Waimakariri land and water solutions programme

Hydrology Current State Report

Report No. R16/68
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Environment Canterbury
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Kaunihera Taiao ki Waitaha

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Summary

Background

The Waimakariri Water Zone Committee and the local community are working with Environment Canterbury and Waimakariri District Council to improve water quality and quantity outcomes for the Waimakariri Canterbury Water Management Strategy (CWMS) Zone. The Waimakariri Water Zone Committee will ultimately make recommendations, via the Zone Implementation Programme addendum, for on the ground actions and amendments to Canterbury Land and Water Regional Plan (LWRP).

The Waimakariri Zone surface hydrology is characterised by:

- The large alpine Waimakariri River along its southern boundary,
- The hill-fed Ashley River/Rakahuri and its tributaries and estuary,
- The Ashley-Waimakariri Plain and associated groundwater zones (Ashley, Eyre, Cust),
- The Loburn fan, *and*
- A network of spring fed streams and lagoons near the coast.

Much of the land to the east of Rangiora where these spring-fed streams are located is reclaimed swamp, which is still subject to poor drainage, occasional flooding and an extensive land drainage network.

The Waimakariri River is not within the Waimakariri Zone; rather, it is in the Alpine Rivers Zone, which will be assessed later.

This report seeks to provide an understanding of the hydrological character of the current environment and factors that affect the Waimakariri Zone.

What we did

To form an understanding of the current state hydrology and to confirm trends occurring within the zone, we collected all relevant data from the Waimakariri Zone including climate, hydrology, water use data, and historical information about the region. All information stated in this report is based on the current state at the time of writing this report (2016).

We also reviewed the surface water monitoring network within the Waimakariri Zone (flow monitoring and gauging sites, and rainfall monitoring sites). We used data from these sites to develop statistics and identify changes over time in the flow and rainfall data.

What we found

Climate

The Canterbury Plains are prone to extended dry periods with high evapotranspiration, especially during north-westerly winds. Irrigation demand is high in the summer months when evapotranspiration is well above the average rainfall and there is a large soil moisture deficit.

Flow in the rivers and streams fluctuate with the seasons. In spring, snow melt increases flows in the alpine and foothill-fed rivers. There is little rainfall in summer, resulting in lower flows, with some river reaches going dry. In winter, the Waimakariri Zone receives higher rainfall on the plains, which supplies higher flows to the lowland rivers and recharges aquifers.

Hydrology

We noted two distinct changes over the extended period of analysis for the Waimakariri Zone (1972-2016):

- Base flow has increased in lowland streams since the construction/implementation of the Waimakariri Irrigation Ltd (WIL) scheme (2000).

- Base flows have reduced in the Ashley River/Rakahuri since 2001, as measured at the Gorge recorder above the plains.

There is a complex pattern of flow loss and gain across the plains of the Waimakariri Zone east of the foothills, where the watercourses overlie highly permeable alluvial gravels. Rivers and streams that flow through this part of the zone experience flow losses as they leave the hill catchments; these losses then recharge the groundwater system and resurface as stream flow in the lowland areas of the Waimakariri Zone. The extent of flow absence in some watercourses is a function of both inflows and as a result of lower groundwater levels, in particular around Rangiora.

Water use

Water allocation in the Waimakariri Zone is governed by two plans; the Land and Water Regional Plan (LWRP) and the Waimakariri River Regional Plan (WRRP). For each of these plans, two key aspects apply to the surface water allocation regime: minimum flow and allocation limits. The minimum flow is the flow in the watercourse that determines when water abstraction must cease, and the allocation limit is either the maximum instantaneous rate of take or the total volume of water that can be abstracted in a water year.

Recreation

We identified ‘opportunity windows’ for instream recreational activities (e.g. kayaking) through a desktop literature review of required flows for those activities.

What does it mean

The current state hydrology of the Waimakariri Zone is complex, with multiple influences and values. This information will inform the Waimakariri Water Zone Committee’s decisions relating to the water quality and quantity as part of the land and water solutions programme.

Glossary

Term	Meaning
Accrual period	The time amassed between hydrological events
Aquifer	An underground layer of permeable rock which holds groundwater
Ephemeral	A watercourse which only flows for limited periods of time, usually during heavy rainfall or snowmelt
Estuarine	Where fresh water from rivers and streams mix with the saline ocean water
Evapotranspiration	The loss of water to the atmosphere from soil and vegetation.
FAO56	A form of evapotranspiration calculation which uses sunshine, temperature, humidity and wind speed to calculate the evapotranspiration rates
FDC	Flow duration curve
FRE3	A hydrological measure of stream health based on the occurrence of a flow greater than three times the median
Foehn winds	A warm dry westerly wind developed in the lee of the Southern Alps.
Hydroperiod	The seasonal pattern of the water level that results from the combination of the water budget and the storage capacity of the wetland.
Isohyd	Lines joining areas of equal water yield
Lacustrine	Standing waterbodies classified as or associated with lakes
LWRP	Land and Water Regional Plan
MALF7d	Mean Annual Low Flow calculated with a 7 day moving mean
Mean	A measure of average determined by summing the values and then dividing by the number of values
Median	A measure of average determined as the middle value
MF	Minimum flow
NIWA	National Institute of Water and Atmospheric Research
Orographic effects	The resulting effects of mountains, especially in regards to their position and form.
Palustrine	Inland waterbodies which lack flowing water
Percentile (Q5, Q25, Q50, Q75, Q95)	A measure used in statistics indicating the value below which a given percentage of observations in a group of observations fall. For example, the 20^{th} percentile (Q20) is the value below which 20 % of the observations may be found.
Riverine	Surface water bodies connected or related to rivers
RMA	Resource Management Act
Soil moisture balance	The balance between evapotranspiration and surface water which determines soil moisture
Stage	The water level measured above some point from which flow can be determined based on river bed surveys
Stationarity	A time series is stationary if its statistical properties (e.g. mean, standard deviation) are constant over time
Surficial lithology	The definition of rock units for use in in mapping
SWAP	Surface water abstraction point
SWAZ	Surface water allocation zone

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1 Introduction

1.1 The plan change for the Waimakariri Zone

The Waimakariri land and water solutions programme is led by the Waimakariri Water Zone Committee and it aims to examine how land and water is managed in the Waimakariri Zone. The Waimakariri Water Zone Committee is a joint committee of the Waimakariri District Council and Environment Canterbury that includes representatives of the local community and Te Ngāi Tūāhuriri Rūnanga. The output from the Waimakariri land and water solutions programme is an addendum to the Zone Implementation Programme that makes recommendations towards actions on the ground and changes to the Canterbury Land and Water Regional Plan (LWRP, **Map 1**). This requires Environment Canterbury, the Waimakariri Water Zone Committee and other stakeholders to have a robust understanding of the character of the current environment, its values, issues, pressures and opportunities, and what values and outcomes are desired for the future of the area.

This report defines the current state of the surface water hydrology of the Waimakariri Zone.

1.2 Current planning framework of the zone

Two regional planning documents are currently active within the Waimakariri Zone: the *Waimakariri River Regional Plan, incorporating Plan Change 1 (2011)* and the *Land and Water Regional Plan (2015)*. These plans apply to specific parts of the zone (**Map 2**) and do not overlap.

Our report defines the current state of surface water hydrology across the entire zone, regardless of the applicable plan.

1.3 The role of surface hydrology

Hydrology is the study of water in all its phases and locations - commonly referred to as the hydrological cycle. Specifically in the context of this plan change, surface hydrology refers to the surface water found within the zone’s flowing watercourses, standing waterbodies and wetlands.

An understanding of surface hydrology is critical as it explains a great deal about contributions to aquifers, the likely ecology of habitats, the quality of groundwater and surface water, the nature of human-uses of water and the extent of likely effects resulting from these uses.

Much of the information we have presented herein is used across the other study areas for the sub-regional process such as hydrogeology, ecology and water quality.

1.4 This report

This report defines the key characteristics of the zone's surface water hydrology, establishing information that is used in the preparation of current state reports for other disciplines, and in the subsequent scenario and solutions work. We have presented the information across the following sections:

Section 2 Context provides additional context to the report and the information presented, in particular the elements which impact the character of the area's hydrology

Section 3 Monitoring network details the monitoring network present in the area

Section 4 Climate details the climate of the area

Section 5 Watercourses details the flows in the main watercourses

Section 6 Watercourses losses and gains details the pattern of losses and gains evident in the main watercourses as they flow across the plains

Section 7 Standing waterbodies/wetlands details the standing waterbodies and wetlands

Section 8 Surface water allocation regime details the current allocation regime for abstractions from surface waters

Section 9 Reliability of supply details the reliability of water supply

Section 10 Water use provides an inventory of the water use in the area

Section 11 Recreation discusses recreational matters

Section 12 Conclusion concludes the work

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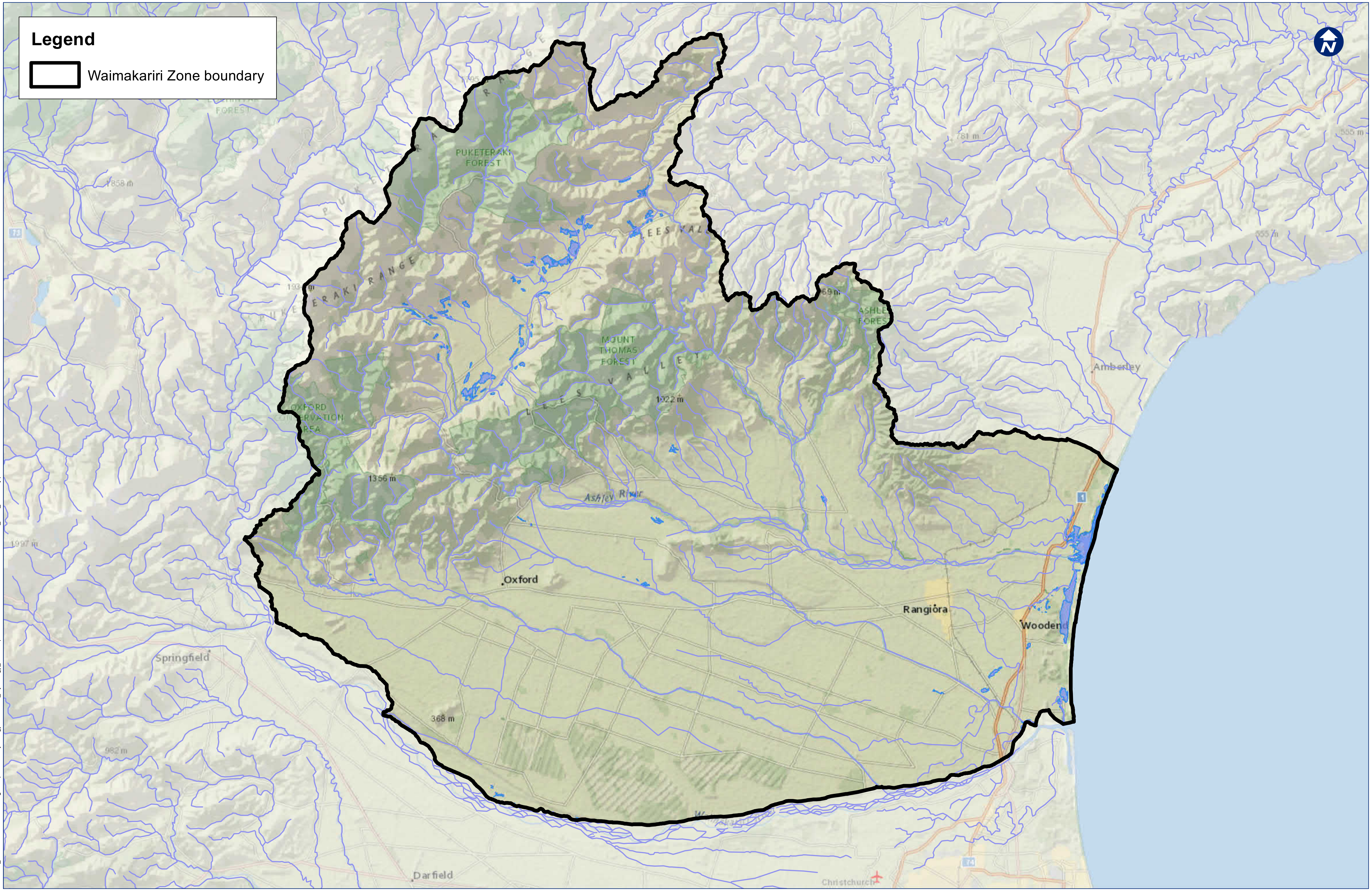

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Map features depicted in terms of NZTM projection.

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Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **Waimakariri Zone boundary**

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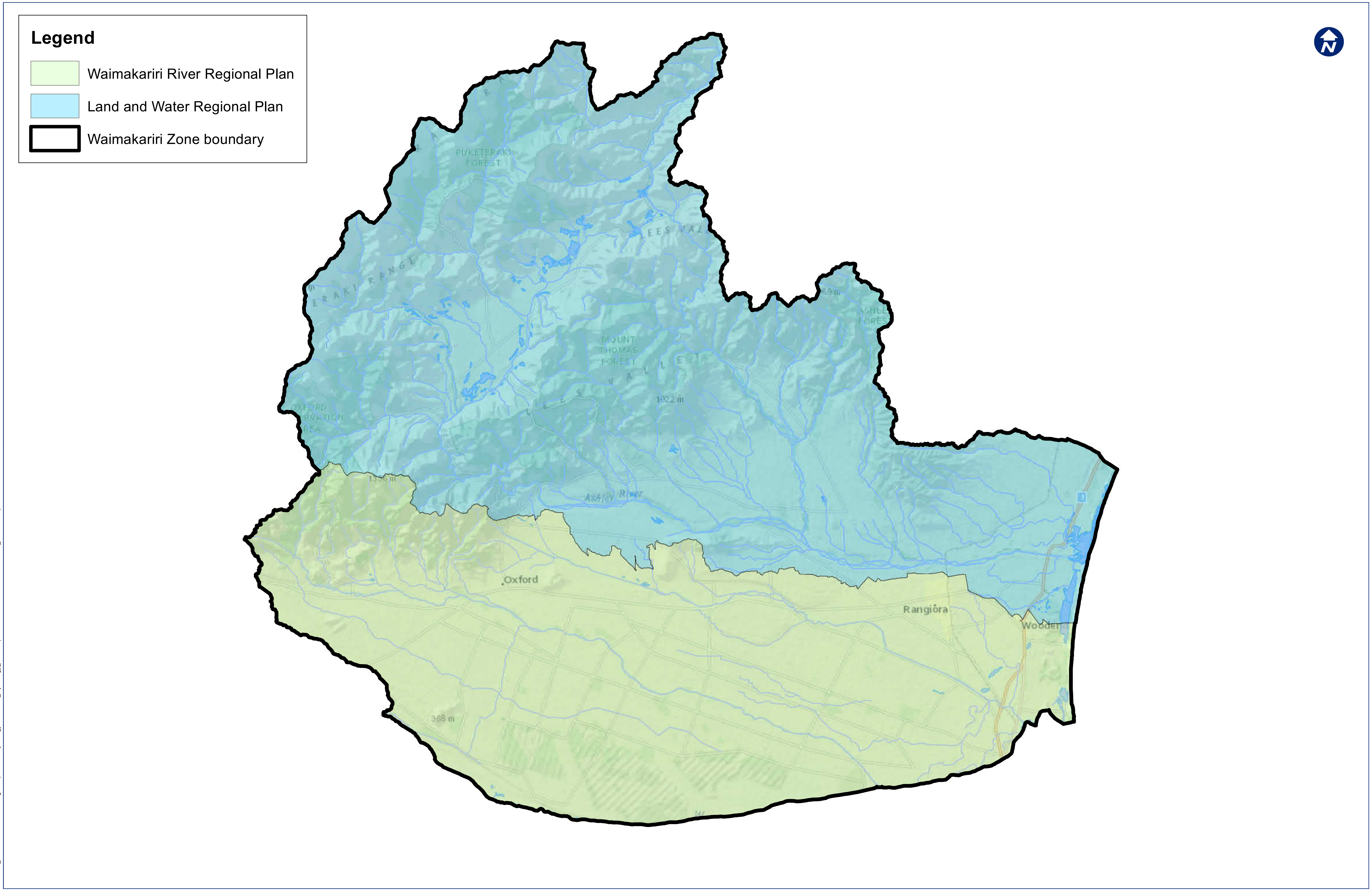

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Map features depicted in terms of NZTM projection.

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Waimakariri land and water solutions programme

Project: Current State Reporting - Hydrology

Title: Plan boundaries

Scale: 1:250,000 (A3 size)

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Status: Final

Map No. Map 02

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2 Context

2.1 General description

The Waimakariri Zone (**Map 1**) extends across the Ashley-Waimakariri Plain, north of the Waimakariri River to just south of the Kowai River. The zone includes the foothills which drain onto the Plains, including the Lees Valley.

The Waimakariri River is not within the Waimakariri Zone, as it is to be included in a separate LWRP Alpine Rivers chapter, with science and planning work not scheduled to commence until after the completion of the Waimakariri land and water solutions programme. Despite its exclusion from the Waimakariri land and water solutions programme boundaries, the river is relevant to this work as a major source of water to consumptive users in the zone. It also provides a small amount of groundwater recharge in the eastern-most part of the zone and hence we provide relevant information on it where appropriate.

