintain their life-supporting capacity for aquatic ecosystems and their natural character". As a means to achieve this objective the Water Plan provides for the setting of minimum flows in Otago rivers[2].

The purpose of this report is to provide information on the Pomahaka River that is relevant to determining the flows desirable for sustaining aquatic habitat. Hydrological data have been summarised and analysed to determine low flow return periods for the Pomahaka River. Rainfall data have been provided to show the variation in rainfall throughout the catchment. A brief overview of the topography, vegetation, land use and environmental concerns within the catchment has been provided along with a summary of the recreational and biodiversity values of the Pomahaka River. A physical habitat study (Instream Flow Incremental Methodology or IFIM) has also been carried out to determine the effects of low flows on the availability of habitat for both the native and introduced sports fish found within the catchment.

1.1 Focus of document

In order to manage a stream for aquatic ecosystems there needs to be a clear focus on what the management objective is. Schedule 1A of the Water Plan[3] identifies the ecosystem values that must be sustained, and a key value that requires sufficient flow is the regionally significant presence of trout. Other ecosystem values listed in Schedule 1A are expected to be sustained at flows provided to sustain brown trout (*Salmo trutta*). IFIM data have been discussed with a focus on the management objective and the natural low flow regime of the Pomahaka River. Flows to sustain these aquatic ecosystem values in both the upper and lower Pomahaka River have been suggested.

[1] Objective 6.3.1 of the Regional Plan: Water for Otago (2004), pg 55.
[2] Policies 6.4.1 – 6.4.11 of the Regional Plan: Water for Otago (2004), pp 58-69.
[3] Schedule 1A of the Regional Plan: Water for Otago (2004), pg 296.

2. The Pomahaka Catchment

The Pomahaka River Catchment is located in southwest Otago. The river is approximately 98 km in length and has a catchment area of approximately 2060 km^2. The Pomahaka Catchment is known to have relatively high, reliable rainfall. It flows from its headwaters in the Umbrella Range in a south-west direction to its junction with the Clutha River/Mata-Au near Clydevale (Figure 2.1). A small section of the Pomahaka Catchment, primarily the Kaiwera Stream is not contained within the Otago Region (Figure 2.1).

2.1 Vegetation

Snow tussock dominates the upper catchment with remnant pockets of beech forest. The mid and lower reaches of the catchment are dominated by pastoral grasses. There are also extensive areas of forestry within the catchment particularly around Dusky, Conical Hill and the Blue Mountains (Hayes & Young 1999).

2.2 Land use

Land use in the upper catchment of the Pomahaka is primarily extensive sheep and beef grazing. The mid and lower reaches of the catchment are dominated by high intensity farming, with smaller farms and higher stocking rates relative to the upper catchment. In recent years conversions to dairy farming have become increasingly common in the lower catchment. There are also extensive areas of production forestry within the catchment particularly around Dusky, Conical Hill and the Blue Mountains (Hayes & Young 1999).

2.3 Topography and soils

The upper Pomahaka Catchment is bounded by the Umbrella Mountains to the north, and the Blue Mountains to the east. Land to the south and west is generally rolling hinterland. Soils within the Pomahaka Catchment, particularly on the river flats and terraces are considered fertile. Yellow grey and yellow brown earths dominate the Pomahaka Catchment (Greenwood 1999).

2.4 Environmental concerns

Deteriorating water quality is a primary environmental concern in the Pomahaka River. This is reflected by increasing turbidity, nutrient concentrations and decreasing invertebrate community health with distance travelled from the headwaters (Young & Hayes 1999; Clutha Catchment Monitoring Report, 2000). Many tributaries of the Pomahaka River also have poor water quality, particularly the Heriot Burn, Crookston Burn and Wairuna (Clutha Catchment Monitoring Report, 2000). The poor water quality can be attributed to the intensive agriculture and the extensive tile drain network present in the Pomahaka Catchment (Young & Hayes 1999; Clutha Catchment Monitoring Report, 2000).

Water quality must be taken into account when considering minimum flow requirements for four main reasons.

(i) Dilution factor for pollutants entering the river will decrease as flow decreases, therefore increasing the severity of impacts on the receiving environment.

(ii) If water is available from the river for irrigation, there will be potential for further intensification of agriculture. The evidence already suggests that intensification in the catchment has already far surpassed environmentally sustainable levels (Young & Hayes 1999).

(iii) Any water taken from the catchment and used for irrigation will increase the amount of agricultural runoff entering the river. This issue is made even more pertinent by the presence of a vast tile-drain network.

(iv) In these circumstances water temperatures can be elevated and biofilms on stone surfaces can build up. While natural events occur, these can be exacerbated by significant water takes.

Otago Regional Council policy is to address water quality issues at source, including where possible addressing non-point source contamination, rather than simply providing sufficient flows to assimilate waste. Efficiency of water application will reduce wasteful practices that result in runoff. Water temperature is preferably addressed by provision of riparian vegetation. For these reasons, it is considered inappropriate to restrict consumptive use of water in order to achieve water quality outcomes. Water quality is not directly considered by this report, but by providing flows sufficient for aquatic ecosystem, there will be indirect benefit to the assimilation of some contamination.

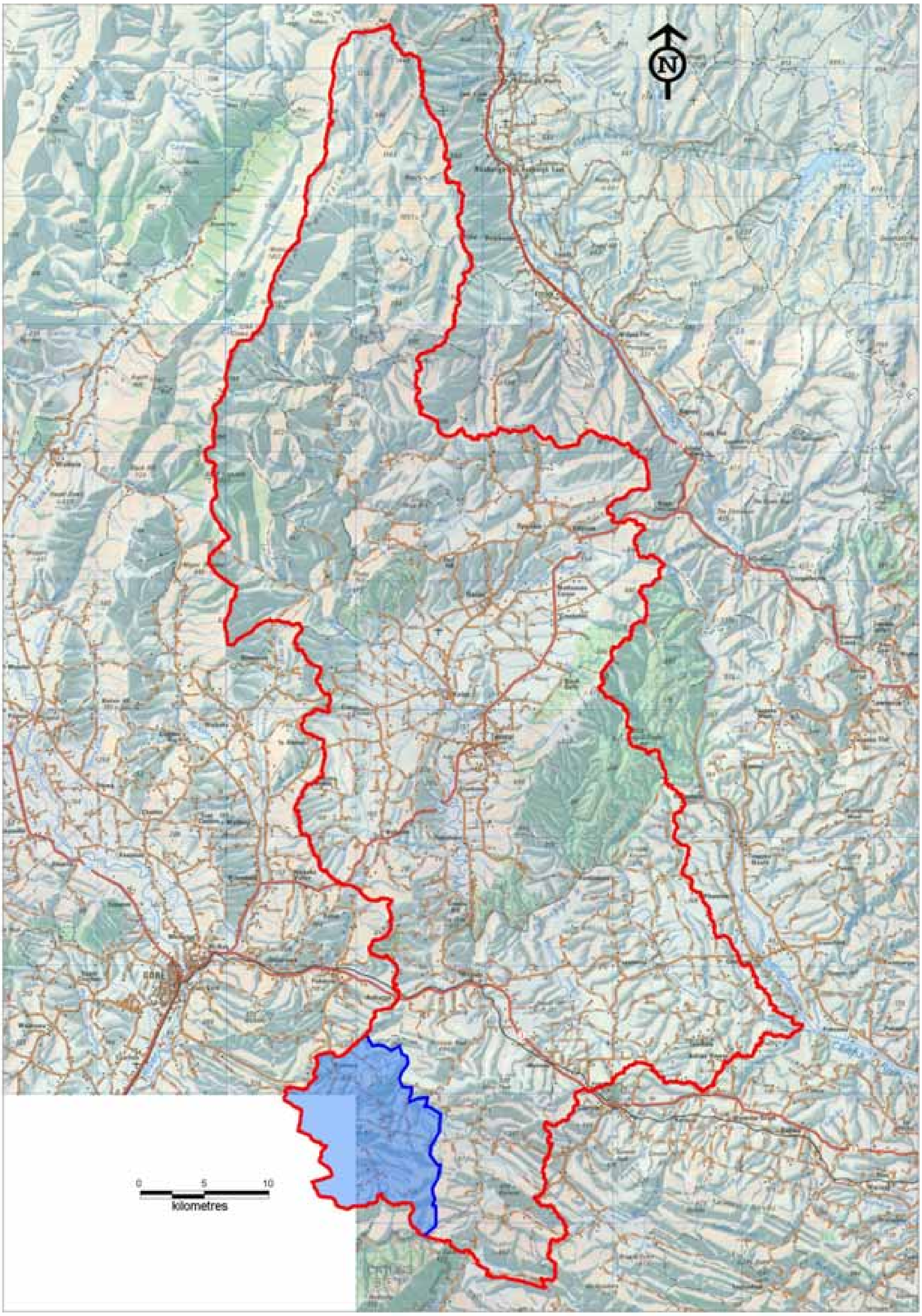

Figure 2.1. The Pomahaka Catchment, Otago, New Zealand and the section of the Pomahaka Catchment that is not within the Otago Region (shaded in blue)

2.5 Rainfall

The Pomahaka climate is considered mild, with consistent rainfall throughout the year. Annual rainfall for the catchment generally varies from around 700mm in the low altitude parts of the catchment to 1400mm in the Blue Mountains, Umbrella Mountains and the upper catchment of the Waipahi (ORC data). Rainfall intensities vary greatly throughout the catchment due to a combination of factors such as altitude, aspect and topography (Figure 2.2 & Figure 2.3).