The Waimakariri Zone surface hydrology is characterised by the large alpine Waimakariri River along its southern boundary, the hill-fed Ashley River/Rakahuri and its tributaries and estuary, the Ashley-Waimakariri Plain and associated ground water zones (Ashley, Eyre, Cust), the Loburn fan, and a network of spring fed streams and lagoons near the coast. Much of the land to the east of Rangiora, where these spring-fed streams are located is reclaimed swamp, which is still subject to poor drainage, occasional flooding and an extensive land drainage network.

The north-western portion of the zone is hill and high country. These hills, including Mt Oxford, Mt Richardson, and Mt Thomas dominate the zone's western landscape (Canterbury Water, 2012).

2.2 Conceptual zone hydrology

The surface water hydrology of the Waimakariri Zone is complex, however we have simplified it into its main elements and the connections between these elements (**Figure 1**). This shows how changes to water quantity and quality in any element influence subsequent elements. An understanding of this flow-on effect is critical to the decision making process for the zone.

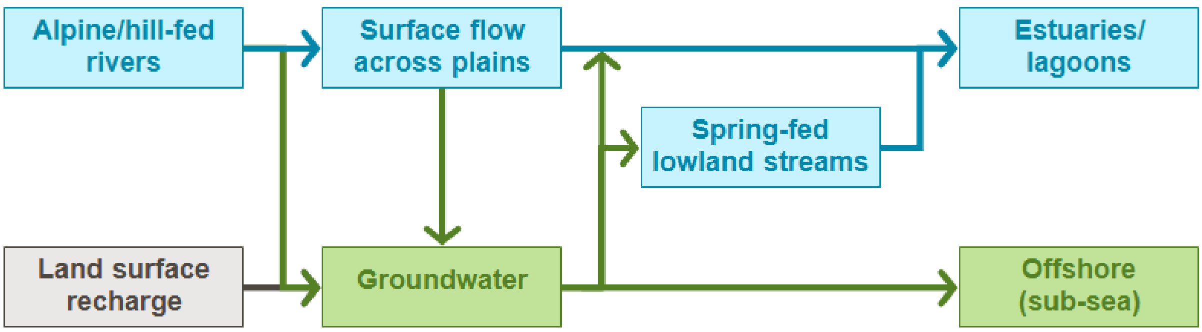


Figure 1 - Conceptual zone hydrology

This conceptualisation is dominated by the larger watercourses (Waimakariri River and Ashley River/Rakahuri). The majority of their flow comes from high elevation catchments, and in the case of the Waimakariri River, the Main Divide. This water flows out of the hills, across the plains and out to sea, via river mouths.

As these larger watercourses exit the hills and flow on to the plains they also lose flow to ground, which recharges the aquifers beneath the plains. The smaller hill-fed rivers such as the Cust, Eyre and Okuku Rivers also recharge the aquifers, although the water they contribute is less than that of the two larger rivers. The water contained in the aquifers flows slowly towards the coast, and may return to the surface via springs or continue offshore.

Groundwater returns to the surface via springs supplies the lowland streams around Rangiora and Kaiapoi. Some of this water also enters the larger watercourses, which gain flow along their lower reaches.

The final element of this system is land surface recharge to groundwater. Naturally this occurs via rainfall directly on the plains, but recharge also occurs from the application of irrigation water and leakage from irrigation and stockwater infrastructure.

Connected to these systems, to a greater or lesser degree, are the standing waterbodies/wetlands of the zone. Wetlands, swamps, marshes, lagoons and man-made ponds generally have a delicate water balance and changes to any elements of the zone hydrology that are linked to such features will affect those water bodies.

2.3 Summary of existing work

An extensive and varied body of scientific investigation has been developed for the Waimakariri Zone. In the 1980s Cowie and Bowden led water resource assessments at the North Canterbury Catchment Board/Regional Water Board for the Waimakariri and Ashley catchments respectively.

Since then there has been a persistent interest in the water resource offered by these catchments, and its potential uses, whether recreational, cultural, social or consumptive.

To address the myriad of ongoing and conflicting potential uses of the water resource, permanent and temporary monitoring sites have been established for rainfall and flow, and these data, along with other data sets and analysis, have been used to develop an understanding of the zone's hydrology. The key pieces in this body of work are listed below, and it is these references upon which we rely for this current work. We provide a full reference list at the end of this document.

1. Bowden MJ, *et al*. (1982) The Water Resources of the Ashley Catchment. The North Canterbury Catchment Board and Regional Water Board.
2. Cowie B, *et al*. (1986) Waimakariri River and Catchment Resource Survey. The North Canterbury Catchment Board and Regional Water Board.
3. Mosley M (2001) Ashley River: Flow Management Regime. Report No. U01/14. Environment Canterbury
4. Glennie J (2004) Planning report on the review of the statutory minimum flows and water allocation for the Ashley River/Rakahuri and its lower tributaries. Report U04/31. Environment Canterbury.
5. Dodson M *et al* (2012) Ashley-Waimakariri groundwater resources investigation. Report No. R12/69. Environment Canterbury
6. Smith J (2012) Surface water balance components of the Ashley-Waimakariri plans. Report No. R12/58. Environment Canterbury
7. Smith J (2015) Waimakariri Catchment Resource and Technical Information. Water Resource Science Ltd

2.4 Surficial lithology

For the zone's hydrology the surficial lithology (**Map 3**) is important because it affects the rate at which water is lost (or gained) from a watercourse. This is particularly important when interpreting the results from monitoring stations which record flow in watercourses.

The hill catchments of the zone, including that of the Waimakariri River, Ashley River/Rakahuri and Okuku River have very little in the way of flow loss to groundwater. However, once flow leaves the hill catchments and crosses onto the alluvial gravels that make up the Ashley-Waimakariri Plains, significant flow losses can occur.

The losses experienced in the Lees Valley in the upper Ashley catchment, and the wider upper valley of the Waimakariri River, are returned to the river channel due to the presence of gorges downstream of these valleys. The flow in these two rivers is monitored within the gorges (Ashley at Gorge and Waimakariri at Otarama). Although this initial loss/storage affects the character of flow, it does not change the overall volume significantly.

Surficial lithology and soil classification are also important in determining preferential flow paths for groundwater. In the lowland areas around Rangiora and Kaiapoi such flow paths have been detected (Dodson, 2013). These generally follow paleo channels of the larger rivers.

The Silverstream/Kaiapoi River flows in a paleo channel formed prior to 1868 by the Waimakariri River (**Figure 2**). This paleo channel creates an area of increased conductivity that links the Waimakariri River and Silverstream. This connection was confirmed by comparing flow data and well depth between the well M35/0658 and the Waimakariri River (Sanders, 2000) and Silverstream (Dodson, 2013). Consequently, Silverstream receives some recharge from the Waimakariri River, whereas other nearby streams are recharged solely by land surface recharge.

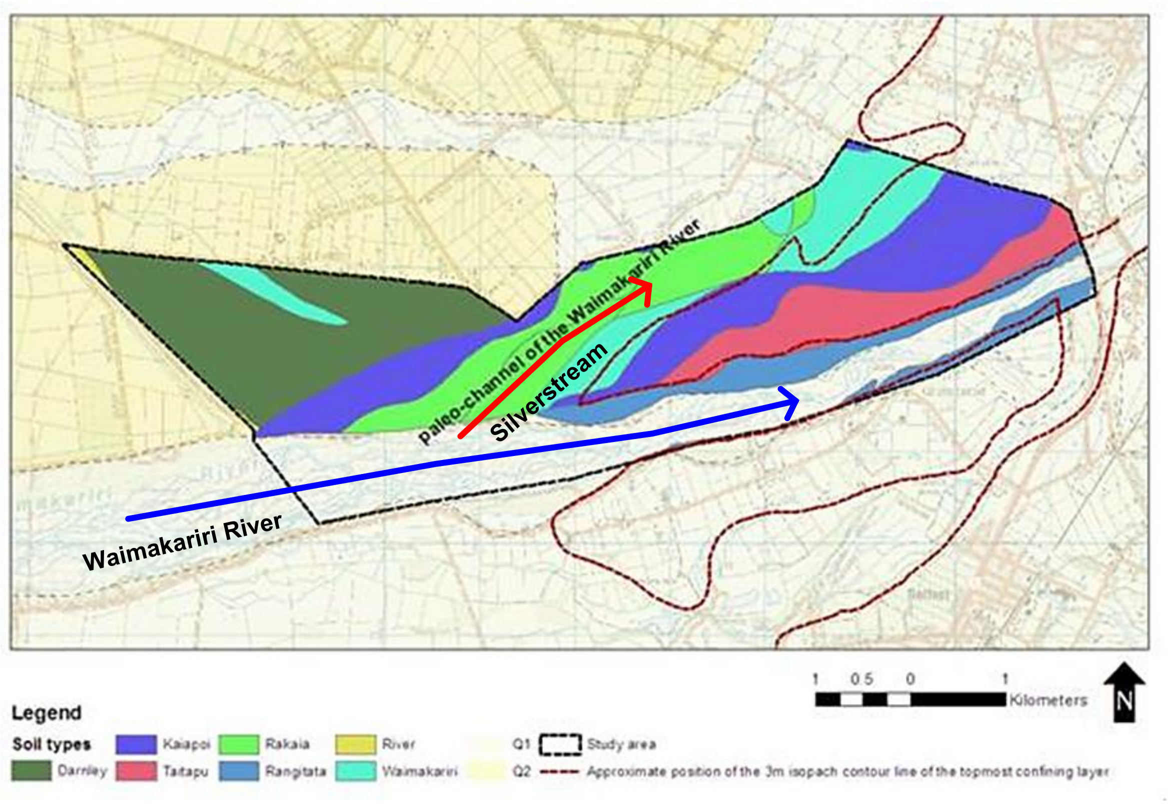


Figure 2 - Silverstream soil classifications (Dodson, 2013), showing the paleo channel

2.5 Land use

We do not directly consider land use (**Map 4**), however, it is useful to have an understanding of current land use so that patterns of future development may be considered, allowing the identification of future hydrological data requirements.

2.6 Infrastructure

The key infrastructure in relation to surface water hydrology is associated with the Waimakariri Irrigation Limited, Ngai Tahu Farming Limited and Claxby Irrigation Limited abstractions from the Waimakariri River, and subsequent distribution networks, as well as that of Loburn Irrigation Company which abstracts from the Okuku River (**Map 5**). We have defined the main elements of these schemes below as they become significant contributors to the surface water hydrology of the zone, particularly in the spring-fed lowland streams.

These infrastructure based schemes import water into the zone from the Waimakariri River, which would not naturally form part of the zone's water balance. The exception to this is the 65 L/s used by Loburn Irrigation Company, which comes from the Okuku River within the zone. Each scheme currently relies on a 'run of river' operating strategy, and irrigation only occurs between September and April.

Between September and April, up to 14.8 m^3/s of Waimakariri River water can be introduced to the zone by the schemes for irrigation purposes. In addition to this, up to 2.1 m^3/s of stockwater can be taken from the Waimakariri River and distributed around the zone at any time during the year, primarily by the Waimakariri Irrigation scheme. The maximum summer import of water from the Waimakariri River can therefore be 16.9 m^3/s.

2.6.1 Waimakariri Irrigation Limited

Waimakariri Irrigation Limited's (WIL) network of storage and conveyance (**Map 5**) is well established, having commenced operation in 2000. It is estimated (Cooper, 2011) that 10 % of race water is lost to ground through leakage from WIL's unlined open race system.

WIL are currently seeking consent to construct 8.2 Mm^3 of storage at Wrights Road, which is intended to improve the reliability of water across the scheme. The current WIL consent has a notional constraint on the maximum area that can be irrigated (**Figure 3**); however, the area is large enough that this does not pose a particular restriction. Nevertheless, the consent does contain constraints around the efficient use of water and the leaching of nitrogen to groundwater.

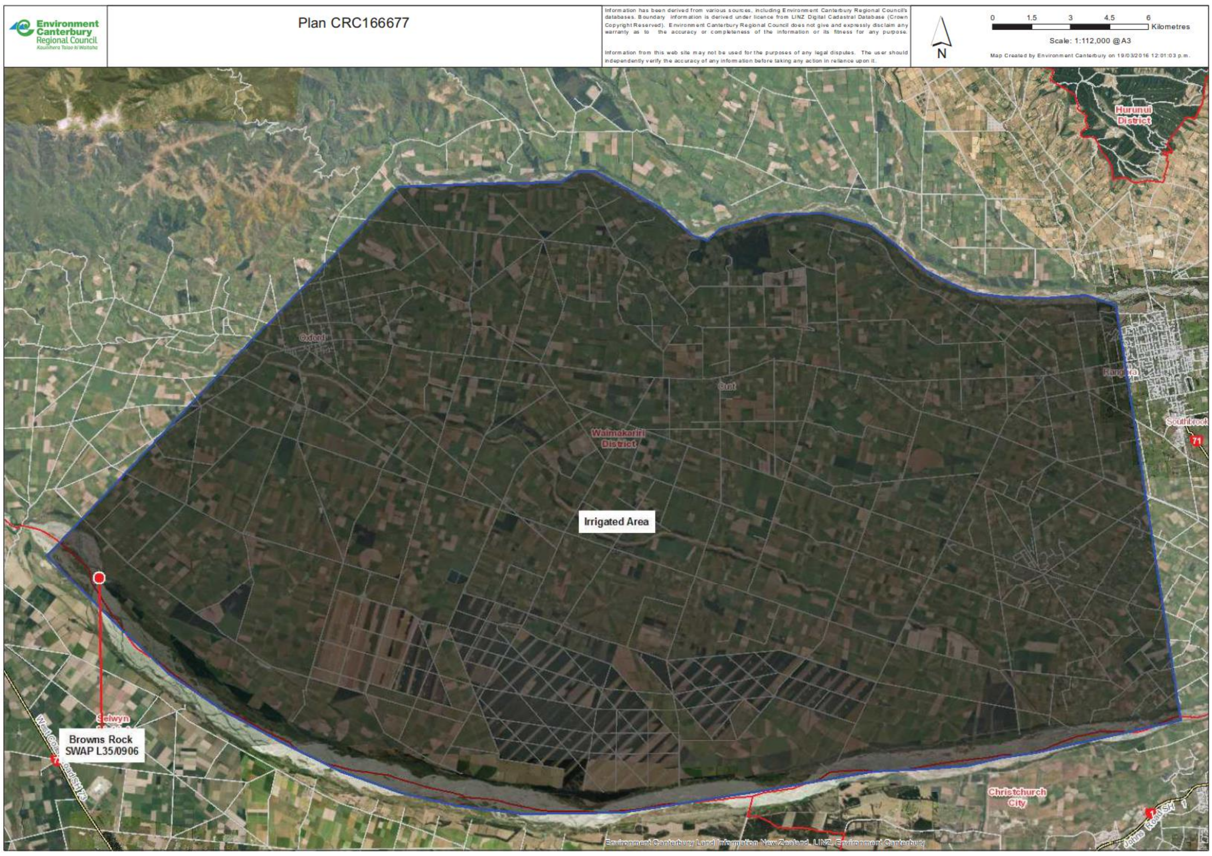


Figure 3 - Water use area for WIL

2.6.2 Ngai Tahu Farming Limited

Ngai Tahu Farming Limited (NTFL), a subsidiary of Ngai Tahu Property Limited, is currently converting the existing Eyrewell Forest to approximately 6,000 ha of irrigated dairy and diary support farms (**Figure 4**). This conversion includes the installation of 30 km of open-race distribution network which has capacity to convey 4 m^3/s of water to extensive on-farm storage. No details are available regarding network capacity or installed storage volumes. NTFL share the WIL intake infrastructure at Browns Rock.