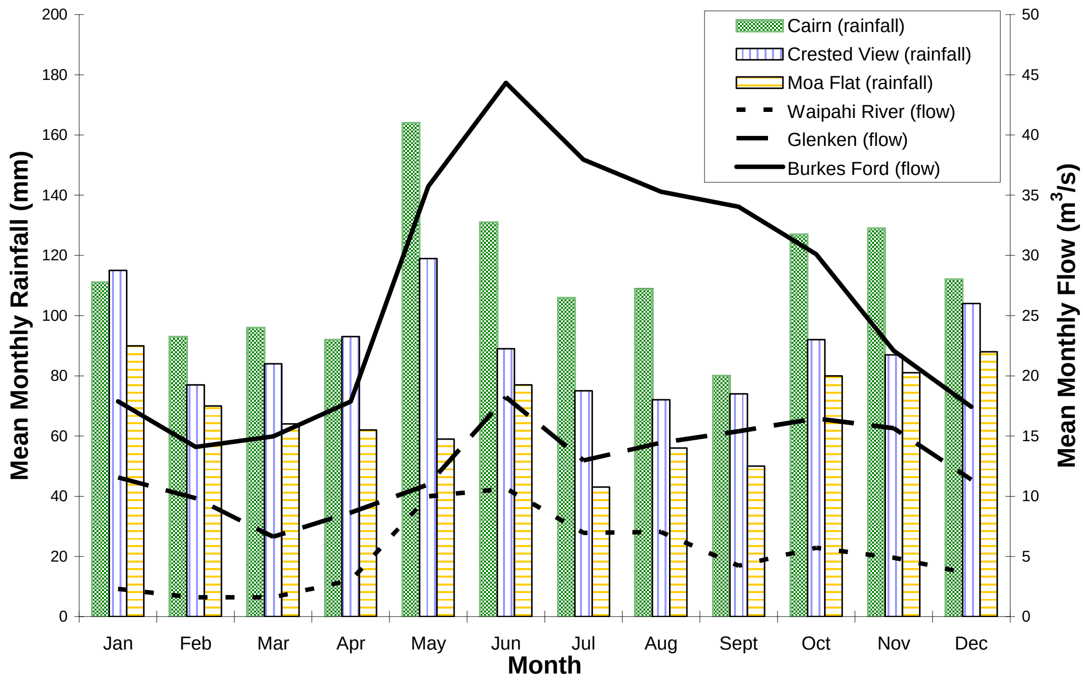

Figure 2.2. Mean monthly rainfall and flows for selected monitoring sites in the Pomahaka Catchment (refer to Figure 3)

2.6 Hydrology

The Pomahaka River is a major tributary of the Clutha catchment entering the true right bank of the Clutha River/Mata-Au between Clydevale and Balclutha. Three long-term continuous flow recorders are situated within the catchment, two on the Pomahaka main stem and a third on the Waipahi River (Figure 2.3).

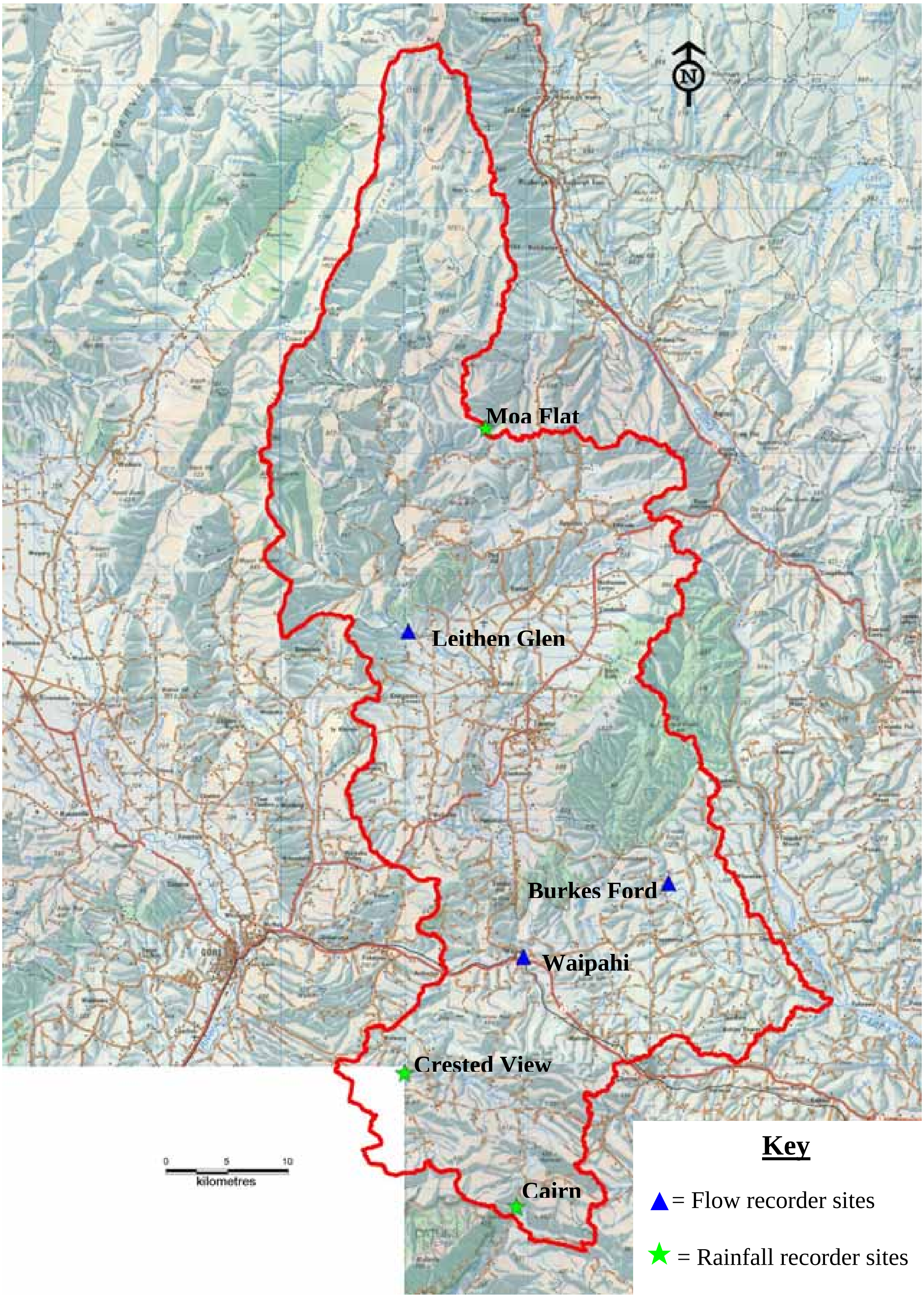

Figure 2.3. Flow and rainfall recorder sites within the Pomahaka Catchment

2.6.1 Annual Statistics

Information gathered from flow recorder sites in the upper Pomahaka (Leithen Glen, site no. 75234), lower Pomahaka (Burkes Ford, site no. 75232) and Waipahi (site no. 1075204) have been analysed to provide information about the long-term statistics of the stream flows within the catchment (Figure 2.3 & Table 2.1). It should be noted that at times of low flow, recorded flows can be skewed due to water abstraction, but due to the relatively low level of allocation of the Pomahaka River water resource, this is not considered a significant factor when analysing hydrological statistics for the Pomahaka Catchment.

Table 2.1 Summary of Annual Statistics of Pomahaka Catchment Flow Sites

Site	Location	Catchment area (km^2)	Term of record (yrs)	lowest recorded flow (m^3/s)	Mean recorded flow (m^3/s)	Max recorded flow (m^3/s)
Leithen Glen	Upper Pomahaka	711	12	0.83	12.7	479.4
Burkes Ford	Lower Pomahaka	1924	34	0.92	26.9	1157.3
Waipahi	Waipahi	300	8	0.17	5.0	379.9

The Lower Pomahaka at Burkes Ford and the Waipahi at Waipahi show the same trends in flow regime, with peak flows occurring in the period May-September (Figure 2.2). The Upper Pomahaka at Leithen Glen flows are slightly different to the other two sites in the catchment with consistently high flows over spring (Figure 2.2). This is due to the spring snowmelt, as the upper Pomahaka Catchment receives significant snowfall over the winter period. Comparing mean monthly flows to the mean monthly rainfall for the Pomahaka Catchment highlights the significant relationship of rainfall to the flows of the Pomahaka River (Figure 2.2).

2.6.2 Annual 7-days low flows and their frequency analyses

Mean annual 7-day low flows[4] (MALF or $Q_{7,m}$ in m^3/s) and the corresponding specific MALF[5] (SMALF or $SQ_{7,m}$ in litres/sec/km^2) have been provided in Table 2.2 at the three flow recorder sites in the Pomahaka Catchment.

[4] The mean of the lowest 7-day average flow for each hydrological year of record.
[5] Specific discharge from one unit catchment area at times of the 7-day mean annual low flow.

Table 2.2 Recorded low flows for three flow recorder sites in the Pomahaka catchment

Site	Location	Lowest recorded flow (m^3/s)	MALF (m^3/s)	Area (km^2)	SMALF ($l/s/ km^2$)
Waipahi	Major Tributary	0.17	0.6	300	1.98
Leithen Glen	Upper Pomahaka	0.83	2.2	711	3.08
Burkes Ford	Lower Pomahaka	0.920	4.3	1924	2.22

The specific MALF is higher for the upper Pomahaka at Leithen Glen (3.08), while it is lower for the Waipahi River (1.98) and lower Pomahaka River (2.22). The higher specific yield in the Upper Pomahaka Catchment is more than likely due to a combination of snow melt in spring, high water yielding snow tussock vegetation and topography. In order to gain some insight into the low flow regime of the Pomahaka River return periods of low flows have been calculated (Table 2.3).

Table 2.3. Low flows for selected return periods in the Pomahaka Catchment

Site	Lowest recorded flow (m^3/s)	MALF (m^3/s)	$Q_{7,5}$ (m^3/s)	$Q_{7,10}$ (m^3/s)	$Q_{7,20}$ (m^3/s)	$Q_{7,50}$ (m^3/s)	$Q_{7,100}$ (m^3/s)	Method used to determine frequencies
Waipahi	0.170	0.6	0.419	0.346	0.295	*	*	Normal Distribution, fitted to logged data
Leithen Glen	0.830	2.2	1.354	1.160	1.036	0.924	*	Gumbel Distribution, fitted to logged data
Burkes Ford	0.920	4.3	2.487	2.038	1.730	1.438	1.271	Normal Distribution, fitted to logged data

*Insufficient data to usefully extrapolate figures

Table 2.3 shows that the recorded minimum flows in the Pomahaka Catchment are all less than 20-yr 7-day low flows. In addition, the Leithen Glen recorded minimum flow is less than a 50-yr-7-day low flow, while the Burkes Ford site has recorded a low flow that is less than a 100-yr 7-day low flow (Table 2.3).

2.7 The Pomahaka's fish species

The Pomahaka River supports a diverse ecosystem, with 10 species of fish and one species of freshwater crayfish listed as being present in the catchment (NIWA freshwater database, Otago Fish and Game) (Figure 2.4 & Figure 2.5). There are three species of introduced sports fish recorded on the NIWA freshwater database as being found in the Pomahaka Catchment, however, information from Otago Fish and Game states that perch (*Perca fluviatilis*) are also found in the lower reaches. Brown trout (*Salmo trutta*) are the most common species of fish in the catchment (Figure 2.4), and are considered the ecosystem value requiring the greatest consideration in setting a flow regime. Seven of the 10 species listed by the NIWA fish database as being present in the Pomahaka Catchment are native (Figure 2.5).

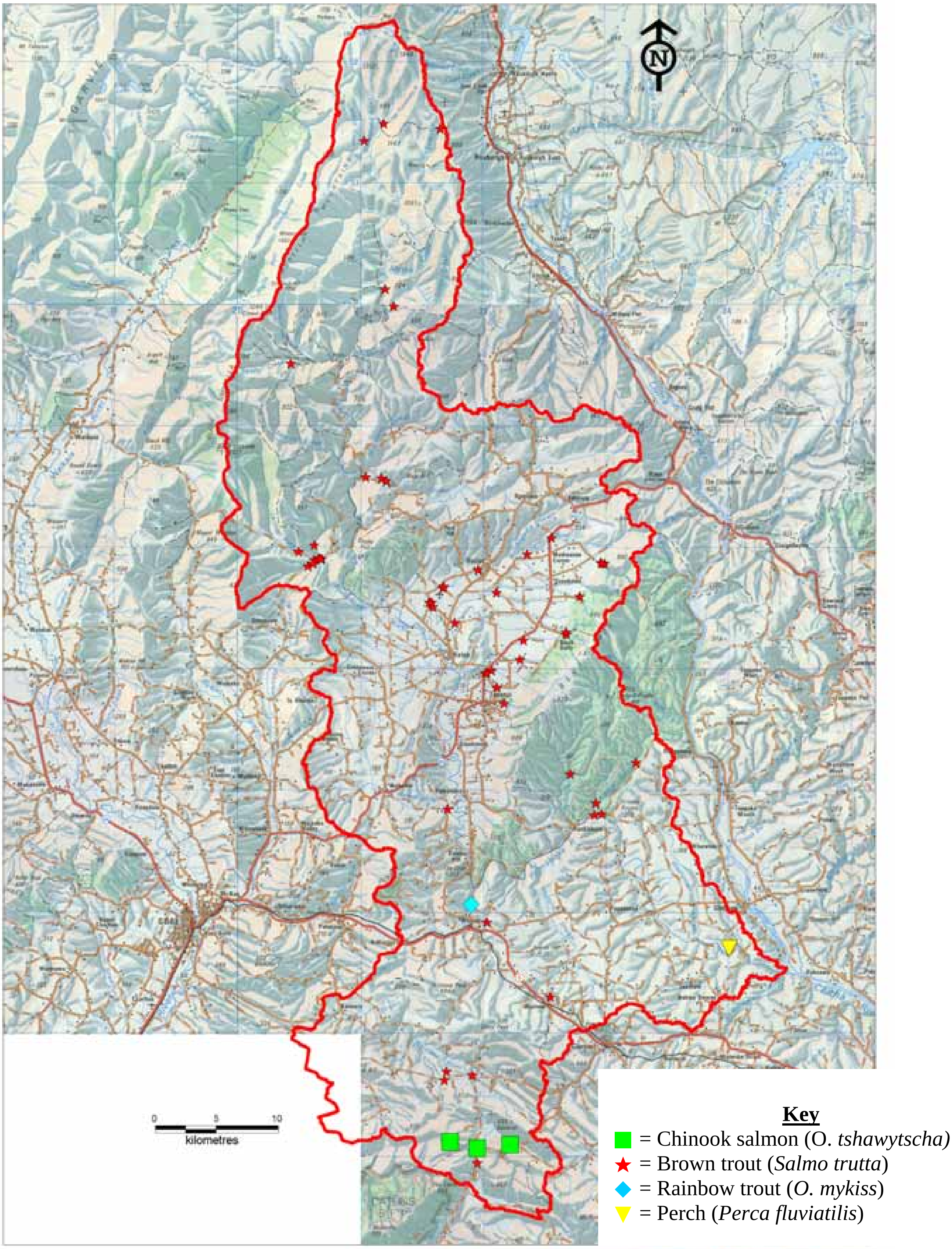

Figure 2.4. Sites where sports fish have been recorded in the Pomahaka Catchment. Data from the NIWA freshwater fish database and Otago Fish and Game

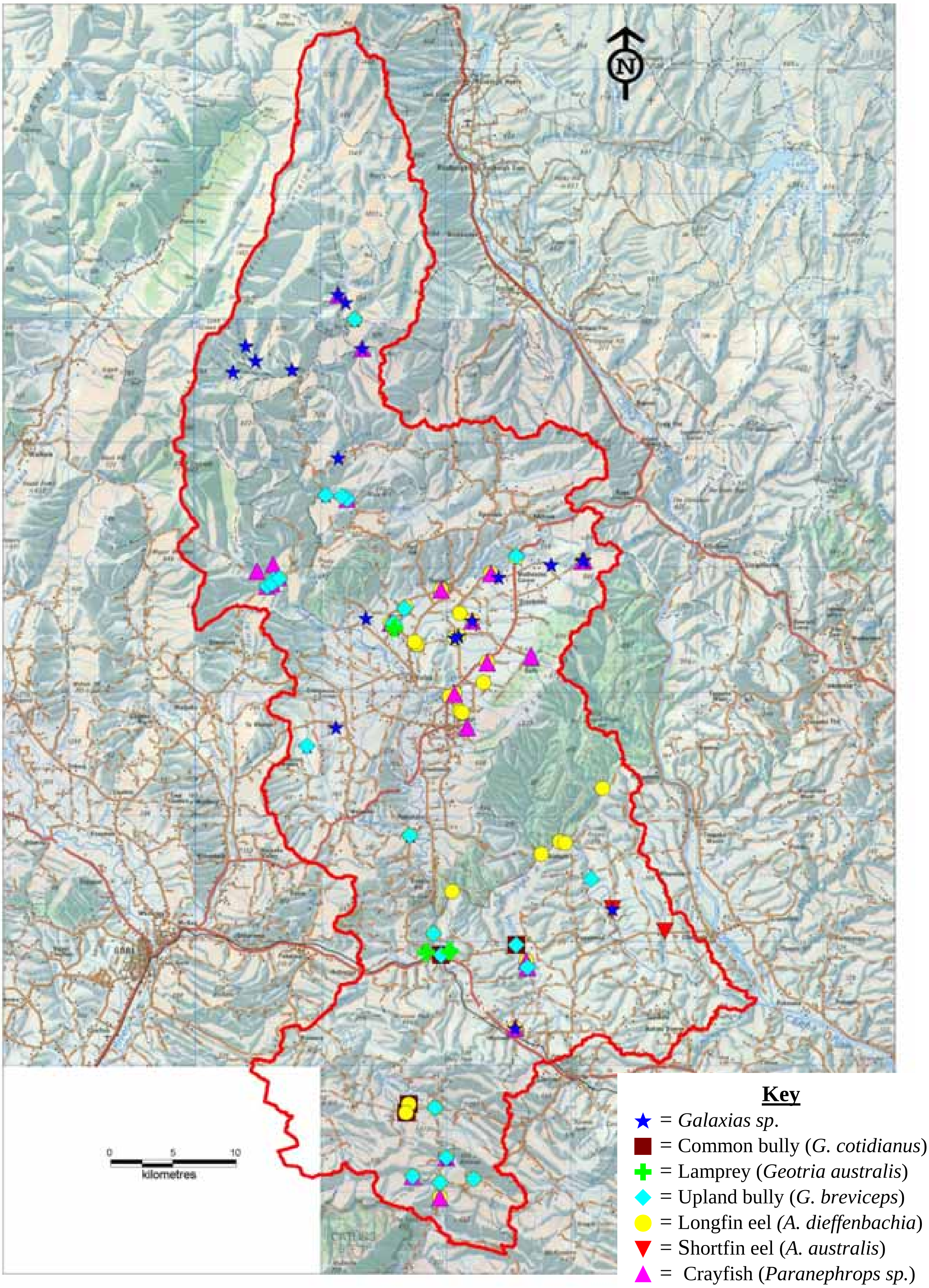

Figure 2.5. Sites where native fish have been recorded in the Pomahaka Catchment from the NIWA freshwater fish database

3. Recreational and biodiversity values

The Pomahaka River is one of the larger catchment tributaries of the Clutha River/Mata-Au, and has many recreational and biodiversity values that make it of interest to the community of Otago and Southland. Below is a summary of information available on the Pomahaka Catchment with information incorporated from agencies that have an interest in the flow regime of the Pomahaka River.