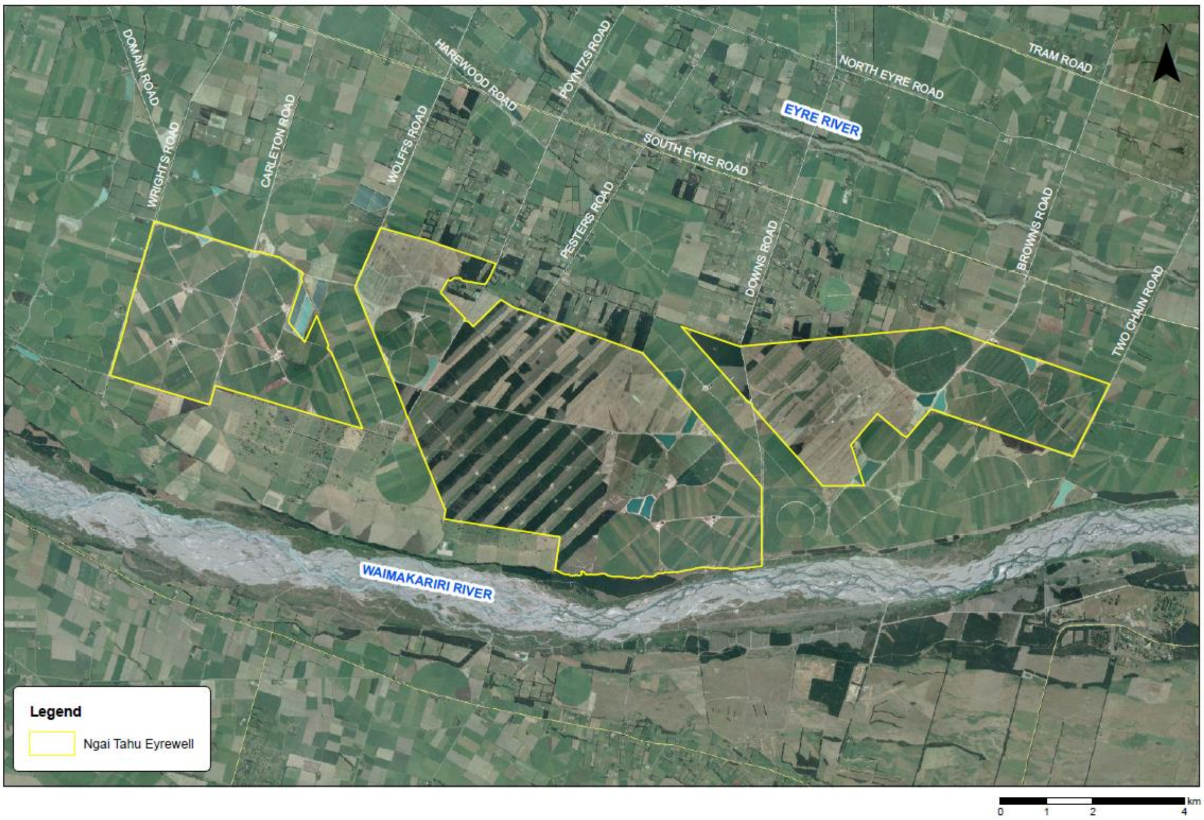


Figure 4 - NTFL development plan (PDP, 2016)

2.6.3 Claxby Irrigation Scheme

The Claxby irrigation scheme, formerly the Spencer-Bower and Prattley irrigation scheme, has an intake that diverts water from the Waimakariri River near the Eyrewell forest (**Map 5**). The area available for irrigation under the scheme is 2,868 ha (Smith, 2012) (**Figure 5**). The scheme area is spray irrigated. Until relatively recently the Claxby irrigation scheme had some border dyke irrigation but now that it has now been removed there is no border dyke irrigation in the Waimakariri Zone.

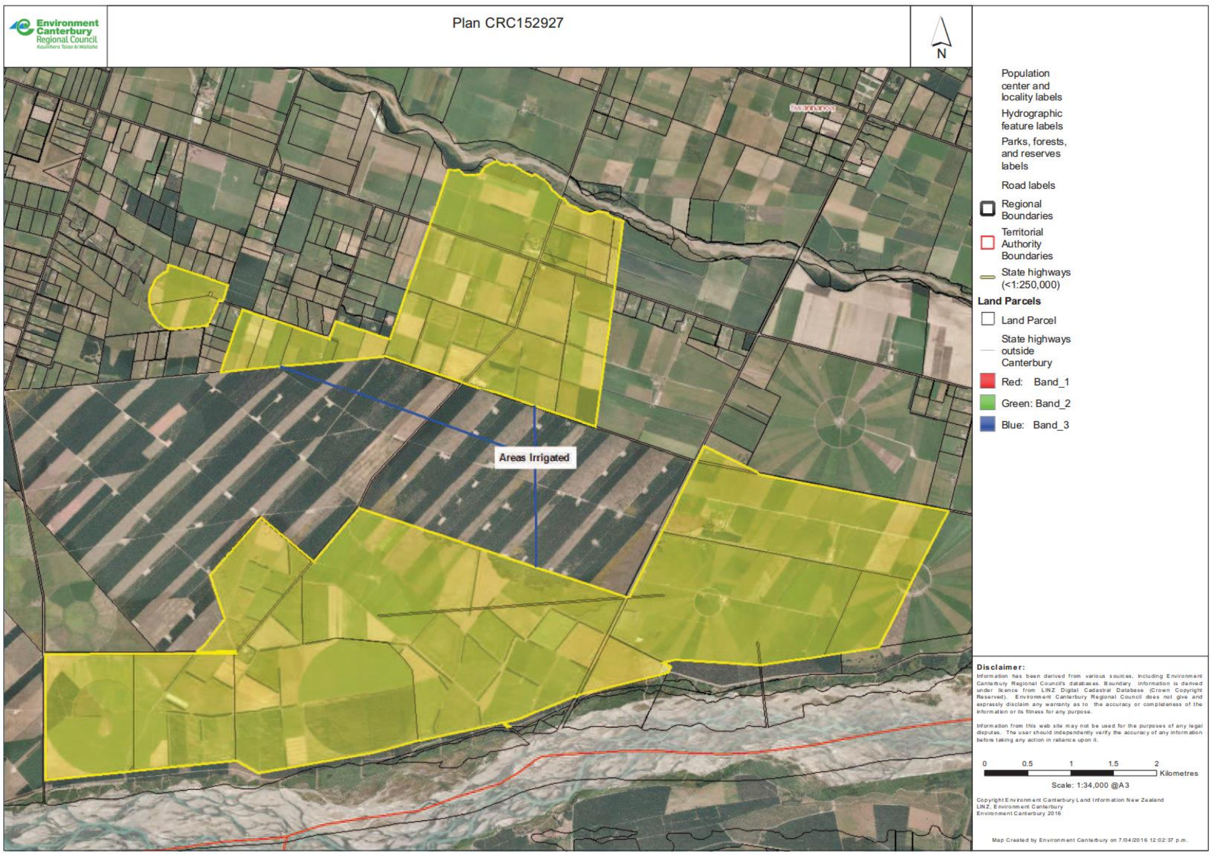


Figure 5 - Water use area for CIL

2.6.4 Waimakariri District Council

WIL undertake the delivery of stockwater by arrangement with WDC. It has been noted previously (Dodson *et al*., 2012) that the stockwater races had a different construction method to that of the WIL irrigation races, and consequently losses to ground are considerably higher in stockwater races than irrigation races. Opus (2004) estimated that the loss from stockwater races was as high as 91 %. This aligns with nearby race networks of a similar age, with Selwyn District Council reporting an 89 % loss of water from their stockwater races (SDC, 2011).

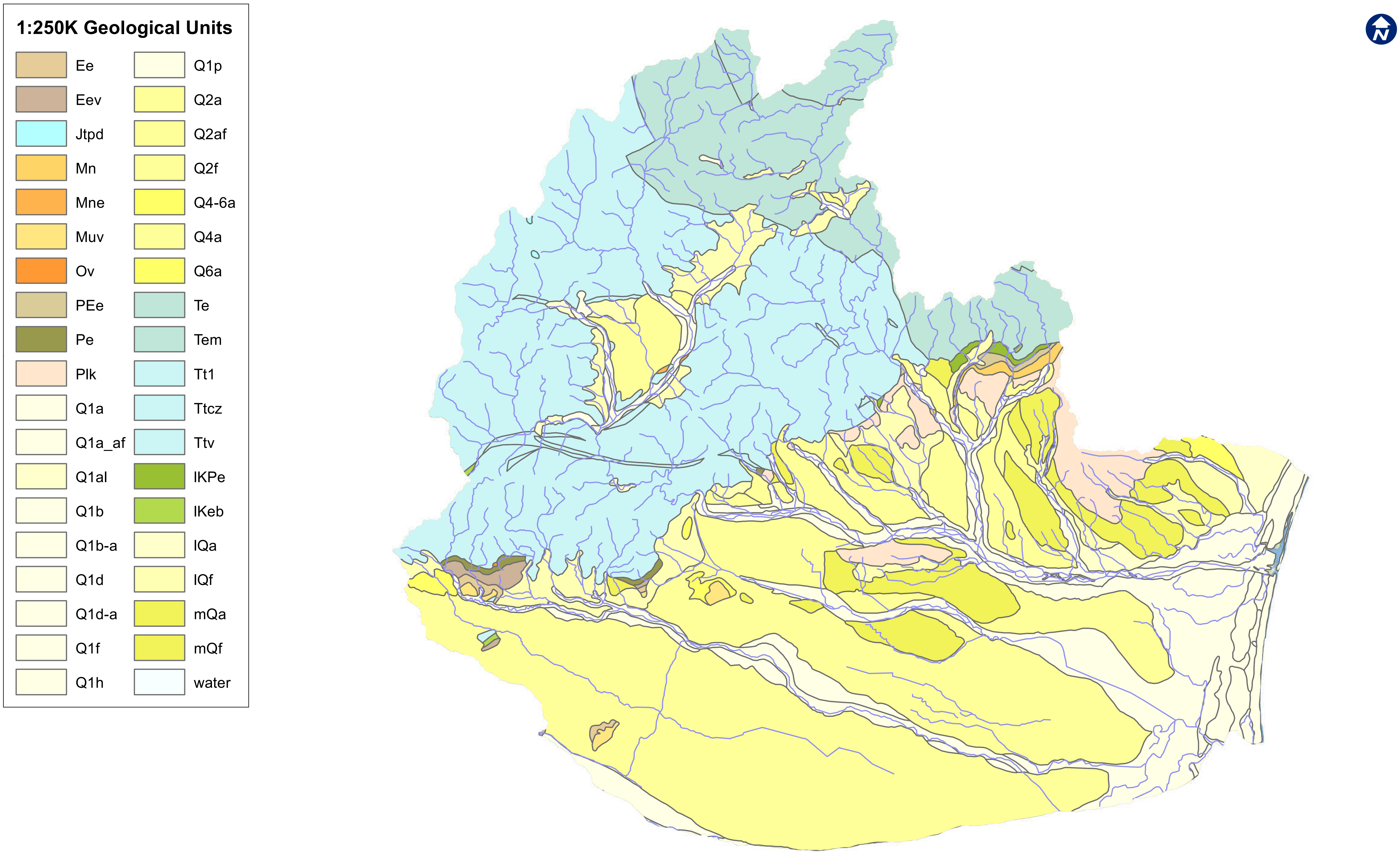
2.6.5 Loburn Irrigation Company

The Loburn Irrigation Company scheme was established in 1978 as a small community irrigation scheme to supply trickle irrigation suitable for fruit trees. The system is entirely piped, with the initial supply being run with a pressure pump and a gravity fed system running the rest of the scheme. The intake is located on the Okuku River where water is pumped from a gallery in the river gravels (**Map 5**).

2.6.6 Surface water losses from infrastructure

Assuming a loss of 90 % for stockwater races and 10 % for irrigation water races, and applying it to the maximum river abstraction rate during summer months, then it is likely that at least 1.5 m^3/s of water is being lost to ground from the infrastructure described above. This does not include consideration of NTFL's 'B' block take, which would increase losses further during its operation, nor does it include any on-farm inefficiencies such as on-farm race leakage, poor application practices, or by-wash discharges resulting from scheme operation, all of which would add more water to ground.

The WIL, WDC and NTFL irrigation infrastructure influences three Groundwater Allocation Zones in the Waimakariri Zone: the Eyre River Zone, the Cust Zone and the Ashley Zone (**Map 6**). The Eyre River Zone is affected the most, with approximately 65 % of the irrigation infrastructure being located within this zone. The remainder of the WDC/WIL irrigation infrastructure is distributed between the Cust (25 %) and Ashley (5 %) Zones.



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Surficial lithology provided by GNS Science based on the QMAP Christchurch 1:250K Geological Map of New Zealand.
Forsyth, P.J.; Barrell, D.J.A.; Jongens, R. (compilers) 2008: Geology of the Christchurch area: Scale 1:250,000. Lower Hutt: GNS Science. Institute of Geological & Nuclear Sciences 1:250,000 geological map 16. 67 p. + 1 folded map

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Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

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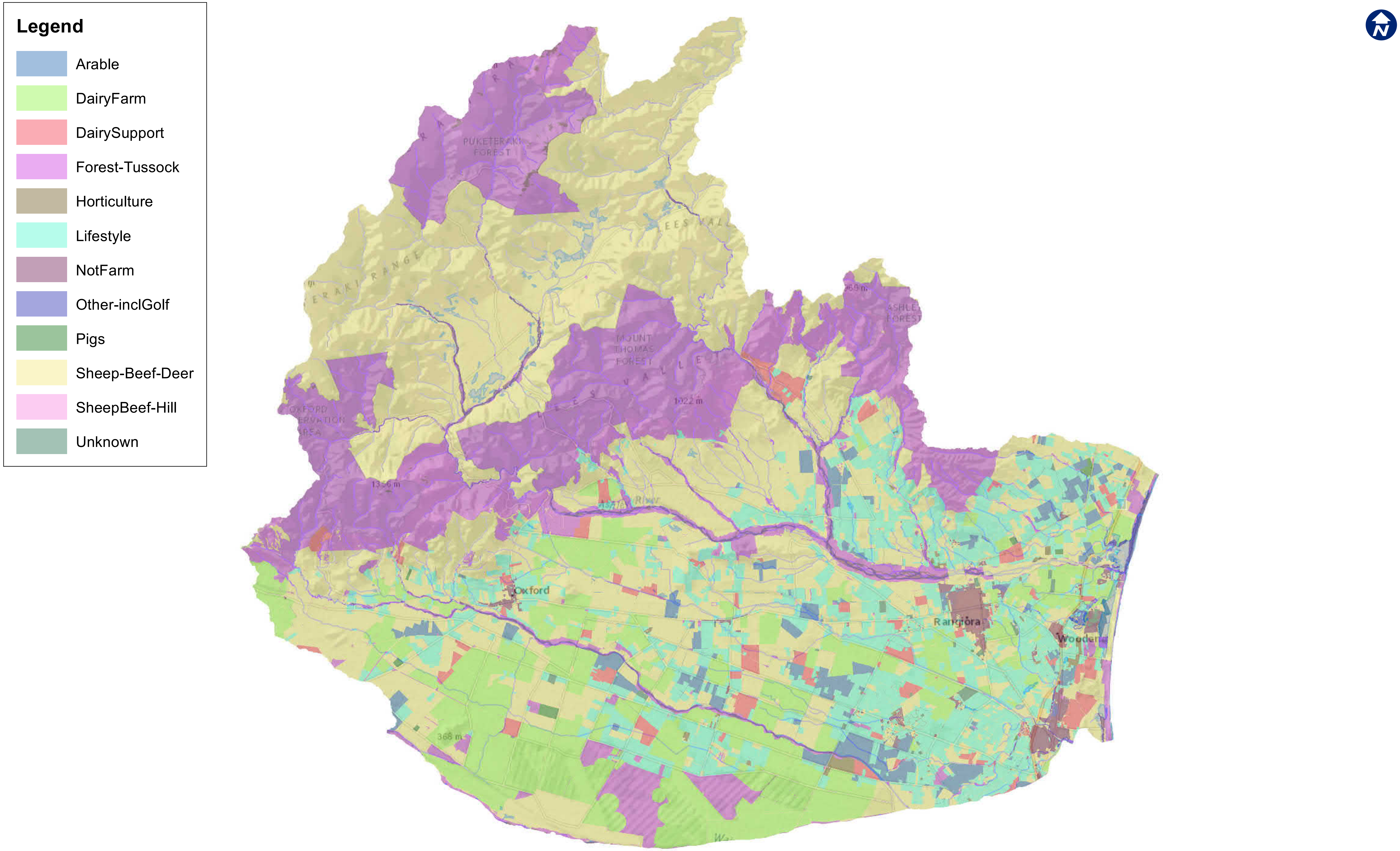

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Notes: Land use information sourced from AgriBase developed with land cover database infilling. The data has also included local farmer, DOC, and industry group reviews.

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Project: **Current State Reporting - Hydrology**

Title: **Land Use**

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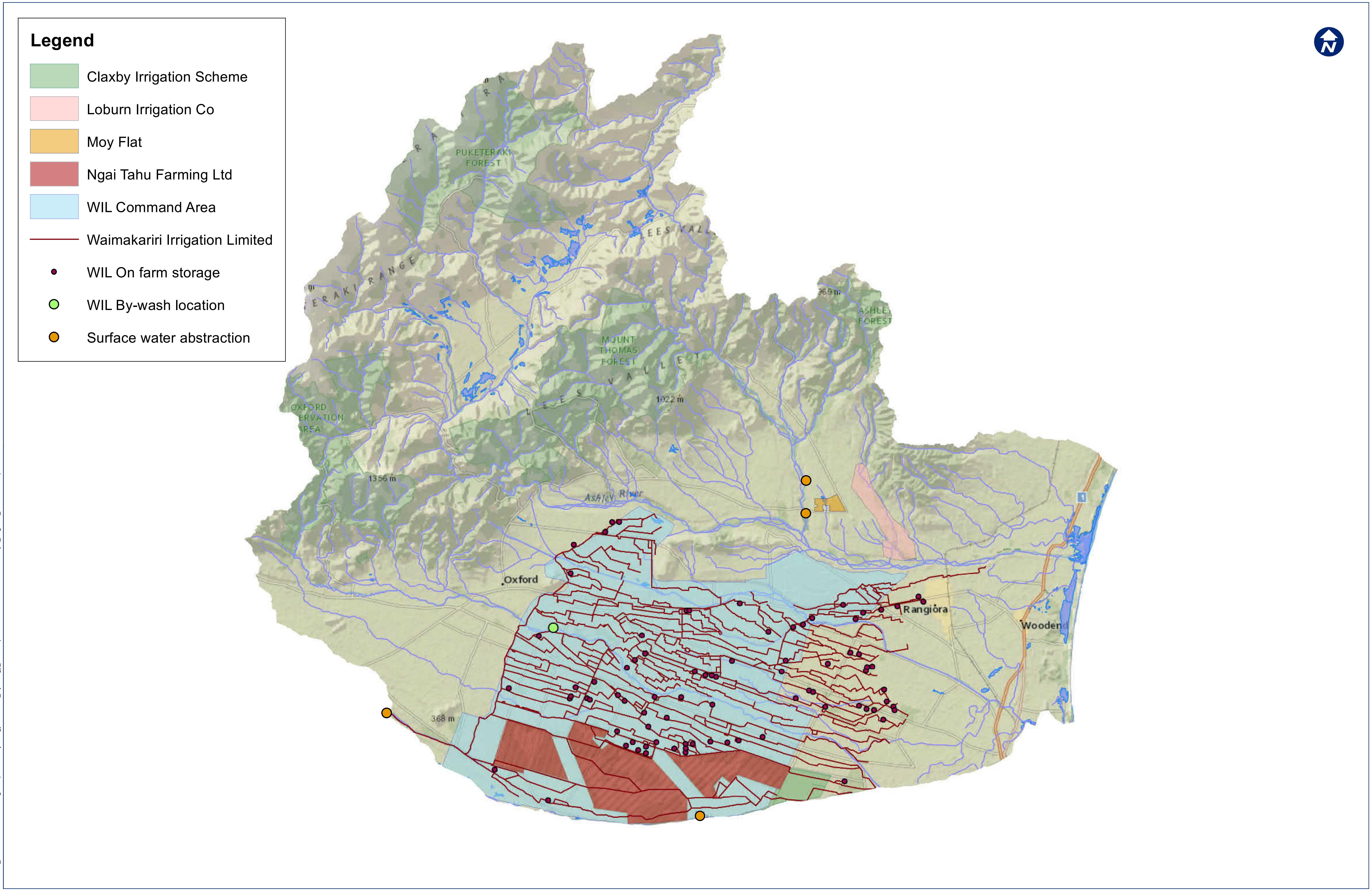

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Map features depicted in terms of NZTM projection.

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

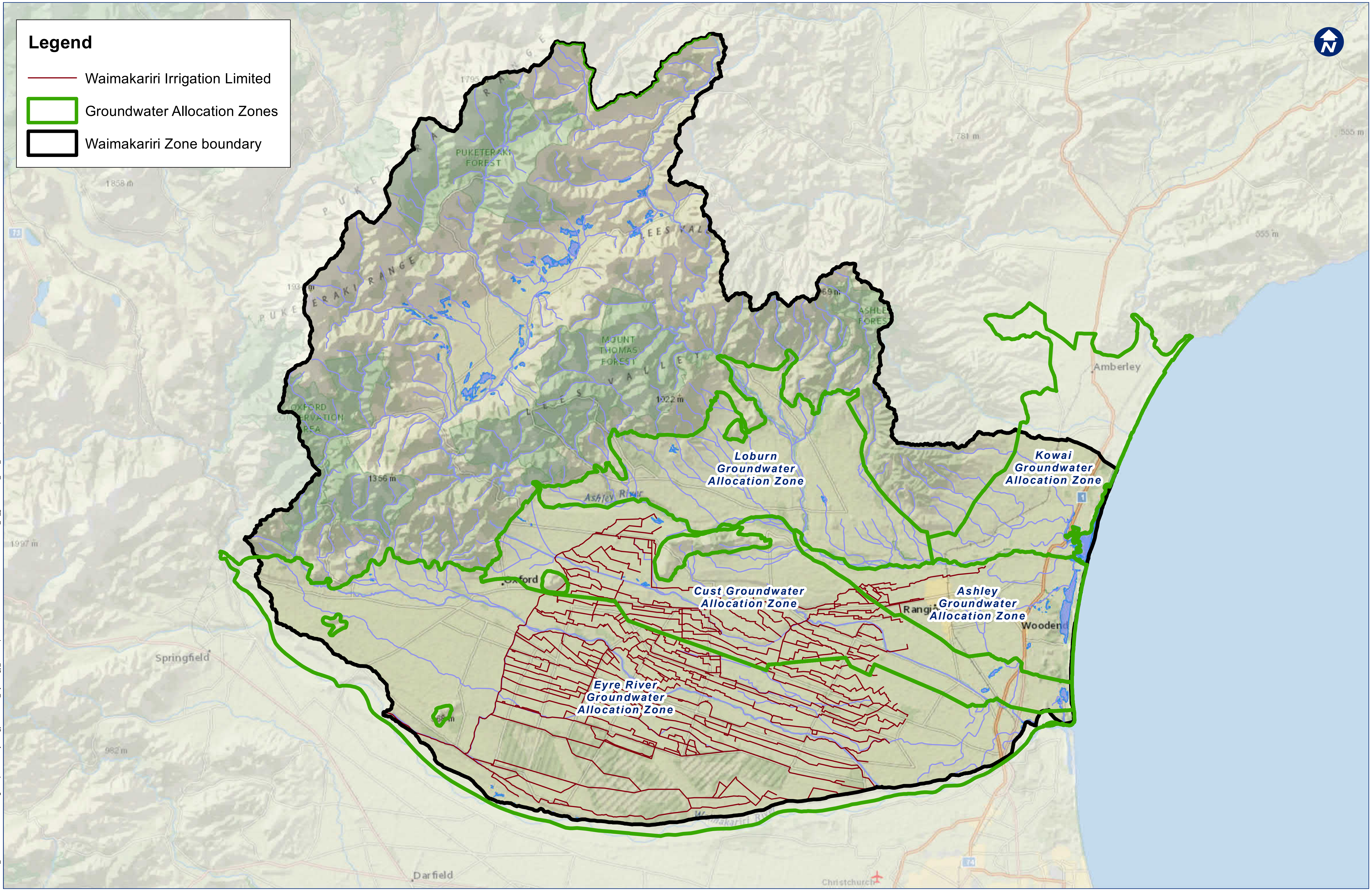
Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **Major Irrigation Infrastructure**

Scale: 1:250,000 (A3 size) — 2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 05** | Rev. 1



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Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **Contribution to groundwater from infrastructure**

Scale: 1:250,000 (A3 size) — 2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No.: **Map 06** | Rev. 1

3 Monitoring network

3.1 Introduction

In this section we describe the hydrological monitoring network established within the Waimakariri Zone. Hydrological data is collected by multiple organisations, primarily Environment Canterbury, local authorities and the National Institute of Water and Atmospheric Research (NIWA). The network consists of fixed stations that monitor rainfall, evaporation, groundwater level, river stage, and river flow. This fixed network is complemented by individual estimates of river flow (gaugings) taken manually at a wide variety of locations.

The network has evolved over time, usually in response to needs for data to understand environments and the effects human activities may have on these environments. As such, data availability varies as environments become understood and as the location, and potential effects, of activities develop.

The following section provides details of available monitoring data for river flow, rainfall and evaporation.

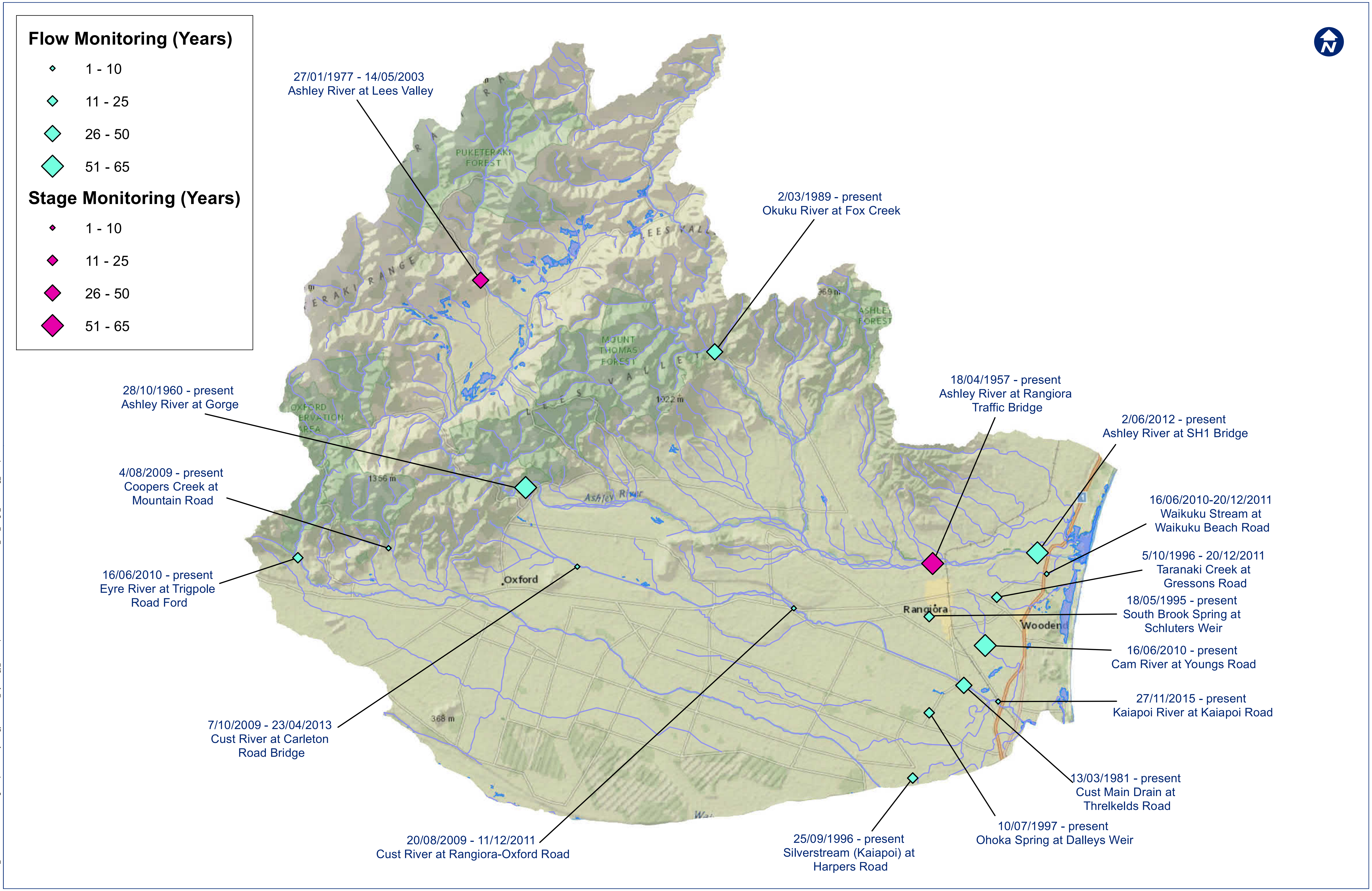
3.2 Flow Network

Environment Canterbury and NIWA collect river flow information using both fixed stage/flow monitoring stations and manual gaugings.

Fixed flow and stage monitoring stations are located across the Waimakariri Zone (**Map 7**). Many of these monitor the flow of water as it leaves the hill catchments; the remainder are located on the plains, monitoring flow patterns that are a result of loss to and gains from groundwater. As we stated above, the location of the monitoring network has evolved over time, and not all sites have data available for the same period (**Figure 6**).

Manual flow gaugings (**Map 8**) have been conducted across the Waimakariri Zone, resulting in large amounts of flow data. The manual gaugings are undertaken where there is insufficient need, or unsuitable conditions, to install a permanent gauge. Concurrent manual gaugings are also taken where a detailed understanding of flows along a single watercourse are required; often this is required to determine the losing and gaining nature of a watercourse, whether through natural processes or as a result of abstraction or discharges.

The following sections provide a summary of the available data.



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Environment Canterbury Regional Council
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Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **Flow and Stage Monitoring Sites**

Scale: 1:250,000 (A3 size) — 2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 07** | Rev. 1

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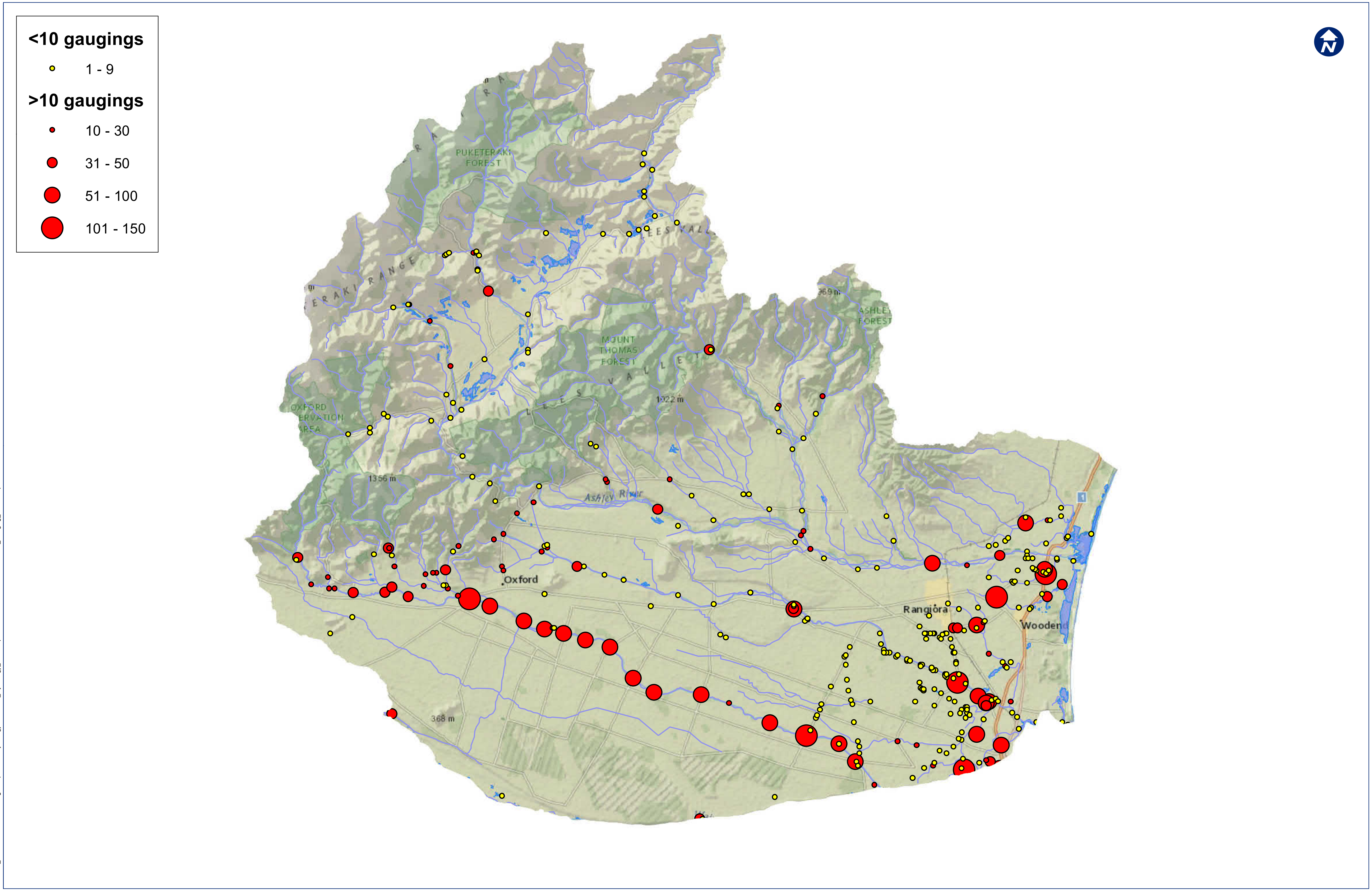

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Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **Flow Gauging locations**

Scale: 1:250,000 (A3 size)

2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 08** | Rev. 1

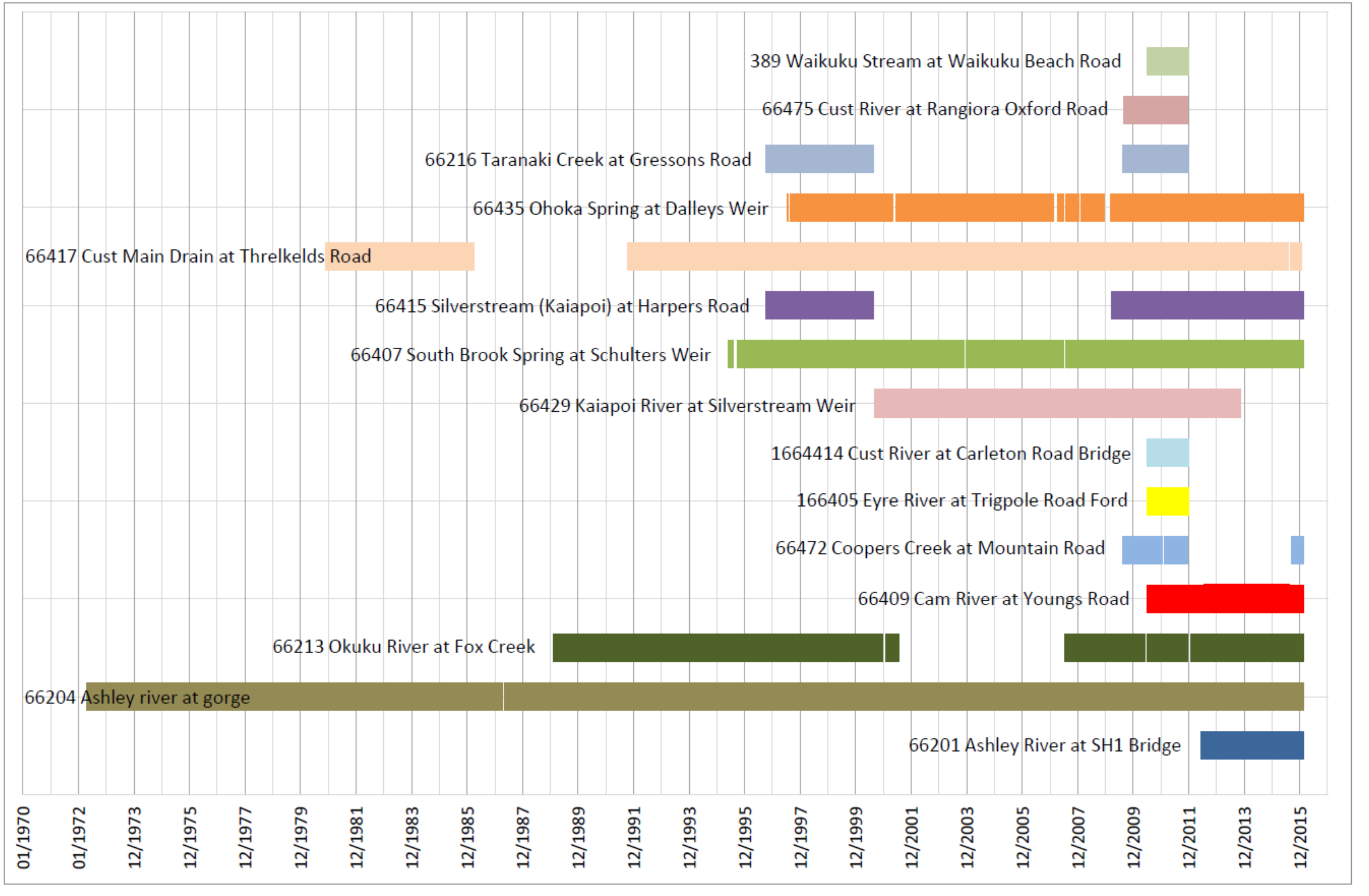


Figure 6 – Flow data overlap chart

3.2.1 Ashley River/Rakahuri

The Ashley River/Rakahuri has two flow monitoring sites: at the Ashley Gorge and at the SH1 Bridge.