3.1 Recreational values

The most significant recreational pursuits carried out on the Pomahaka River are angling and game bird hunting and these are recognised in the Water Plan[6] with specific mention of trout spawning habitat, juvenile trout habitat, and the regionally significant presence of trout and game birds. It is noted that other pursuits such as kayaking and swimming also occur within the catchment.

3.1.1 Sports fish species and angling reaches

The Pomahaka River is a popular fishery with local and visiting anglers. Brown trout, rainbow trout, chinook salmon and perch are all found within the Pomahaka Catchment. An estimated 6873 angler days were spent on the Pomahaka in the 1995/96 season (Unwin & Brown, 1998), and more recently in 2001-02 the National Angler Survey (Unwin & Image, 2003) estimated 6004 angler days for the river.

From an angling perspective, the river can be divided into 3 broad reaches (Hollows 2004):

- Upper reaches from the headwaters to Leithen Glen flow recorder (Figure 2.3). Classic high country stream, with steep gorges, deep pools and clear, slightly tea-stained water. The headwaters can be considered a seasonal fishery, which is reliant on annual summer and autumn runs of migratory fish from the sea and Lower Clutha. Flows that physically allow fish passage are therefore crucial to maintain the fishery.
- Middle reaches from Leithen flow recorder to Burkes Ford flow recorder (Figure 2.3). Flowing predominantly through flat pasture lands with a gravel bed. Water is slightly more turbid than the upper reaches, but sight fishing is still possible.
- Lower reaches from Burkes Ford flow recorder to Clutha River/Mata-Au confluence (Figure 2.3). There is a mixture of gorges and flats and the water becomes more turbid making fish harder to spot.

3.1.2 Fish size

Average fish size is large in the headwaters (2-3kg) with trophy fish in excess of 4kg not uncommon. In the middle reaches fish of 1-2kg predominate while in the lower reaches greater numbers of fish in the 0.5-1.0 kg-size bracket can be expected. Returning chinook salmon average 2-6kg. Perch are relatively common downstream of Swans Bridge (Clinton – Clydevale Road) and average 0.5-1kg (Hollows 2004).

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[6] Schedule 1A of the Regional Plan: Water for Otago (2004), pg 296.

3.1.3 Game bird species and hunting

Game species present are mallard duck, grey duck, paradise shelduck, New Zealand shoveler, pukeko and to a lesser extent Canada geese (increasing in numbers though). Highest use by hunters on the Pomahaka River is from Tapanui downstream. Some maimais are present in the Kelso flats area with a few upstream of this (Hollows 2004).

Lower flows, particularly during the spring, may result in a decrease in breeding habitat for a majority of the above game species due to the loss of backwaters and shallow feeding margins. Low flows during the late summer can also reduce feeding habitat (shallow margins and back-waters) which are critical during the moult period (Hollows 2004).

3.2 Biodiversity values

The Water Plan[7] lists many natural values for the Pomahaka River, including high fish and invertebrate diversity, rare invertebrates, the significant presence of eels and it is free of pest aquatic weeds. Further information supplied from the Department of Conservation Southland is as follows:

- Ecosystems at risk from managed flow regimes are mostly in the context of more modified landscapes. In reaches between the Clutha/Mata-au junction and the junction with Leithen Burn upstream. There are many areas of lowland gently rolling land or plains. A few abandoned channels and side creek areas retain remnant flax and Carex sedge vegetation. While modified and little surveyed. Such places will be of regional significance in harbouring some indigenous flora and fauna mostly lost from lowland wetlands that once occurred more widely in the region.

- In the main stem of the Pomahaka River areas of native *millfoils myriophylum* species are susceptible to flow regime changes.

- Plant, invertebrate, fish and bird components of riverine ecosystems are affected by low flow accrual periods, especially where water flows remain low for more than a week during warm summer periods.

[7] Schedule 1A of the Regional Plan: Water for Otago (2004), pg 296.

4. Physical habitat survey

The Otago Regional Council contracted NIWA to carry out a study to determine the flows required to maintain acceptable habitat for the fish species present in the Pomahaka River.

The primary aims of the study were to:

- Conduct instream habitat surveys in critical reaches of the Pomahaka River.
- Conduct a hydraulic analysis in the above streams using RHYHABSIM (Jowett 1989) to determine how weighted usable area (WUA) for brown trout and native fish habitat varies with discharge.
- Assess flow requirements for the Pomahaka based on the habitat requirements of the native and introduced fish species.

4.1 Instream flow incremental methodology (IFIM) Summary

The instream flow incremental methodology (IFIM; Bovee 1982) is a holistic way to assess flow regimes by considering the effects of flow changes on instream values, such as river morphology, physical habitat, water temperature, water quality, and sediment processes. As the habitat methods used are based on quantitative biological principles, they are considered more reliable and defensible than assessments made in other ways (White 1976; Annear & Conder 1984; Dunbar et al. 1998; Tharme 1996; Annear et al. 2002). The IFIM strength lies in the ability to quantify the loss of habitat caused by changes in the natural flow regime, which helps the evaluation of alternative flow proposals (Jowett 2004).

Assessing suitable physical habitat for aquatic organisms that live in a river is the ecological aim of IFIM assessments. The consequences of loss of habitat are well documented; the environmental bottom line is that if there is no suitable habitat for a species it will cease to exist (Jowett 2004). Habitat methods allow for a more focused flow assessment and can potentially result in improved allocation of resources (Jowett 2004). However, it is essential to consider all aspects such as food, shelter, and living space and to select appropriate habitat suitability curves for an assessment to be credible (Orth 1987; Jowett 1995, Biggs 1996).

4.1.1 Habitat preferences and suitability curves

The IFIM requires detailed hydraulic data, as well as knowledge of the ecosystem and the physical requirements of stream biota. The basic premise of habitat methods is that if there is no suitable physical habitat for the given species, then they cannot exist. However, if there is physical habitat available for a given species, then that species may or may not be present in a survey reach, depending on other factors not directly related to flow, or to flow related factors that have operated in the past (e.g., floods). In other words, habitat methods can be used to set the outer envelope of suitable living conditions for the target biota (Jowett 2004).

Biological information is supplied in terms of habitat suitability curves for a particular species and life stage (Jowett 2004). A suitability value is a quantification of how well suited a given depth, velocity or substrate is for the particular species and life stage (Jowett 2004). The result of an instream habitat analysis is strongly influenced by the habitat criteria that are used. If these criteria specify deep water and high velocity requirements, maximum habitat will be provided by a relatively high flow. Conversely, if the habitat requirements specify shallow water and low velocities, maximum habitat will be provided by a relatively low flow and habitat will decrease as the flow increases. The suitability curves developed in New Zealand for large, feeding adult brown trout (Hayes & Jowett 1994) specify higher depth and velocities than curves for adult brown trout developed in the U.S. (Raleigh et al. 1986). Whether this is due to differences in the sizes of fish has not been clarified. However, it is clear that it is important to use suitability curves that are appropriate to the river and were developed for the same size and life stage of fish, and behaviour, as those to which they are applied.

The procedure in an instream habitat analysis is to select appropriate habitat suitability curves or criteria, and then to model the effects of a range of flows on the selected habitat variables in relation to these criteria. The area of suitable habitat, or weighted usable area (WUA), is calculated as a joint function of depth, velocity and substrate type for different flows. Instream habitat is expressed as the total area of suitable habitat (WUA (m^2/m). WUA (m^2/m) is the measure of the total area of suitable habitat per metre of stream.

Generally, native fish are found in similar habitats over a wide range of rivers. McDowall (1990) has described these habitats in descriptive terms. The quantitative approach taken in New Zealand has been to develop general habitat suitability criteria for species of interest by using data collected from several rivers. To date, general habitat suitability curves have been developed for several native fish species, some of it published (e.g., Jowett & Richardson 1995) and some of it unpublished.

4.2 IFIM for the upper Pomahaka River at Leithen Glen

The Upper Pomahaka flows from the Umbrella Mountains and is confined by a series of gorges. The upper Pomahaka River tends to contain bedrock riffles, while gravel and cobbles dominate the pools.

The habitat surveys of this reach were carried out at a flow of 4.5 m^3/s, with calibration measurements at 11.0m^3/s and 16.0m^3/s and at a flow of 3.35 m^3/s, with calibration at 3.6 m^3/s and 4.6 m^3/s. At the survey flow of 3.35-4.5 m^3/s, the average width of the river was 23.8 m, depth 0.49 m, and velocity 0.37 m/s. Substrate assessments at all sites were similar, with 29-31% bedrock and the remaining substrate a mixture of cobbles, gravels and fine gravel.