Ashley at Gorge (66204) monitoring site has data recorded from 1972 until present. The data recorded between 1972 and 1987 have periods of questionable data quality (Chater, 2004) because of poor stage resolution and poor gauging frequency.

Ashley at SH1 Bridge (66201) monitoring site has recorded data from 2012 until present. The site is located in a losing reach and is known to become periodically dry (Smith, 2012).

The entire Ashley River/Rakahuri catchment is approximately 1,200 km^2, with headwaters located in the Puketeraki Range and its highest point at over 1,900 m. The headwaters are dominated by native forestry and intermediate alpine ecosystems, and the Lees Valley area is mostly unirrigated pasture. Below the Ashley Gorge, the middle reach of the Ashley River/Rakahuri is surrounded by sparsely populated farmland, which is primarily irrigated pasture. The lower Ashley River/Rakahuri floodplain is densely populated with a significant urban population. Rural land use around the middle and lower reaches includes intensive dairying, horticulture, dry-land sheep farming, and forestry (Boyle and Surman, 2009).

The river typically experiences higher flows during winter and spring, and often becomes dry near Rangiora during summer (Dodson *et al*., 2012).

3.2.2 Okuku River

The Okuku River monitoring site is located at the Fox Creek confluence where the Okuku River emerges from its gorge. The Okuku River at Fox Creek (66213) monitoring site has a recording period from 1989 until present.

The Okuku River catchment is approximately 222 km^2 above the Fox Creek gauge, with its headwaters located near the eastern end of the Puketeraki Range. It is rain fed, primarily from hillslope runoff from intermediate ranges. The Okuku River leaves the upper catchment through a deep narrow gorge after which it flows through the Loburn area, which is built up from alluvial fan aggradation gravels and silts of varying ages (Boyle and Surman, 2009). Downstream of Loburn, the Okuku River joins the Ashley River/Rakahuri.

In the Puketeraki and Okuku Ranges the land is primarily native and planted forestry, with the Puketeraki Range being classified as an intermediate alpine range. The Loburn area consists of farmland, irrigated pasture for dairying, orchards and dry-land sheep farming (Boyle and Surman, 2009).

3.2.3 Cust River and Cust Main Drain

The Cust River and the Cust Main Drain are monitored at two locations: the Threlkelds Road Bridge and the Carleton Road Bridge. The flow record of Cust Main Drain at Threlkelds Road (66417) extends from 1980 until present, although no data is available between April 1986 and October 1991. In 1991 the site was reinstated 500 m downstream of the original site. Flow records are at times affected by upstream gravel extraction, giving rise to a rating change at the site but no real changes to flow. In May 1999 the gravel extraction site was moved downstream of the recorder (Chater, 2009).

The Cust River at Carleton Road Bridge recorder (1664414) is located on the plains approximately 5 km east of Oxford, 26 km upstream of the Threlkelds Road gauge. The site has a recording period from June 2010 until December 2011, providing only one full water year of data.

The entire Cust River catchment is approximately 250 km^2, with its headwaters in the Ashley foothills (Dodson *et al*., 2012). The Cust River is primarily rain-fed, dominated by hillslope runoff from the foothills, with little surface water storage in the upper reaches (Dodson *et al*., 2012). The Cust River is ephemeral in the upper reaches but gains flow in the lower reaches, with strong groundwater influences (Smith, 2012).

The upper reaches of the Cust River flow through farmland, primarily irrigated pasture. After reaching Rangiora the flow transitions into the Cust Main Drain where it is confined within stopbanks, discharging into the Kaiapoi River.

3.2.4 Eyre River

The Eyre River has a monitoring site at the Trigpole Road ford in the Eyre-Oxford foothills. The Eyre at Trigpole Road ford (166405) monitor has recording data from 2010 until present. No recordings were taken between December 2011 and September 2015 giving only one full water year of data recorded since 2010.

The entire Eyre River catchment is approximately 210 km^2, with its headwaters in the Eyre foothills (Dodson *et al*., 2012). It is rain-fed, dominated by hillslope runoff from the Eyre foothills, with little surface water storage in the upper reaches. The Eyre River has permanent flow in the upper reaches but loses flow as it crosses the plains. The river usually dries before reaching Oxford and rarely flows along its full length (Dodson *et al*., 2012).

A by-wash discharge structure from the WIL irrigation scheme is located on the Eyre River, discharging 5 km downstream of Oxford at a maximum rate of approximately 440 L/s (Sanders, 2003). We have discussed this by-wash with WIL operations staff and it is understood to occur at a variable rate which depends on the operation of the race network.

3.2.5 Cam River

The Cam River has a monitoring site at Youngs Road near Rangiora. The Cam River at Youngs Road (66409) has a record period of 2010 until present. The surface catchment at the monitoring site is 35 km^2.

The Cam River is a spring-fed stream that flows into the Kaiapoi River at Kaiapoi. It receives stormwater runoff from Rangiora. In the past it received treated sewage effluent from Rangiora (Main and Lavender, 2003), however this discharge has stopped since the commissioning of an ocean outfall in 2006. Upstream, the Cam River is fed by North, Middle and South Brooks, which flow southeast from Rangiora.

3.2.6 Kaiapoi River

Two flow monitoring sites are located on the Silverstream/Kaiapoi River: one at Harpers Road and the other downstream of the fish farm at the Silverstream weir. The Silverstream/Kaiapoi River at Silverstream Weir (66429) site has flow data from 2000 until 2013 and is monitored by NIWA.

The Silverstream/Kaiapoi River at Harpers Road (66415) is located at the Harpers Road Bridge 750 m from the Waimakariri River. Both sites are primarily spring-fed with no defined surface catchment.

3.2.7 Coopers Creek

Coopers Creek has a monitoring site located at Mountain Road in the Eyre-Oxford foothills. The Coopers Creek at Mountain Road site has a recording period from 2009 until present with a gap between December 2011 and September 2015, giving approximately two full water years of data recorded since 2009.

The catchment at this site is approximately 19 km^2, with its headwaters in the Oxford foothills. Coopers Creek flows north to south where it discharges to the Eyre River at Oxford.

Coopers Creek at Mountain Road is also a manual flow gauging site, being in operation from 2009 until present. Our analysis of the flow monitor data showed considerably higher flows than that suggested by the manual gaugings. Similarly, the flow rates from an adjacent, similarly sized catchment were more consistent with the manual gaugings that the automatic recorder.

To assess the performance of the flow monitor, we undertook a simplistic annual water balance using VCSN precipitation and Potential Evapotranspiration (PET) data. This analysis suggests that the flow monitor is recording an annual volume of water greater than the estimated rainfall on the catchment.

Whilst specific rainfall data is not available from within the catchment, estimates based upon VCSN data are sufficient to raise suspicion over data from this site.

3.2.8 Ohoka Spring

Ohoka Spring at Dalleys Weir (66435) is located west of Kaiapoi and flows west to east towards the Kaiapoi River. The monitoring site has data recorded from 1997 until present. The flow record contains multiple gaps with the largest being two and half months from December 2008 until February 2009.

3.2.9 South Brook Spring

South Brook is a spring-fed stream passing through the south of Rangiora township. The South Brook Spring at Schluters Weir (66407) monitoring site is located at the spring head with no apparent surface catchment. The recording period at the site is from 1995 until present. Numerous gaps exist in the recorder data with the longest period, almost seven weeks, occurring at the beginning of the flow record in August 1995.

The land use of the surrounding area is semi-rural, with Rangiora urban areas located within 500 m of the springhead.

3.2.10 Gauged sites

The Waimakariri Zone has numerous sites at which manual flow gaugings have been collected. These gaugings are useful to assess flow at sites that do not justify the installation of permanent monitoring equipment. By using nearby permanent recording stations we are able to determine the flow characteristic of a gauging site beyond the small number of data points collected (**Table 1**).

Table 1 - Gauging sites

Gauging Site	No. of gaugings	First gauging	Last gauging	Minimum gauged flow (L/s)	Maximum gauged flow (L/s)
Hill-fed					
166406 Eyre River at Washpen Road ford	26	1/04/04	11/05/11	16	1047
166408 White Stream at Upper Perhams Road ford	25	1/04/04	11/05/11	18	356
1516 Mounseys Stream at Island Road	31	6/09/83	8/12/15	33	549
166414 Trout Creek tributary 1 at Bush Road	25	1/04/04	11/05/11	0	202
166415 Trout Creek tributary 2 at Bush Road	25	1/04/04	11/05/11	0	23
166413 Trout Creek at Bush Road	25	1/04/04	11/05/11	7	402
166416 Gammans Creek at Bush Road bridge	38	1/04/04	21/12/11	33	728
1664413 Ellis Drain south of Victoria Street	18	7/10/09	11/05/11	0	10
1664412 Ellis Drain north of Victoria Street	18	7/10/09	11/05/11	0	0.2
1664411 Ellis Drain at The Grange	17	7/10/09	11/05/11	4	58
1664410 Ellis Drain u/s of Ashley Gorge Road	17	7/10/09	11/05/11	3	36
66205 Deep Creek at Carleton Road culvert	28	2/10/56	11/05/11	0	5050
1620 Glentui River at Ashley Gorge Road	24	13/09/72	4/01/89	2	720
240 Garry River at Birch Hill Road Bridge	24	13/09/72	22/04/09	11	860
242 Karetu River at Main Loburn Road	11	14/09/72	29/07/10	10	197
1613 Grey River at D/S Grey River West Branch	12	22/07/75	20/05/03	14	1606
Lowland					
368 Kaiapoi River at Skewbridge Road	45	9/01/64	28/06/11	452	3190
370 Ohoka Stream at Kaiapoi River confluence	67	6/03/96	6/03/15	291	1309
366 Cam River at Youngs Road	12	19/07/61	7/10/09	1090	11400
66432 Courtenay Stream at Ashley Meat Factory	92	5/03/69	19/02/14	293	707
66215 Taranaki Creek at Preeces Road	50	15/03/72	27/01/16	68	419
1343 Silverstream at hatchery	18	28/04/75	11/05/11	173	1282
66414 Griegs Drain at Taylors Road	119	12/11/73	12/12/11	57	101

3.3 Climate stations/Virtual Climate Station Network (VCSN)

3.3.1 Precipitation

Available recordings of rainfall in the zone date back to 1891 in Rangiora. There are the typical groupings of rain gauges around urbanised areas, but also a spread of monitors across more rural areas, which were likely used to support agricultural decision making. In addition there are several gauges which are/were located in the headwaters around Lees Valley. It is likely that these were placed to assist in the understanding of flows in the larger rivers that source most of their flows from the high ranges (**Table 2, Map 9**). These recordings have a sporadic temporal distribution, making it difficult to find concurrent recordings between sites.

Sporadic temporal distribution of precipitation was one of the drivers behind the development of the Virtual Climate Station Network (VCSN). Managed by NIWA, the VCSN is a useful tool to consider precipitation (and PET) over a large area, or where rain gauge density is low. The network takes available rainfall records and infers rainfall and PET time series for a 0.05° latitude and longitude grid of virtual stations across the country (**Map 10, 11**).

Concerns have been raised regarding the accuracy of this data for day-to-day predictions of precipitation (Smith, 2012), however this does not preclude their use over a monthly or yearly timeframe, and the VCSN data can be of particular use for zone-wide investigations such as that being undertaken here.

We also note that the VCSN used here were updated by NIWA to include additional Environment Canterbury rainfall data, which was not included in the original VCSN development. This allows for more accurate predictions, lessening somewhat the concerns raised in Smith (2012).

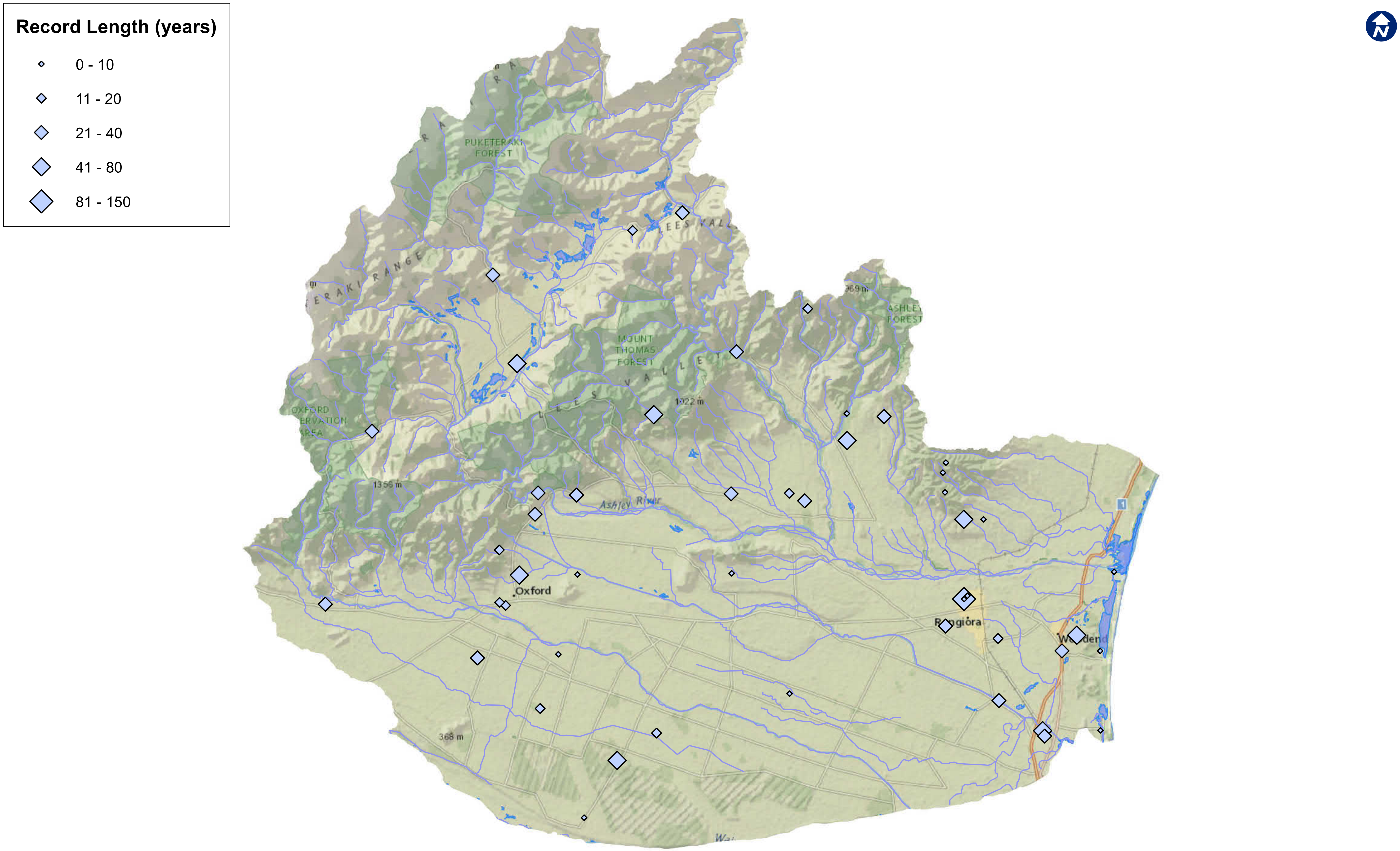
3.3.2 Potential evapotranspiration

Potential evapotranspiration is measured at Sinai weather station. In the past there have been concerns raised over the reliability of PET measurements taken at Sinai; consequently, Smith (2005) recommends that the PET output from the station be ignored and that a FAO56 calculation be made instead. However, where we have required estimates of evaporation for this work we have instead referred to the VCSN data (**Map 12**).

Table 2 - Raingauge summary

Monitoring site	Location	Authority	Periodicity	Duration
Open sites				
Rangiora EWS	Rangiora, approximately 4 km south of Ashley River	NIWA	Telemetered	16/02/99 - Present
Ashley at Lees Valley	Ashley River upstream of Lees Valley	ECan	-	23/06/88 - Present
Waimakariri at 42a Peraki St,Kaiapoi	Kaiapoi, lowland/coastal	CCC	-	01/04/87 - Present
Ashley at Ashley Gorge	Ashley Gorge	ECan	Telemetered	02/09/87 - Present
Ashley at Townshend	Ashley River headwaters, at confluence of Shifton Stream and Townshend River	ECan	Telemetered	17/02/76 - Present
Eyrewell (Sinai) at Poyntzs Rd	South of Eyrewell forest, 1.5 km from the Waimakariri River, plains	ECan	Telemetered	15/09/10 - Present
Taranaki Creek at Floodgate	At Taranaki Creek floodgates adjacent to Waikuku Beach, lowland/coastal	ECan	Telemetered	23/11/13 - Present
Glentui 1	Approximately 2.5 km east of Ashley Gorge opening, adjacent to unnamed tributary of the Ashley River, Mt Thomas foothills	MetService	Daily	01/12/47 - Present
Cust Main Drain at Threlkelds Road	On Cust Main Drain stopbanks approximately 3 km upstream of Kaiapoi, plains	ECan	Telemetered	02/12/87 - Present
Ashley at Okuku School	Between Bullock Creek and Okuku River, 2 km northeast of Bullock Creek and Ashley River confluence, plains	ECan	Telemetered	04/12/98 - Present
Ashley at Pig Flat	In the Okuku River headwaters, Okuku Ranges	ECan	Telemetered	18/02/76 - Present
West Eyreton at Larundel Farm Cws	Between Eyre and Cust Rivers, approximately 8 km west of Mandeville North, plains	NIWA	Hourly	01/07/11 - Present
Woodend, Gladstone at Woodend	Between Woodend and Pegasus, lowland/coastal	MetService	Daily	01/09/72 - Present
Closed sites				
Okuku	Between Mt Thomas Stream and Garry River	MetService	Daily	01/11/65 - 01/11/03
Rangiora	Within Rangiora, approximately 1.5 km south of Ashley River	MetService	Daily	01/01/1891 - 31/05/12
Okuku Pass	Headwaters of Karetu River, Ashley Forest	MetService	Daily	01/01/37 – 31/12/49
Wharfedale	Lees Valley on Ashley River	MetService	Daily	01/01/48 - 01/02/89
Loburn	Approximately 2 km east of the Grey River and Okuku River confluence, plains	MetService	Telemetered	01/03/37 - 01/03/84
Ashley at Ashley Gorge	Ashley Gorge at Ashley Gorge Drain, Ashley foothills	NIWA	-	10/08/49 - 04/01/88
Neptune Observatory	Kaiapoi town, lowland/coastal	MetService	-	01/01/08 - 31/10/54
Woodend 1	South of Te Kohanga Wetlands and Pegasus town, lowland/coastal	MetService	Daily	01/02/55 - 31/07/64
Okuku at Fox Ck	Okuku River at confluence with Fox Creek, Okuku foothills	ECan	Telemetered	07/10/88 - Present
Birch Hill	Garry River at Birch Hill, Mt Thomas foothills	MetService	-	01/01/02 - 01/06/43
View Hill	Eyre foothills, 500 m from confluence of White Stream and Eyre River	MetService	Daily	01/01/45 - 01/06/79

Monitoring site	Location	Authority	Periodicity	Duration
Horrelville	Near Eyrewell forest, approximately 5 km south of Horrelville, plains	MetService	Daily	01/01/45 - 31/05/59
Woodend 2	South of Woodend, lowland/coastal	MetService	Daily	01/04/65 - 01/11/05
Oxford	Directly north of Oxford town, plains/foothills	MetService	Daily	01/10/18 - 31/03/73
Lytham at South Eyre Road	Approximately 4 km south of Oxford, plains	Private	-	26/07/73 - 17/06/09
Glentui 2	Approximately 3 km north of Oxford, Ashley foothills at The Grange	MetService	Daily	31/01/84 - 03/01/99
Rangiora,Loburn	On Grey River, approximately 3 km upstream of confluence with Okuku River, foothills	MetService	Daily	29/02/84 - 31/01/86
Rangiora	Within Rangiora, approximately 3.5 km south of Ashley River	MetService	Daily	01/01/65 - 30/04/98
Carleton Eyre Barton	Approximately 5 km east of Oxford, adjacent to the Eyre River, plains	MetService	Daily	01/05/20 - 30/06/29
Eyrewell Forest	Adjacent to Eyrewell forest, approximately 6 km south of Horrelville, plains	MetService	Daily	01/01/42 - 01/01/90
Oxford 1	Between the Eyre River and View Hill Stream, 8 km southeast of Oxford, plains	MetService	Daily	01/12/03 - 30/09/18
Stony Ck at Stony Ck Rd	In the headwaters of Stony Creek, Mt Grey (east)	NIWA	-	24/09/79 - 09/01/84
Mt Thomas	Between Bullock Creek and Okuku River, 2.5 km north of Bullock Creek and Ashley River confluence, plains	MetService	Daily	01/01/48 - 01/11/64
Rangiora, Ayers Street	Within Rangiora, 1.5 km south of Ashley River	MetService	Daily	08/02/96 - 01/11/04
Oxford, Matai	Within Oxford town, plains	MetService	Daily	02/01/99 - 01/11/11
Golden Downs, Loburn	In the headwaters of the Makerikeri River, Mt Grey foothills	MetService	Daily	30/11/85 - 01/01/07
Glenburn	In the Ashley River headwaters, below Okuku Saddle on Duck Creek, Okuku foothills	MetService	Daily	01/01/48 - 01/08/60
Oxford,Midlands	Approximately 4.5 km southeast of Oxford town, plains	MetService	Daily	01/01/39 - 31/05/48
Stony Ck at Lawrence Rd	In the headwaters of Stony Creek, Mt Grey (east)	NIWA	-	24/09/79 - 15/10/86
Ashley Forest 2	Saltwater Creek headwaters, Mt Grey (east) foothills	MetService	-	30/11/76 - 01/06/78
Kairaki	Adjacent to Pines Beach Wetlands, next to Kairaki Creek, lowland/coastal	MetService	-	01/07/87 - 01/02/90
Ashley Forest 1	South of Saltwater Creek headwaters, 5 km north of Rangiora town	MetService	Daily	01/11/41 - 01/01/90
Rangiora B	Between the Cust River and the Ashley River, approximately 17 km west of Rangiora, plains	MetService	Daily	01/10/55 - 01/01/64
Oxford 2	Within Oxford town, plains	MetService	Daily	01/04/73 - 01/02/84



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Environment Canterbury Regional Council
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Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **Rainfall Monitoring locations**

Scale: 1:250,000 (A3 size) 2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 09** | Rev. 1

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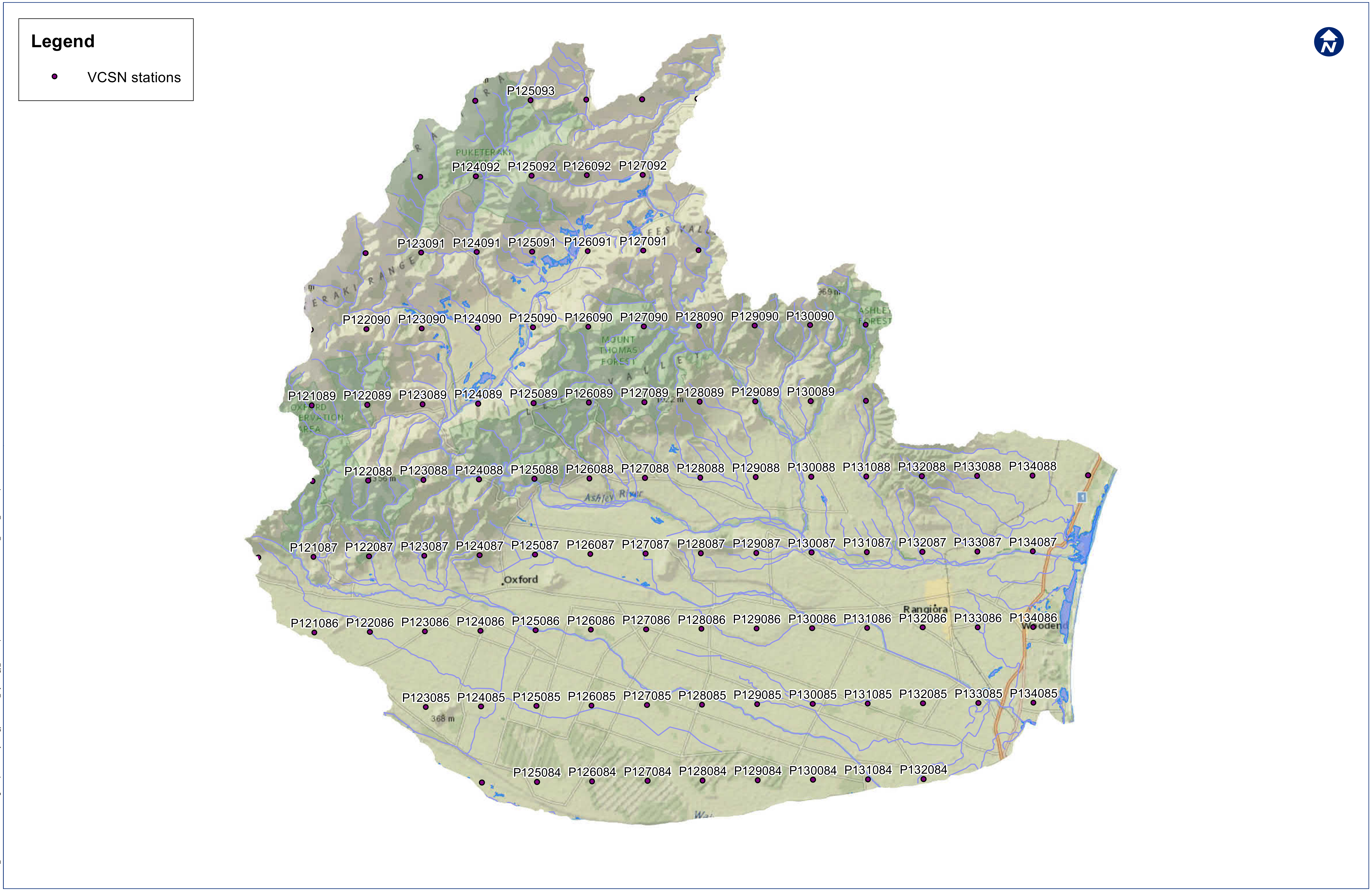

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Kaunihera Taiao ki Waitaha

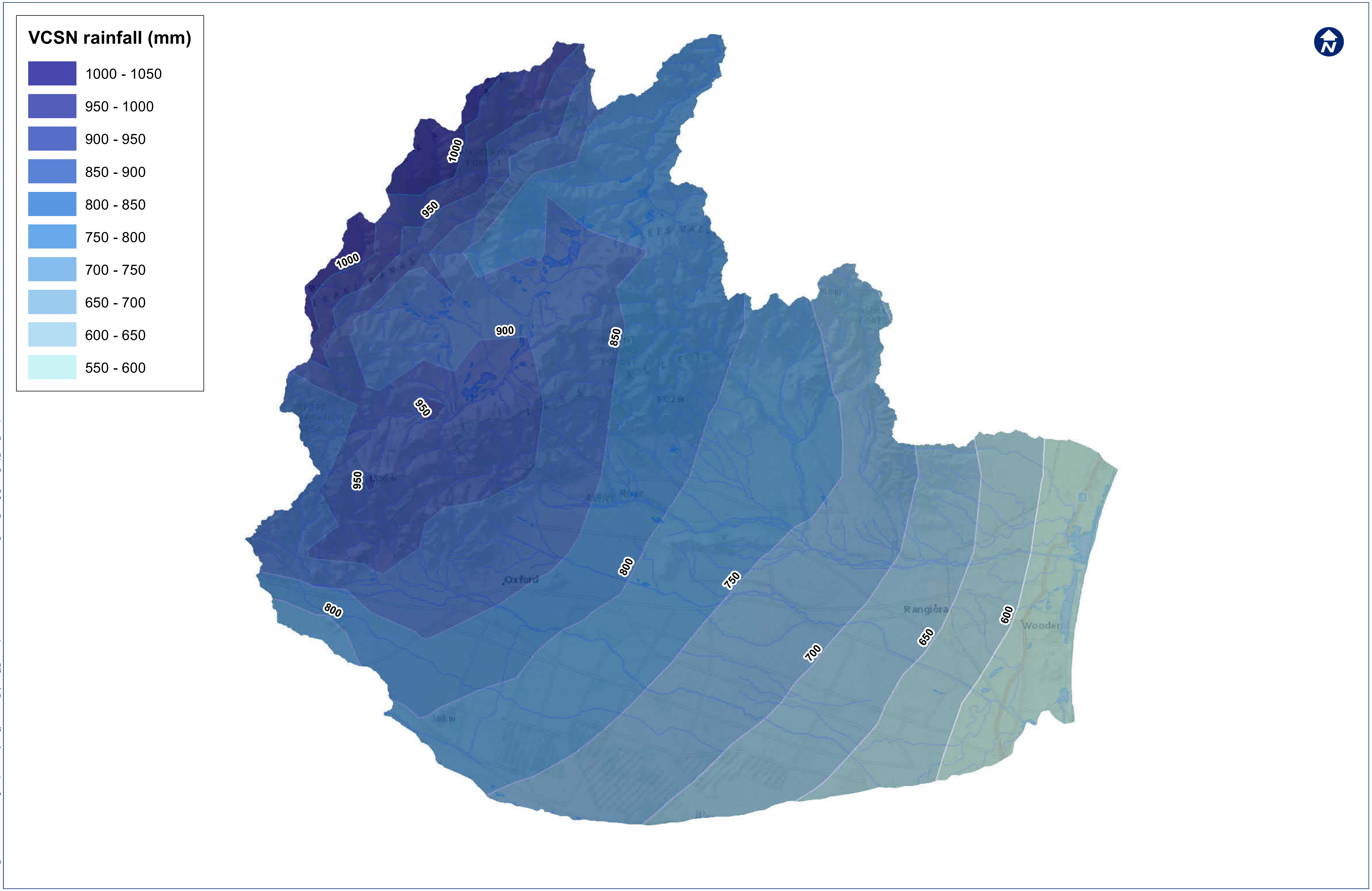
Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **VCSN station locations**

Scale: 1:250,000 (A3 size) — 2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 10** | Rev. 1



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1	SH	MM	Final	20/12/16
A	SH	MM	Draft for review	9/07/16
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Notes: Virtual Climate Station Network generated by NIWA on behalf of Environment Canterbury using NIWA and Environment Canterbury data.

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File Name	Map 11		

Map features depicted in terms of NZTM projection.