Maximum habitat for adult brown trout was provided by a flow of 8m^3/s, and the amount of suitable adult trout habitat began to fall when flows fall below 4 m^3/s (Figure 4.1). Maximum brown trout fry habitat was provided by a flow of 3.4 m^3/s, with a reduction beginning when flows fell below 1.0 m^3/s. Flow requirements of native fish were lower than those of trout, with a flow of close to 1.5 m^3/s providing maximum habitat for upland bullies and roundhead galaxias and a reduction in suitable habitat as flows fell below 0.5 m^3/s.

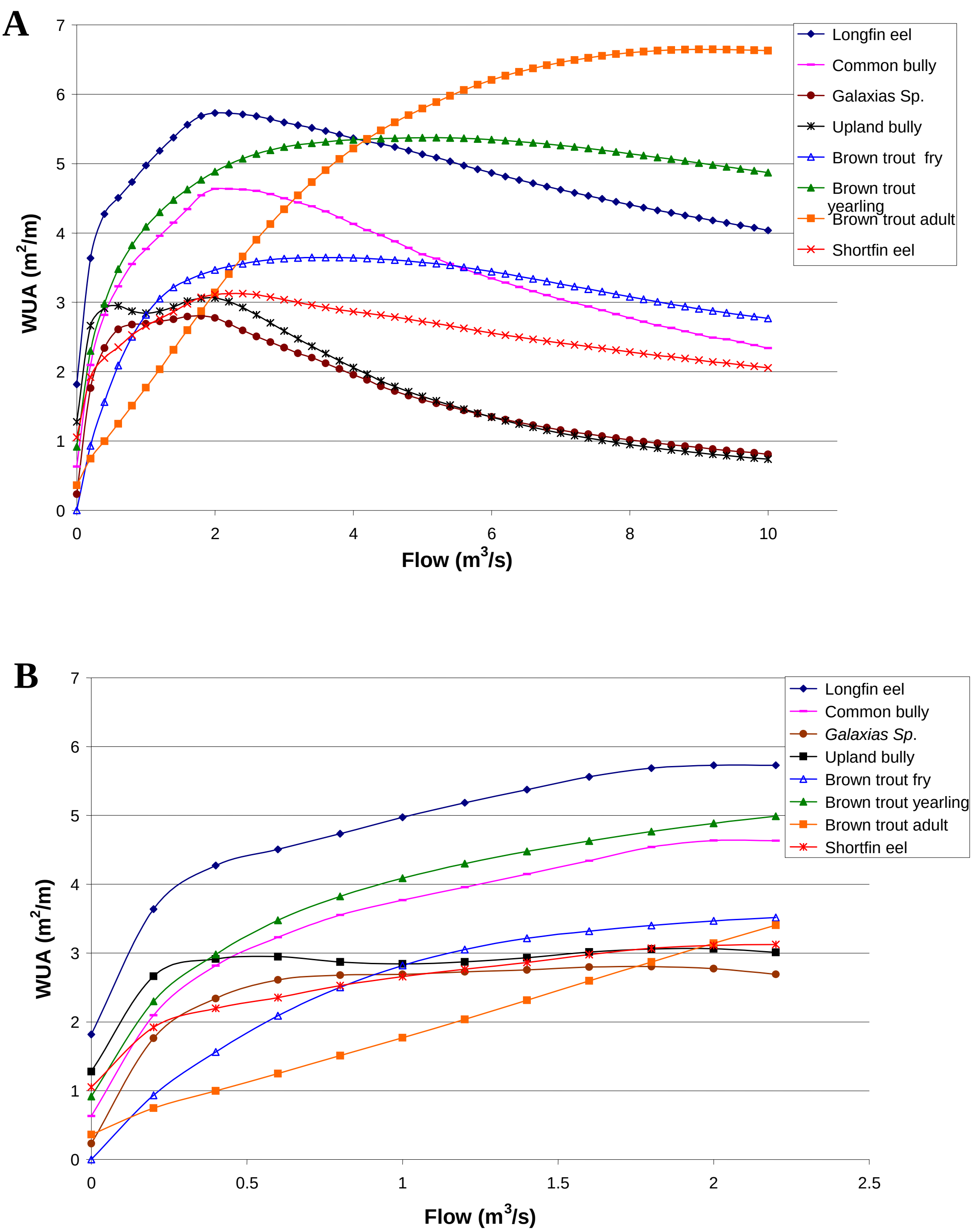


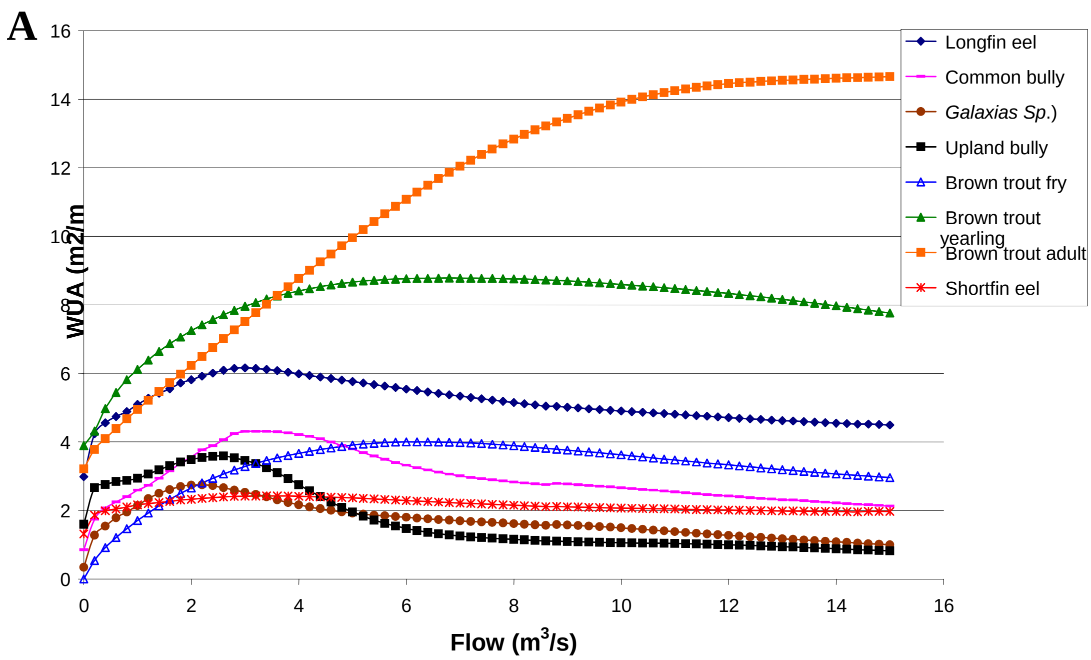
Figure 4.1. Variation of instream habitat at Leithen Glen with flows up to $10m^3/s$ (A) and at flows below 7-day MALF (B)

4.3 IFIM for the lower Pomahaka at Burkes Ford

The lower Pomahaka River flows through developed farmland across a bed of coarse gravel and large cobbles with the exception of the Rankleburn area, which is dominated by exposed bedrock. The lower Pomahaka follows the classic riffle, run, pool morphology.

The habitat surveys of this reach were carried out at a flow of 8.7 m^3/s, with calibration measurements at 12m^3/s and 62m^3/s. At the survey flow of 8.7m^3/s, the average width of the river was 36.5 m, depth 1.06 m, and velocity 0.28 m/s. As at Leithen Glen, substrate was dominated by bedrock (29%), with cobbles (25%) and gravels (19%) making up most of the remaining substrate.

Maximum habitat for adult brown trout was provided by a flow of 13m^3/s, and the amount of suitable adult trout habitat began to fall when flows fell below 7.5m^3/s (Figure 4.2). Maximum brown trout fry habitat was provided by a flow of 6 m^3/s, with a reduction beginning when flows fell below 2.5 m^3/s. Yearling brown trout required slightly higher flows than fry, with maximum habitat at a flow of about 6.4m^3/s, and a reduction when flows fell below about 2.5m^3/s. Flow requirements of native fish were lower than those of trout, with a flow of close to 2.5 m^3/s providing maximum habitat for upland bullies and galaxies species and a reduction in suitable habitat as flows fell below 1 m^3/s.



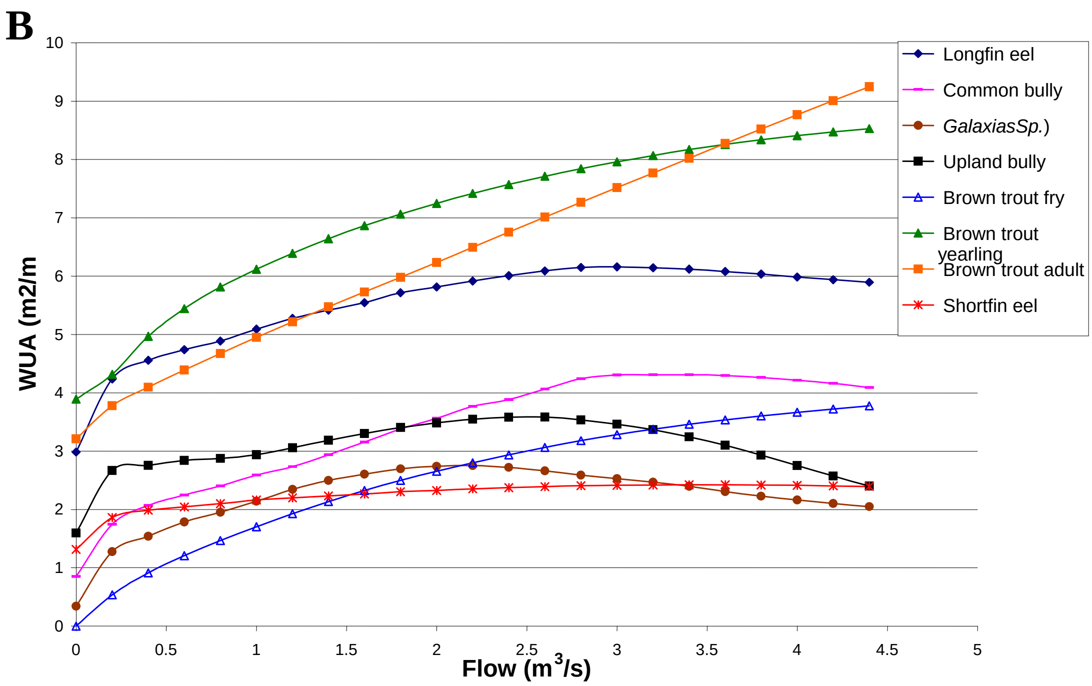


Figure 4.2. Variation of instream habitat at Burkes Ford with flows up to 15m^3/s (A) and at flows below the 7-day MALF (B)

4.4 Discussion – IFIM and Management objective

The IFIM data provides an overview of the flow requirements of different fish species to maintain their preferred habitat requirements (Table 4.1). Flow requirements can be selected so that they provide maximum habitat, or selected so that they prevent a serious decline in fish habitat (Table 4.1). The flow below which habitat declines significantly is known as the point of inflection. It is a point of diminishing return, where proportionately more habitat is lost with decreasing the flow than is gained with increasing the flow. Different size classes of fish and fish species have different points of inflection (Table 4.1). Ecologically the point of inflection represents the flow below which there is serious risk of losing sufficient habitat to maintain a size class or species of fish.

Clear management objectives for aquatic ecosystems are necessary when applying IFIM data (Hudson et, al. 2003; Jowett & Wilding 2003). The Pomahaka River is one of the most important brown trout fisheries in the Otago Region, with 6873 angler days in the 1995-96 season (Unwin & Brown 1998), and more recently in 2001-02 the National Angler Survey (Unwin & Image, 2003) estimated 6004 angler days for the river. Therefore the suggested management objective for the Pomahaka River is to maintain a regionally significant sports fishery, in accordance with Schedule 1A of the Water Plan[8], which includes a regionally significant presence of trout.

Table 4.1. Flow requirements for fish species at each IFIM site in the Pomahaka Catchment

Stream	Target fish species	Recorded 7-day mean annual low flow (m^3/s)	Optimum Flow (m^3/s)	Flow below which habitat declines sharply (m^3/s)
Pomahaka River (Leithen Glen)	Adult brown trout	2.2	8	4
	Yearling brown trout		4	1.5
	Brown trout fry		3.4	1.0
	Galaxias Sp.		1.6	0.5
	Upland bully		1.8	0.5
	Common bully		2.0	1.5
	Longfin eel		2.0	1.0
	Shortfin eel		2.2	0.5
Pomahaka River (Burkes Ford)	Adult brown trout	4.3	13	7.5
	Yearling brown trout		6.4	2.5
	Brown trout fry		6	2.5
	Galaxias Sp.		2.2	1.0
	Upland bully		2.6	-
	Common bully		3	2.0
	Longfin eel		3	1.5
	Shortfin eel		3	0.5

Table 4.1 illustrates that adult brown trout have the greatest flow requirement, overall.

[8] Schedule 1A of the Regional Plan: Water for Otago (2004), pg 296.

5. Flow requirements: discussion and suggested management flows for aquatic habitat

Under the Water Plan[9], Otago Rivers will have minimum flows set to provide for the maintenance of aquatic ecosystems and natural character under low flow conditions. Under the Water Plan[10] when minimum flow levels are reached all consents that are subject to that minimum flow are to cease taking.

5.1 Pomahaka River flows discussion based on technical information

The Pomahaka Catchment covers an extensive area, therefore rainfall can contribute to stream flows in specific areas of the catchment and not others (Figure 2.1). The Pomahaka at Burkes Ford flow recorder has several significant tributaries upstream of it (e.g. Waipahi River and Wairuna Stream) that drain the southern corner of the Pomahaka Catchment and these tributaries all enter below the Leithen Glen flow site (Figure 2.3). This southern corner of the Pomahaka Catchment is particularly susceptible to south-west weather patterns, hence flows from streams in this area can be high when the upper Pomahaka is unaffected. At times, because of its higher topography the Upper Pomahaka can receive rain and snow when the rest of the catchment does not. Therefore, it is recommended that there be two minimum flow sites on the Pomahaka River to recognise the different hydrology patterns of the upper and lower river - one at Leithen Glen in the upper catchment, the other at Burkes Ford in the lower catchment (Figure 2.3). Takes above both sites would be subject to both of the downstream minimum flows. This would mean that if flows at the Burkes Ford site were lower than the minimum flow all takes including those above Leithen Glen would cease taking, even if the Leithen Glen site was above its nominated minimum flow. This recognises that the upper Pomahaka River can contribute a significant amount of water to that which is recorded at Burkes Ford at times of low flow, while also acknowledging that the lower Pomahaka can be high when the Upper Pomahaka is not.

The flows required to maintain introduced sports fish such as trout are generally much greater than those required by native fish. Often optimum flow range is far greater than the flows required to simply maintain habitat for a particular size class or fish species (Table 4.1). IFIM data are available for both the upper (Leithen Glen) and lower (Burkes Ford) Pomahaka River. At the Leithen Glen site, habitat of adult brown trout decreases significantly below 4m^3/s, with 8m^3/s providing optimum habitat (Jowett & Wilding 2003). However, on examining the flow statistics for the Pomahaka River at Leithen Glen it can be seen that the recorded 7-day MALF is 2.2m^3/s. Hence, the Pomahaka at Leithen Glen naturally falls below both the optimum flow and the flow below which habitat decreases significantly for adult brown trout on a regular basis (Table 4.1).

Habitat of adult brown trout decreases significantly below 7.5m^3/s with optimum habitat provided by a flow of 13 m^3/s in the Pomahaka River at Burkes Ford (Jowett & Wilding 2003). The Pomahaka River at Burkes Ford has a recorded 7-day MALF of 4.3m^3/s. Therefore, the Pomahaka River at Burkes Ford naturally falls below both the optimum flow and the point of inflection for adult brown trout annually (Table 4.1).

[9] Policy 6.4.3 of the Regional Plan: Water for Otago (2004), pg 61
[10] Policy 6.4.11 of the Regional Plan: Water for Otago (2004), pg 69

It is of note that under these naturally occurring conditions the Pomahaka trout fishery has been sustained at its popular and regionally significant level. Low flows with return periods in excess of one in 20 years have occurred in the catchment with no significant effects reported for the adult trout fishery (Table 2.3). More recently low flows associated with the 1999 drought were not recorded as an issue for the Pomahaka trout fishery (ORC 2000). This suggests that low flow duration may be more critical than the fact that the 7-day MALF is lower than the point of inflection indicated by the IFIM for both the Leithen Glen and Burkes Ford sites.

Flow duration curves for the Pomahaka River at Leithen Glen and Burkes Ford have been provided to show the percentage of time recorded flows exceed both the point of inflection and the flow that provides optimum habitat for adult brown trout as indicated by the IFIM data (Figure 5.1 & Figure 5.2).

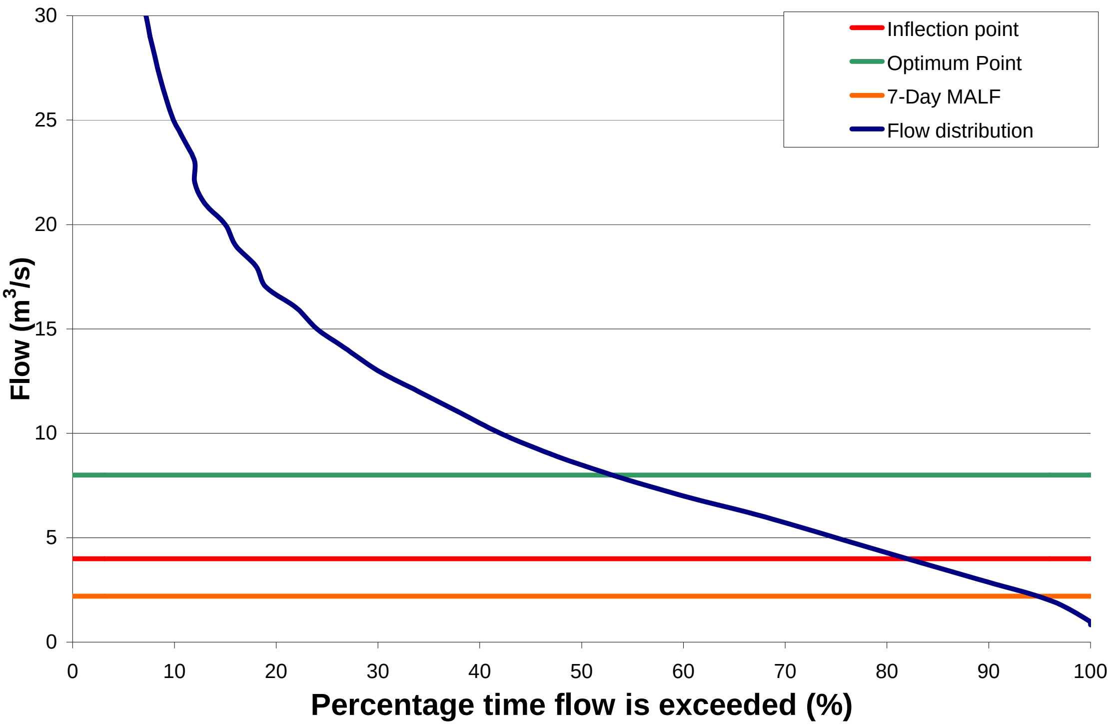


Figure 5.1. Pomahaka River at Leithen Glen flow duration curve with both the optimum flow for adult brown trout habitat and the point of inflection indicated by IFIM