Environment Canterbury Regional Council
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Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **VCSN Annual average rainfall map (1972-2014)**

Scale: 1:250,000 (A3 size) 2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 11** | Rev. 1

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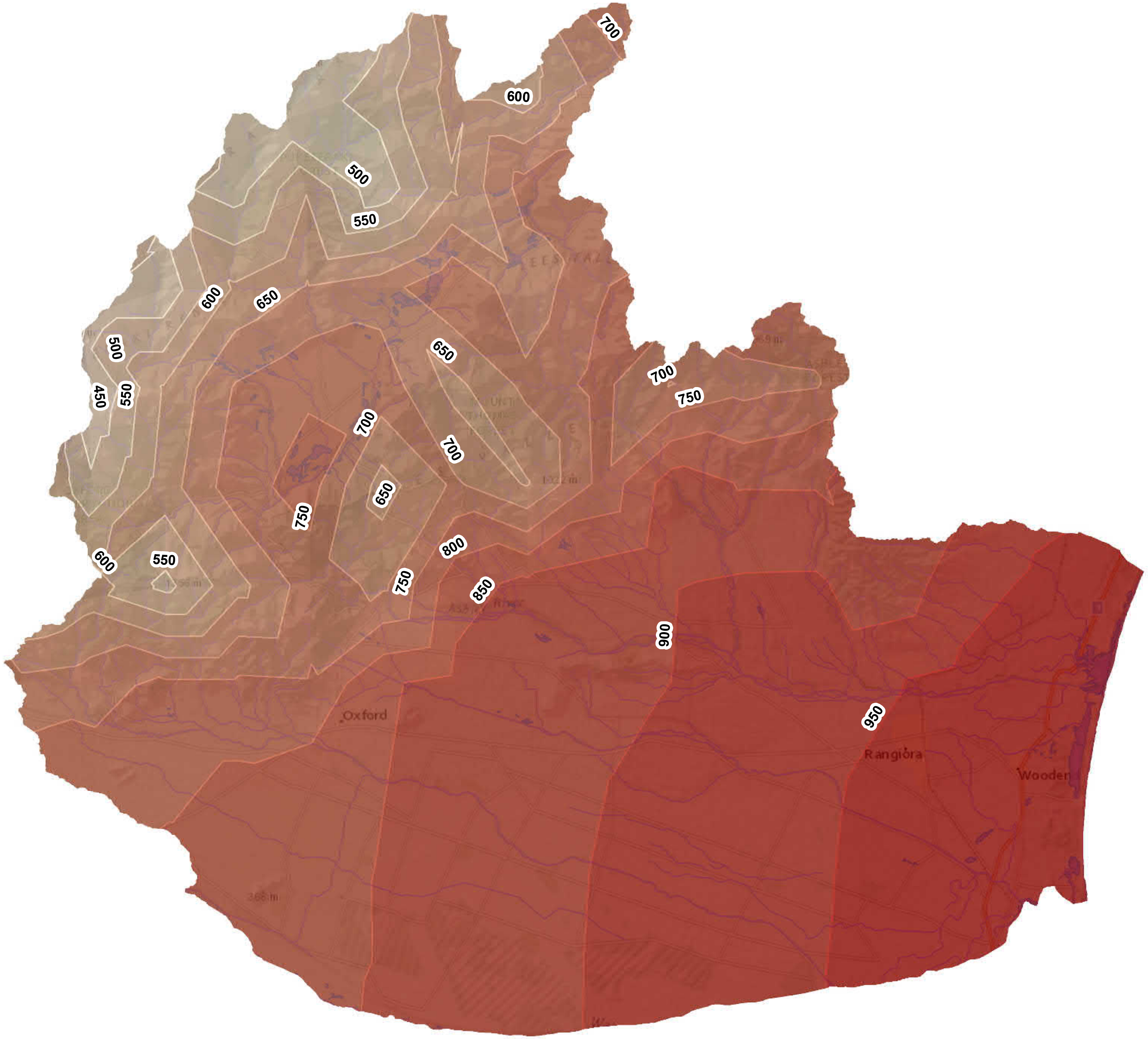

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1	SH	MM	Final	20/12/16
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File Name	Map 12		

Map features depicted in terms of NZTM projection.

Environment Canterbury Regional Council
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Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **VCSN Annual average PET map (1972-2014)**

Scale: 1:250,000 (A3 size) — 2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 12** | Rev. 1

4 Climate

4.1 Introduction

The Waimakariri Zone is located on the east coast. Its most western extent includes the eastern foothills that lead into the Main Divide. The zone's location means that all but the most severe of storms from the West Coast do not provide significant rainfall.

4.2 Precipitation

Within Canterbury, rainfall is greatest along the Main Divide, which has both high elevation and exposure to storms which move up the West Coast. The scale of the Main Divide is such that it protects most of eastern Canterbury, including the Waimakariri Zone, from the majority of the rainfall associated with such storms. As a result, there is a marked decrease in rainfall east of the Canterbury high country. It requires a particularly large event on the West Coast to create 'spillover' rainfall in the headwaters of the Waimakariri Zone.

Therefore, in the Waimakariri Zone, rainfall is derived principally from northerly, eastern and southerly quarters, amounting to around 800 mm per year on average (Srinivasan and Duncan, 2012).

The greatest rainfall totals occur in August, although there is limited variation in the mean monthly rainfall (**Figure 7**).

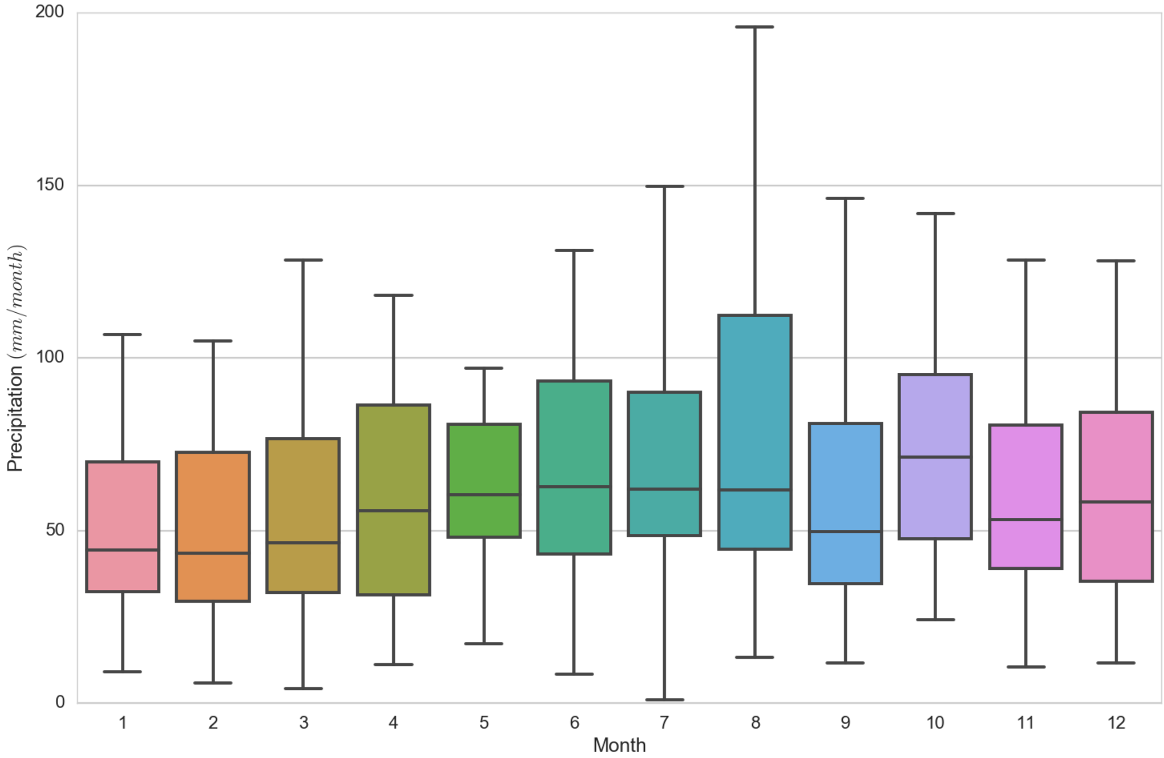


Figure 7 - Mean monthly precipitation for the Waimakariri Zone, based on VCSN data

Spatially, the highest annual average rainfall is located in the Puketeraki Range, in the Ashley River/Rakahuri headwaters. Rainfall totals are highest furthest west and closest to the Main Divide, but also increase because of the orographic effects of the Oxford-Richardson-Thomas foothills (**Map 11**).

4.3 Potential evapotranspiration

PET in the Waimakariri Zone causes soil moisture deficits to peak in summer, whereas surface water runoff and soil moisture peaks in the winter months. Compared to the rest of New Zealand mean soil moisture deficits observed in the zone are relatively high (Macara, 2016). PET is greatly increased during the dry nor-westerly foehn winds.

PET varies greatly throughout the year, with rates peaking in December and January (**Figure 8**).

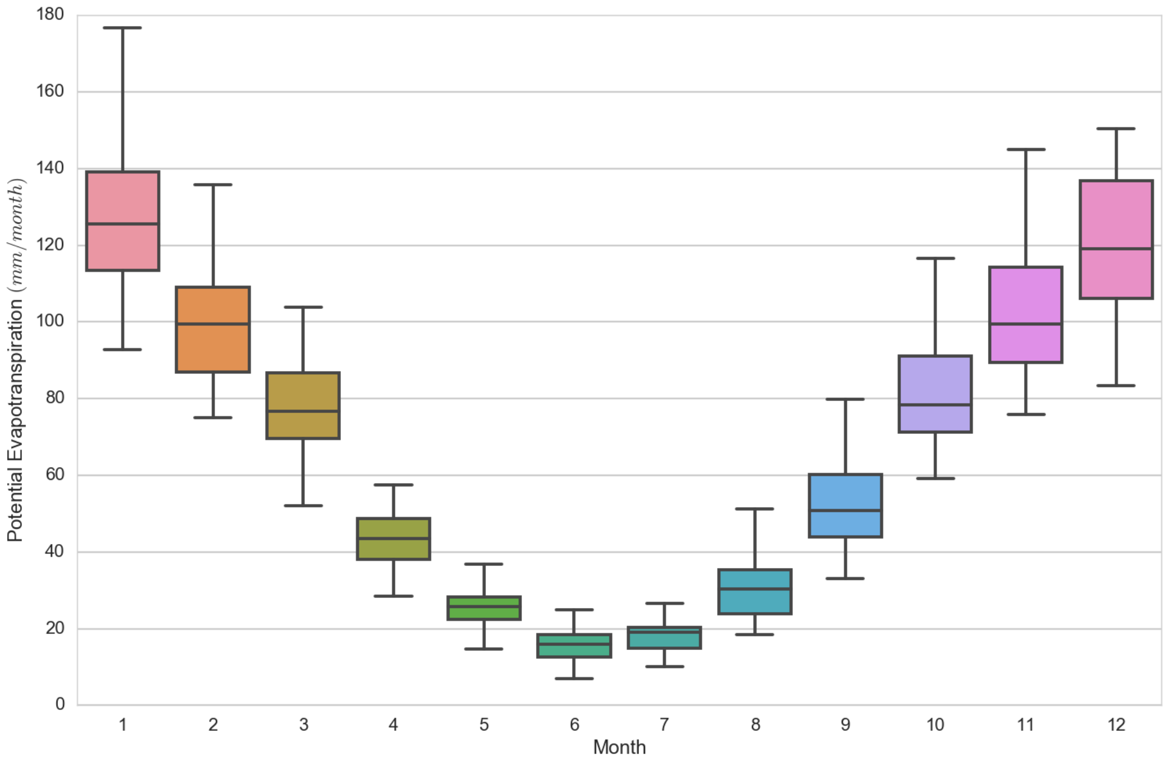


Figure 8 - Mean monthly PET for the Waimakariri Zone, based on VCSN data

The highest average annual evapotranspiration is located towards the east coast (**Map 12**) Evapotranspiration generally decreases towards the Main Divide but there is a localised increase in evapotranspiration within the Lees Valley.

4.4 Soil moisture balance considerations

Taking the difference between monthly precipitation and PET provides an indication as to which months are likely to provide recharge to watercourses and groundwater, and which are not. It also indicates which months are likely to require significant inputs of irrigation water for those users undertaking water intensive agriculture (**Figure 9**). Our analysis shows that for the majority of years a negative water balance exists between November and February, with a positive balance for the rest of the year. This highlights that rainfall is insufficient to meet soil moisture needs for intensive agriculture over the summer months, hence the requirement for irrigation water.

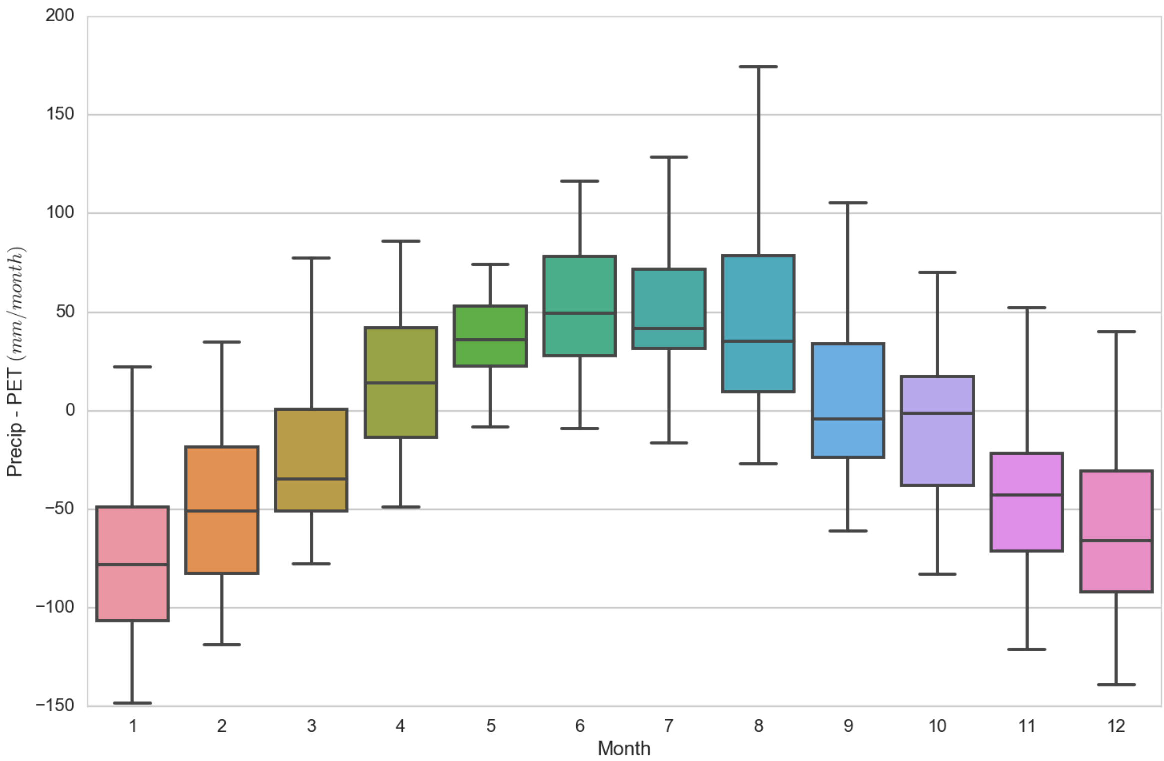


Figure 9 - Difference in mean monthly PET and precipitation for the Waimakariri Zone, based on VCSN data

5 Watercourses

In this section we will provide a summary of the main watercourses with regards to surface water hydrology. We have undertaken a review of the available information and where appropriate expanded on it. The zone's watercourses were split into four groups to assist with the understanding of each watercourse's role in the zone, as well as any potential effects that may occur (**Table 3**, **Map 13**, **Map 14**).

Table 3 - Main watercourses

Category	Watercourse	Character	Notes
Alpine	Waimakariri River	Dominated by runoff from the Main Divide and contributes significant volumes of water to groundwater on the plains.	Information only - not included in Waimakariri Zone. Source of water for large irrigation schemes in zone and minor groundwater recharge.
Hill-fed (Main)	Ashley River/Rakahuri Okuku River	Dominated by hillslope runoff from intermediate alpine ranges. Provides water to the groundwater of the plains. Braided and may run dry in summer due to losses of water to ground.	These watercourses are sources of water for the zone, either directly or through the recharge of groundwater. In their lower reaches they are also receptors for effects of activities occurring on the plains. Important habitat for nesting birds.
Hill-fed (Other)	Group 1: Coopers Creek, Mounseys Stream, Trout Creek, Gammans Creek, Ellis Drain, Deep Creek Group 2: Unamed a,b,c, Glentui River, Washpool Stream, Gary River, Mt Thomas Stream, Bullock Creek, Kowhai Stream Group 3: Fox Creek, Karetu River, Gray River, Makerikeri River Group 4: Unnamed d, e, Saltwater Creek, Stony Creek, Boyne Creek, Foxs Creek	Dominated by hillslope runoff from foothills. Similar to above category but small catchment areas and do not extend into the higher mountains of the Puketeraki Range.	Divided into discrete blocks for this work to represent contributions to the water balance of the zone. <u>Group 1</u> Eyre-Ashley <u>Group 2</u> Richardson-Thomas <u>Group 3</u> Mt Grey (West) <u>Group 4</u> Mt Grey (East)
Lowland	Kaiapoi River Ohoka Spring Cust Main Drain Silverstream Cam River Cust River (main stem) Courtenay Stream Greigs Drain Kaiapoi River No.7 Drain North Brook Middle Brook South Brook Latimers Creek Pancake Stream Saltwater Creek Waikuku Stream Little Ashley Stream Taranaki Creek Eyre River (main stem) Eyre River Diversion	Spring fed and generally not directly connected to hillslope runoff.	These watercourses will show the effects of water quantity and quality changes on the plains. They can be considered as receptors.

5.1 Flow Characteristics

The methodology we used to produce the flow characteristics (**Tables 4 - 7**) in this section is presented in **Appendix A**. Where monitored site data was available for the site of interest that data was used to determine the flow characteristics. When insufficient or no data was available for the site of interest the data were estimated based on nearby and/or similar monitoring data. Sites where data has been estimated (**Tables 4 – 7**) are presented without a site number as they do not form part of the monitoring network.