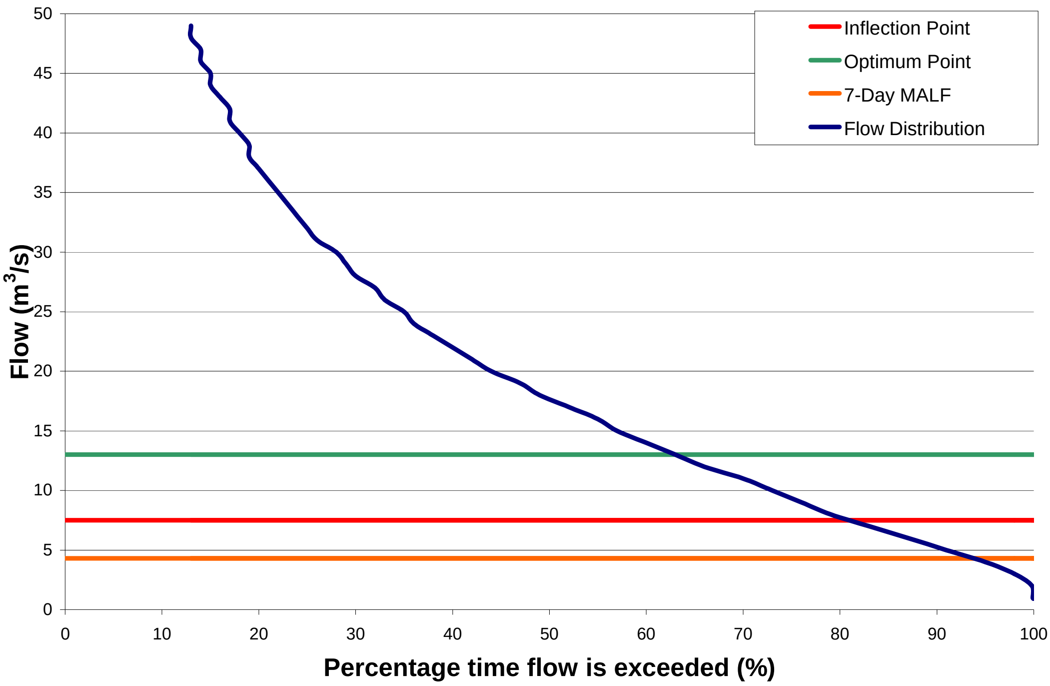


Figure 5.2. Pomahaka River at Burkes Ford flow duration curve with both the optimum flow for adult brown trout habitat and the point of inflection indicated by IFIM

It can be seen that flows recorded on the Pomahaka River exceed the point of inflection 82% of the time at Leithen Glen and 83% of the time at Burkes Ford (Figure 5.1 & Figure 5.2). Flows that provide optimum habitat for adult brown trout are exceeded 53% of the time at Leithen Glen and 63% of the time at Burkes Ford (Figure 5.1 & Figure 5.2). Clearly flows are favourable for adult brown trout in the Pomahaka River for a large proportion of the time.

The 7-day MALF is a hydrological statistic commonly used as a default minimum flow as it represents average annual low flow conditions. Where the point of inflection indicated by IFIM is significantly higher than the 7-day MALF for the target species (as is the case for both Pomahaka IFIM sites) using the 7-day MALF as a minimum flow has some rationale.

However, it is of interest to compare the loss of habitat relative to decrease in flow. At the 7-day MALF of 2.2m^3/s at Leithen Glen there is 3.4 m^2/m of WUA available for adult brown trout (Figure 4.1). If flows were dropped by a quarter to 1.65m^3/s then the available habitat would drop to 2.6 m^2/m of WUA, or 76% of what is available at the 7-day MALF (Figure 4.1). For the Burkes Ford IFIM site there is 9 m^2/m of WUA available for adult brown trout at the 7-day MALF of 4.3m^3/s (Figure 4.2). If flows were dropped by a quarter to 3.2m^3/s then the available habitat would drop to 7.8 m^2/m of WUA, or 87% of what is available at the 7-day MALF (Figure 4.2).

Issues that arise when setting minimum flows revolve around the impact on instream ecology caused by extreme low flows, low flow duration and flow variability (Fisher et, al. 1982; Jowett, 1990; Jowett 1992; Peterson and Stevenson 1992; Dent & Grim 1999; Suren et, al. 2003a; Suren et, al. 2003b). Long duration low flows with little flow variability can promote excessive periphyton growth, lower invertebrate diversity and contribute to increased water temperatures which may impact on fisheries (Jowett, 1990; Jowett 1992; Suren et, al. 2003a; Suren et, al. 2003b).

A key concern with setting a minimum flow is that flow variability is maintained. However, when considering flow variability the amount of water allocated is as important as the actual minimum flow set. That is, if the amount of water allocated is large relative to the natural flow of the stream a large portion of the stream flow variability can be removed.

1999 was considered a dry year for Otago and is often referred to as the 99 drought. To investigate the impacts on flow variability in the Pomahaka due to abstraction the recorded flows for a dry irrigation season (Oct 98 –Apr 99) in the Pomahaka River were analysed. The primary allocation for the catchment was defined as 50% MALF (Water Plan[11]), so it was possible to simulate the effect on flow variability if all primary allocation was removed in a dry irrigation season (Figure 5.3 & Figure 5.4).

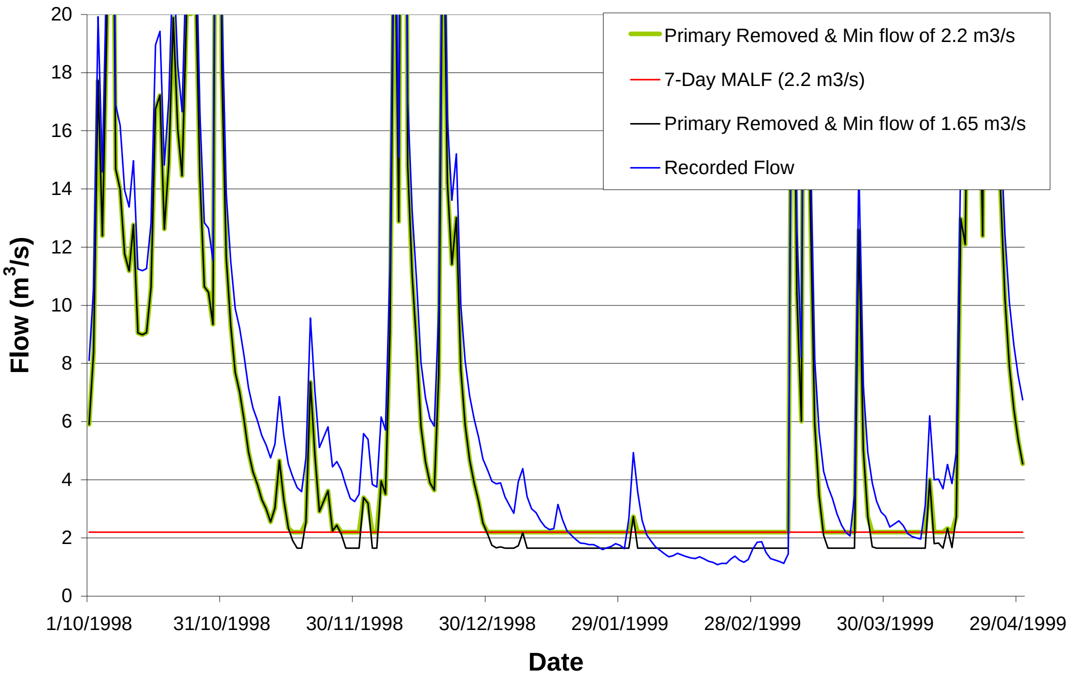


Figure 5.3. Recorded Flows on the Pomahaka River at Leithen Glen (Oct 98 – Apr 99). Also shown is the effect of removing all available primary allocation for the Pomahaka Catchment (2.2 m^3/s) if minimum flows were 2.2 m^3/s and 1.65 m^3/s respectively. The 7-day MALF is also indicated

[11] Policy 6.4.2 (b) of the Regional Plan: Water for Otago (2004), pg 59

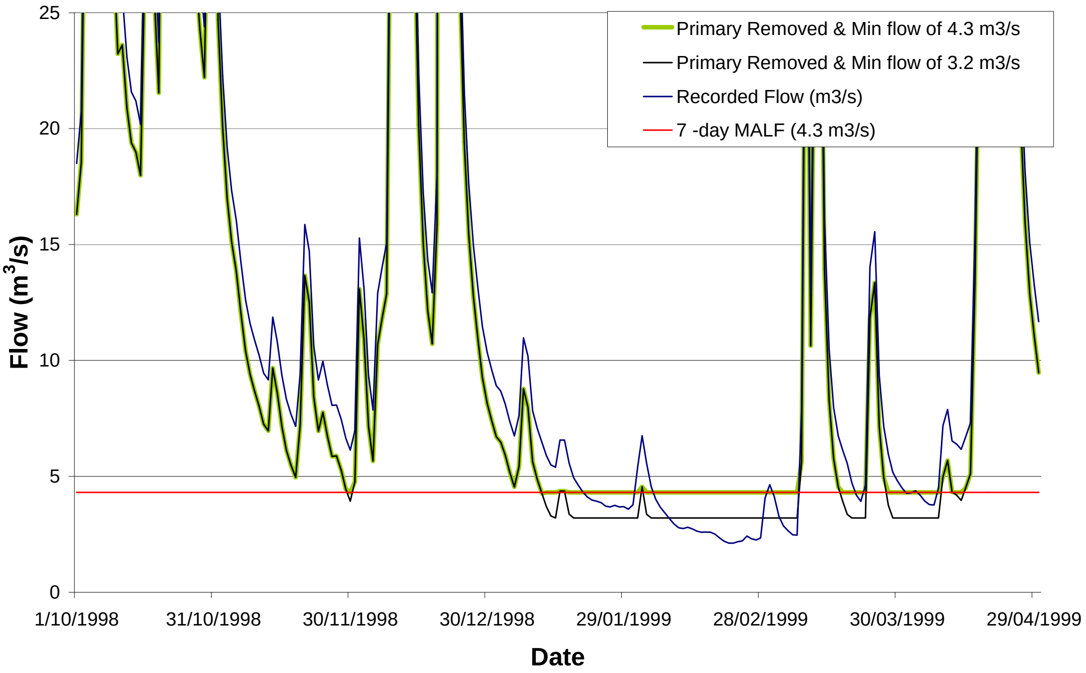


Figure 5.4. Recorded Flows on the Pomahaka River at Burkes Ford (Oct 98 – Apr 99). Also shown is the effect of removing all available primary allocation for the Pomahaka Catchment (2.2 m^3/s) if minimum flows were 4.2 m^3/s and 3.2 m^3/s respectively. The 7-day MALF is also indicated

It can be seen that the Pomahaka fell well below its 7-day MALF in 1999 at both Burkes Ford and Leithen Glen (Figure 5.3 & Figure 5.4). Furthermore, recorded flow would have fallen below minimum flows of 2.2m^3/s and 1.65 m^3/s at Leithen Glen and 4.3 m^3/s and 3.2 m^3/s at Burkes Ford with or without abstraction in the catchment (Figure 5.3 & Figure 5.4). No negative impacts on the trout fishery were reported as a result of the low flows in 1999 (ORC 2000). It would appear that an allocation limit of 50% MALF does not significantly alter the flow variability of the Pomahaka River in a dry year (Figure 5.3 & Figure 5.4).

It should also be noted that the simulated flows in Figure 5.3 are a worst case scenario as it is unlikely that all primary allocation for the Pomahaka Catchment will be abstracted from above the Leithen Glen flow recorder site.

5.2 Suggested management flows for aquatic ecosystems

Flows that represent the point of inflection as indicated by the IFIM at Leithen Glen and Burkes Ford for adult brown trout are higher than the recorded 7-day MALF at both sites. However, it has been shown that recorded flows at both Leithen Glen and Burkes Ford exceed the point of inflection indicated by IFIM most of the time (Figure 5.1 and Figure 5.2). It is also acknowledged that low flows have occurred in the past with no reported impact on the Pomahaka trout fishery (ORC 2000). This suggests factors such as low flow duration and flow variability may be the key to maintaining the Pomahaka trout fishery (Fisher et, al. 1982; Jowett, 1990; Jowett 1992; Peterson and Stevenson 1992; Dent & Grim 1999; Suren et, al. 2003a; Suren et, al. 2003b).

An assessment of flow variability for a period of low flow has been provided. This shows that during a dry season the hydrology of the Pomahaka Catchment provides significant flow variation most of the time (Figure 5.3 & Figure 5.4).

There is clear seasonal variation in flows in the Pomahaka River, with high flows occurring from May through September and lower flows typically occurring from October through to April (Figure 2.2). Although flows do tend to be high in October at Burkes Ford they are generally beginning to recede again after peaking in September. Flows at Leithen Glen tend to peak in October and November however by this time the majority of flows recorded at Burkes Ford are being supplied by the Upper Pomahaka Catchment above Leithen Glen. This highlights the point (Section 5.1) that the Upper Pomahaka at Leithen Glen can be recording its highest flows (October – November) while the Lower Pomahaka at Burkes Ford is not (Figure 2.2). Therefore seasonal minimum flows for the Pomahaka Catchment have been considered below.

By implementing higher minimum flows during the period when there is naturally high flows in the river from (from May to September inclusive) seasonal flow variation is provided for. Furthermore, just as low flow duration may restrict a fishery, the period of time that flows are near optimum may be significant also. The high flow period is the time of year when Pomahaka River flows are likely to be in the flow range that provides optimum trout habitat as indicated by the IFIM and, as a result, may be critical in sustaining the adult brown trout fishery (Figure 5.1 and Figure 5.2). Brown trout migration and spawning also tends to occurs over the winter period particularly when flows are naturally higher and allow for upstream migration.

Flows of **8.0m^3/s** at Leithen Glen and **13.0m^3/s** at Burkes Ford are suggested to ensure the sustainability of adult brown trout in the Pomahaka River during the high flow period May to September inclusive. Flows of **2.2m^3/s** at Leithen Glen and **4.3m^3/s** at Burkes Ford are suggested to ensure the sustainability of adult brown trout in the Pomahaka River during the lower flow period from October to April inclusive, and it is suggested that flows should not be allowed to drop below those flows due to consumptive use.

The low flow period minimum flows are well below the point of inflection indicated by the IFIM survey for adult brown trout (Table 4.1), but as flows of **2.2m^3/s** and **4.3m^3/s** represent the 7-day MALF, this is the average low flow that the Pomahaka River reaches annually. This is consistent with the findings of Jowett (1990, 1992) that the percentage of adult trout habitat at the 7-day MALF acts as a bottleneck to trout density. Hence, there would be limited benefit in setting a minimum flow to support the brown trout fishery higher than those suggested as ultimately the natural low flows experienced by the Pomahaka River during low flow periods are restricting adult trout habitat.

The high flow period (from May to September inclusive) minimum flows represent the flows that provide optimum adult trout habitat indicated by the IFIM survey (Table 4.1). Flows of **8.0m^3/s** at Leithen Glen and **13.0m^3/s** at Burkes Ford are well below the mean flows recorded at each site on the Pomahaka River on average for the period from May to September inclusive (Figure 2.2).

The minimum flows of **2.2m^3/s** at Leithen Glen and **4.3m^3/s** at Burkes Ford (October – April incl.) and **8.0m^3/s** at Leithen Glen and **13.0m^3/s** at Burkes Ford (from May to

September inclusive) would also provide for the native fish and waterfowl found within the Pomahaka Catchment.

Consideration was given to the imposition of a recovery flow for the river, which would be imposed on resource consents so that taking could not resume until after the river flows have recovered once a breach of the minimum flow has occurred. This provision is a strong encouragement for irrigators to ration co-operatively to prevent the minimum flow being breached. When setting a recovery flow, the period for setting it needs to be considered. Ecologically, the low flow period is a time when there is high stress is on the aquatic ecosystem and therefore any form of abstraction can exacerbate this stress. Typically, during periods of low flow, demand for water for out of stream use is also at its highest. Therefore, recovery flows have only been considered for the low flow period from October to April inclusive.

If minimum flows of **$2.2m^3/s$** at Leithen Glen and **$4.3m^3/s$** at Burkes Ford (from October to April inclusive) were set it would not be considered necessary for the Pomahaka Catchment to impose a recovery flow. This is because **$2.2m^3/s$** at Leithen Glen and **$4.3m^3/s$** at Burkes Ford represent the 7-day MALF (the natural average low flow for the catchment) and the amount of taking occurring under primary allocation is small in relation to the MALF.

If, however, the minimum flows for the Pomahaka River were set lower than MALF for the low flow period (from October to April inclusive) then there would be reasonable justification to impose a recovery flow to discourage minimum flow breaches due to consumptive use. An appropriate recovery flow would be the 7-day MALF.

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8. Glossary of terms

7-Day MALF	The mean of the lowest 7-day average flow for each hydrological year of record (MALF).
$Q_7$10	The 7-day low flow with the likelihood of occurring once in a 10 year period.
Pool	Aquatic habitat characterised by slow flowing, deep water with an unbroken surface.
Return Period	Sometimes called the recurrence interval. Return period is the means of expressing the statistical likelihood of a low or flood flow occurring.
Riffle	Aquatic habitat characterised by shallow, stony, fast flowing (where the surface of the water is broken) conditions, favoured by most aquatic invertebrates.
Run	Aquatic habitat characterised by obvious flow, but without the rapid, broken surface conditions of a riffle.
SMALF	Specific discharge from one unit catchment area at times of the 7-day mean annual low flow (MALF).
Weighted Usable Area (WUA)	WUA (m^2/m) is the measure of the total area of suitable habitat per metre of stream.