Table 4 - Foothill/hill-fed flow sites

Monitoring site	Season	Flow statistics								
		Q5 L/s	Q25 L/s	Q50 L/s	Q75 L/s	Q95 L/s	Average L/s	MALF7d L/s	FRE3 per year/ season	Accrual period days
Primary flow sites										
66204 Ashley/Rakahuri River at gorge (normalised)	Water Year	1,778	3,631	6,994	13,085	37,031	12,319	2,040	11	29
	Irrigation Season	1,691	3,012	5,399	10,585	28,323	9,488	2,050	-	-
	Non-irrigation Season	3,233	6,488	10,266	16,760	39,074	15,094	3,500	-	-
Secondary flow sites										
66201 Ashley/Rakahuri River at SH1 Bridge	Water Year	75	1,375	9,027	18,486	62,798	17,021	102	12	26
	Irrigation Season	21	562	2,425	10,432	43,328	10,238	102	-	-
	Non-irrigation Season	1,689	11,166	14,980	21,246	70,692	22,366	2,353	-	-
66213 Okuku River at Fox Creek	Water Year	404	1,015	2,261	4,715	13,884	4,417	446	12	25
	Irrigation Season	396	780	1,429	2,928	9,346	2,919	539	-	-
	Non-irrigation Season	826	1,867	3,271	6,143	16,632	5,753	941	-	-
66409 Cam River at Youngs Road	Water Year	921	1,230	1,343	1,577	2,119	1,487	1,010	2	180
	Irrigation Season	813	1,133	1,273	1,366	1,630	1,280	1,010	-	-
	Non-irrigation Season	1,264	1,343	1,478	1,715	2,338	1,693	1,245	-	-
66472 Coopers Creek at Mountain Road	Water Year	194	350	510	827	1,535	682	168	9	38
	Irrigation Season	161	207	288	402	887	381	148	-	-
	Non-irrigation Season	203	307	574	996	2,039	805	199	-	-
166405 Eyre River at Trigpole Road Ford	Water Year	91	124	208	521	1,406	467	87	17	17
	Irrigation Season	87	105	131	219	474	195	87	-	-
	Non-irrigation Season	124	157	199	319	969	323	121	-	-
1664414 Cust River at Carleton Road Bridge	Water Year	10	34	112	337	945	306	7	10	27
	Irrigation Season	8	20	41	105	230	78	7	-	-
	Non-irrigation Season	73	111	140	230	914	276	73	-	-

Table 5 - Tertiary foothill/hill-fed flow sites (normalised)

Monitoring site	Flow statistics						
	Q5 L/s	Q25 L/s	Q50 L/s	Q75 L/s	Q95 L/s	Average L/s	MALF7d L/s
166406 Eyre River at Washpen Road ford	23	53	132	423	1,244	372	20
166408 White Stream at Upper Perhams Road ford	11	35	78	156	462	146	23[1]
1516 Mounseys Stream at Island Road	50	867	155	277	758	262	37
166414 Trout Creek tributary 1 at Bush Road	2	2	21	56	192	51	2
166415 Trout Creek tributary 2 at Bush Road	0.0	0.0	2	5	19	5	0.0
166413 Trout Creek at Bush Road	12	19	59	131	414	122	14
166416 Gammans Creek at Bush Road bridge	66	79	111	229	565	209	36
1664413 Ellis Drain south of Victoria Street	0.0	0.3	2	6	20	6	0.0
1664412 Ellis Drain north of Victoria Street	0.1	0.1	2	3	11	3	0.1
1664411 Ellis Drain at The Grange	4	8	16	29	82	27	4
1664410 Ellis Drain upstream of Ashley Gorge Road	2	4	9	17	48	16	2
66205 Deep Creek at Carleton Road culvert	0.3	3	15	35	117	33	0.8[1]
1620 Glentui River at Ashley Gorge Road	60	103	180	319	868	302	52
Washpool Stream[2 3]	9	16	28	50	135	47	8
240 Garry River at Birch Hill Road Bridge	73	159	317	602	1,722	566	102
Mt Thomas Stream[2 3]	12	30	64	137	469	145	12
Bullock Creek[2 3]	6	14	30	65	222	69	6
Fox Creek[2 3]	7	23	54	109	325	102	2
Kowhai Stream[2 3]	5	18	42	86	257	80	1
242 Karetu River at Main Loburn Road[2]	19	70	161	326	974	305	5
1613 Grey River at D/S Grey River West Branch	35	126	292	592	1,770	554	8[1]
Makerikeri River[2 3]	26	94	218	442	1,321	413	6
Saltwater Creek[2 3]	0.6	2	5	10	29	9	0.1
Stony Creek[2 3]	5	19	45	91	271	85	1
Shaw Creek[2 3]	1	4	9	18	55	17	0.3
Boyne Creek[2 3]	0.8	3	7	14	41	13	0.2
Foxs Creek[2 3]	5	16	37	75	224	70	1

[1] Indicative values formulated using less than 10 gaugings.

[2] Values estimated using area and rainfall scaling only

[3] Site not located at current monitoring point

Table 6 - Lowland/spring-fed flow sites

Monitoring site	Season	Flow statistics								
		Q5 L/s	Q25 L/s	Q50 L/s	Q75 L/s	Q95 L/s	Average L/s	MALF7d L/s	FRE3 per year/season	Accrual period days
Primary flow sites										
66417 Cust Main Drain at Threlkelds Road	Water Year	421	729	1,063	1,757	4,469	1,751	492	7	49
	Irrigation Season	372	612	813	1,214	2,432	1,099	483	-	-
	Non-irrigation Season	716	1,057	1,508	2,863	5,968	2,541	756	-	-
Secondary flow sites										
66407 South Brook Spring at Schluters Weir	Water Year	0.2	2	3	6	13	4	1	1	431
	Irrigation Season	0.03	2	3	5	7	3	1	-	-
	Non-irrigation Season	2	3	4	7	15	6	2	-	-
66415 Silverstream (Kaiapoi) at Harpers Road	Water Year	127	211	306	430	596	329	195	1	437
	Irrigation Season	118	174	278	347	473	279	173	-	-
	Non-irrigation Season	150	213	393	486	651	375	195	-	-
66429 Silverstream (Kaiapoi) at Silverstream Weir	Water Year	370	660	800	940	1,110	784	559	0	n/a
	Irrigation Season	340	620	750	890	1,050	733	563	-	-
	Non-irrigation Season	520	730	860	970	1,170	858	617	-	-
66435 Ohoka Spring at Dalleys Weir	Water Year	2	4	5	6	8	5	3	1	474
	Irrigation Season	2	4	5	6	7	5	3	-	-
	Non-irrigation Season	2	4	5	6	8	5	3	-	-
66216 Taranaki Creek at Greesons Road	Water Year	104	109	119	141	171	127	101	0	n/a
	Irrigation Season	100	106	111	116	126	111	100	-	-
	Non-irrigation Season	95	123	132	144	172	135	98	-	-
66475 Cust River at Rangiora Oxford Road	Water Year	359	499	719	1,782	3,115	1257	300	11	28
	Irrigation Season	230	368	505	621	1,289	567	214	-	-
	Non-irrigation Season	396	556	1,023	2,092	3,676	1,531	336	-	-
389 Waikuku Stream at Waikuku Beach Road	Water Year	393	470	592	663	749	582	355	2	182
	Irrigation Season	378	422	495	562	647	499	355	-	-
	Non-irrigation Season	601	625	643	673	700	650	602	-	-

Table 7 - Tertiary lowland/spring-fed sites (normalised)

Monitoring site	Flow statistics						
	Q5 L/s	Q25 L/s	Q50 L/s	Q75 L/s	Q95 L/s	Average L/s	MALF7d L/s
368 Kaiapoi River at Skewbridge Road[1]	1,416	1,535	1,664	1,932	2,980	1,930	1,350
370 Ohoka Stream at Kaiapoi River confluence1	532	586	645	767	1243	765	505
366 Cam River at Youngs Road[1]	1,212	1,276	1,345	1,489	2,049	1,487	1,194
66432 Courtenay Stream at Ashley Meat Factory[1]	335	348	363	394	513	393	332
66215 Taranaki Creek at Preeces Road[1]	174	190	207	244	386	243	174
1343 Silverstream at hatchery[1]	659	707	758	865	1,282	864	637
66414 Griegs Drain at Taylors Road[1]	64	65	65	67	72	67	60

[1] Indicative values from regression analysis of lowland/spring-fed sites

5.2 Flow trends

We examined the available data sets for trends to understand stationarity of data, an important principle in the analysis of the data, and also to characterise what is happening in the zone that may affect the scenarios to be considered later in this process. We have presented the main trends below.

5.2.1 Cust Main Drain

Data from the Cust Main Drain at Threlkelds Road were investigated to determine if there was a change in flow since the start of Waimakariri Irrigation Limited in 1999/2000.

Flow percentiles were generated for two periods, split around 2000 (**Figure 10**). For the period following commissioning of the WIL scheme, an obvious increase in flows below the median was identified although flows at higher percentiles appeared to be unaffected. This would support the theory that leakage, by-wash and applied irrigation water is contributing to higher base flows at this site. Smith (2015) also investigated this data and, through an analysis of MALF7d, concluded that a difference between these periods existed and may be attributed to WIL.

We investigated the presence of a similar signature at the other permanent flow monitoring sites; Ohoka Spring and South Brook (**Figure 11, Figure 12**). Ohoka Stream showed a strong difference pre and post WIL which is not unexpected given that it is directly down gradient of the main WIL command area. The response in Southbrook was less clear, with a small increase in base flows, but a larger reduction in peak flows. We consider that the effect, if any, is small enough to be masked by other influences.

An alternative hypothesis for the responses observed is that it is climate driven. The percentile flows from Cust Main Drain were compared with those in the Ashley River/Rakahuri, as this could be expected to also show similar trends if climate were responsible (**Figure 13**). The Ashley River/Rakahuri shows the reverse pattern, with lower flows during the 2002-2015 period. Again, Smith (2015) supports this with an analysis of MALF7d in the Ashley River/Rakahuri which shows lower flows between 2002 and 2015. In addition McKerchar (2010) reported a general decline in streamflow on the east coast as a result of a dryer than normal period between 2001 and 2007. For Cust Main Drain to show an increase in base flow during this period when the plains and hills are showing lower than normal flows, indicates that the change in flows is due to the influence of WIL.

This point is important for the scenarios as the contribution from WIL may mask losses resulting from consented groundwater and surface water takes. The low-flow regime of these watercourses would also change if leakage reduction is pursued by WIL. This will have a consequential effect on nutrient concentrations and flows of groundwater and surface water.

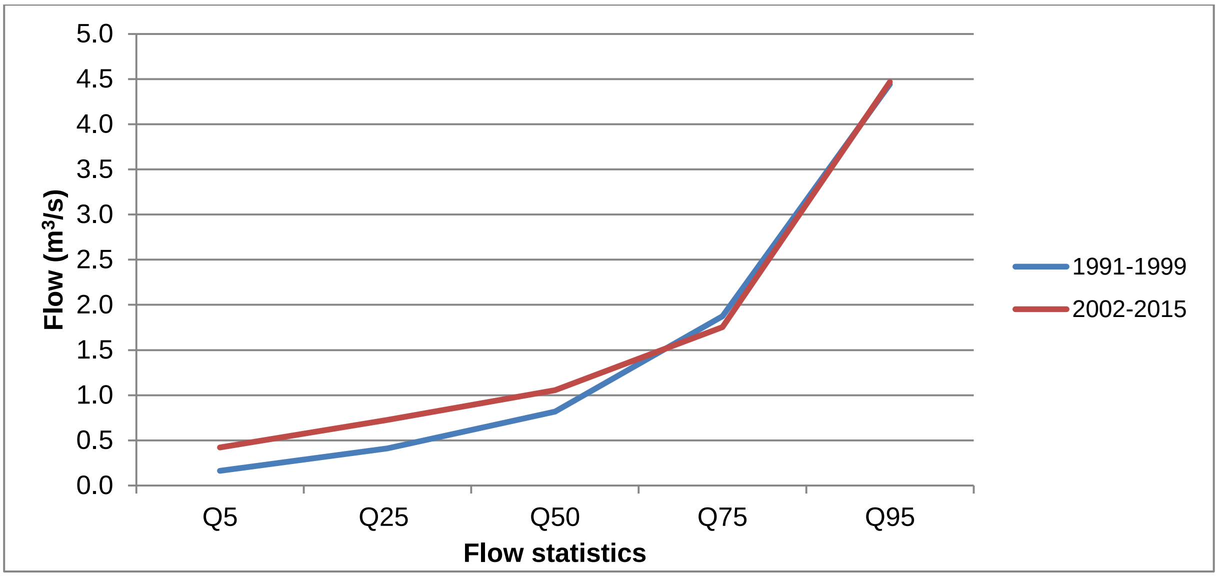


Figure 10 - Cust Main Drain before and after the WIL irrigation scheme

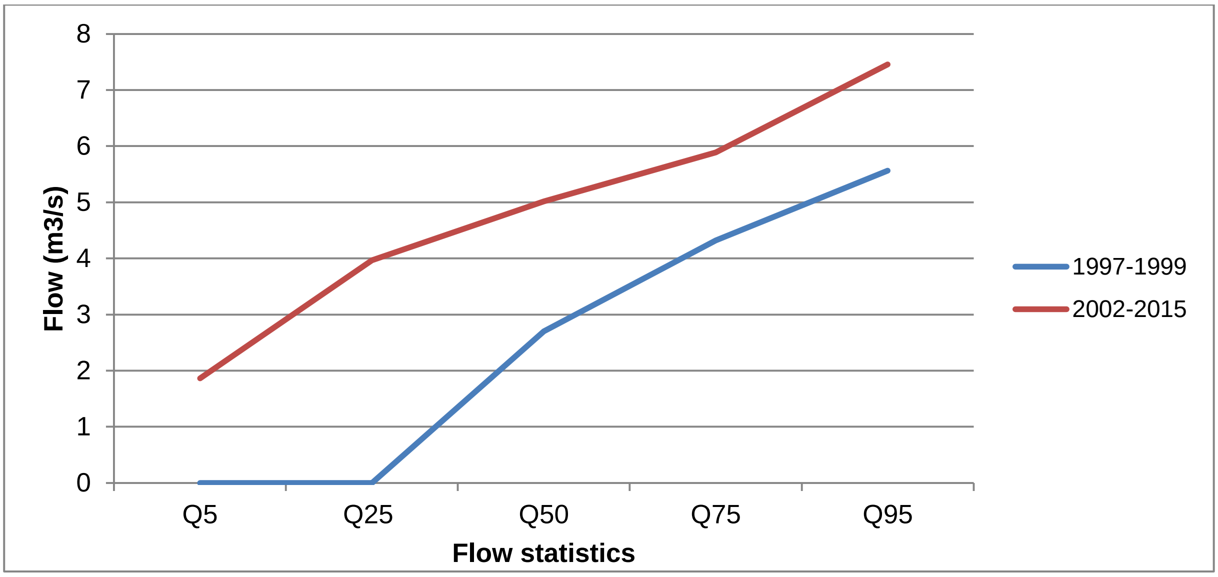


Figure 11 - Flow statistics for the Ohoka Spring before and after the WIL irrigation scheme

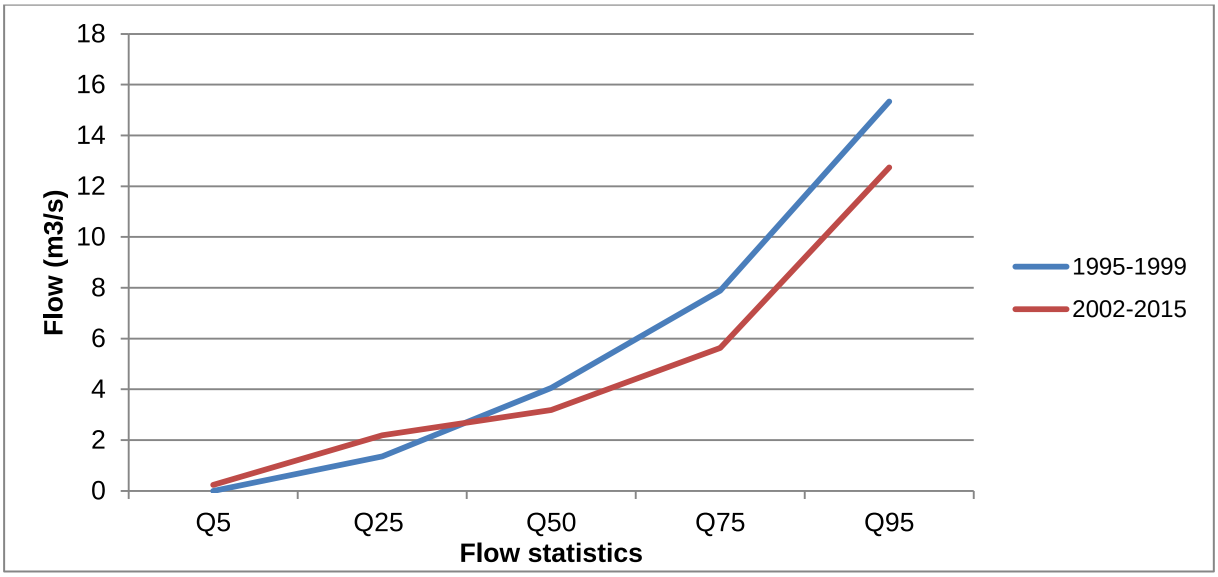


Figure 12 - Flow statistics for the South Brook before and after the WIL irrigation scheme

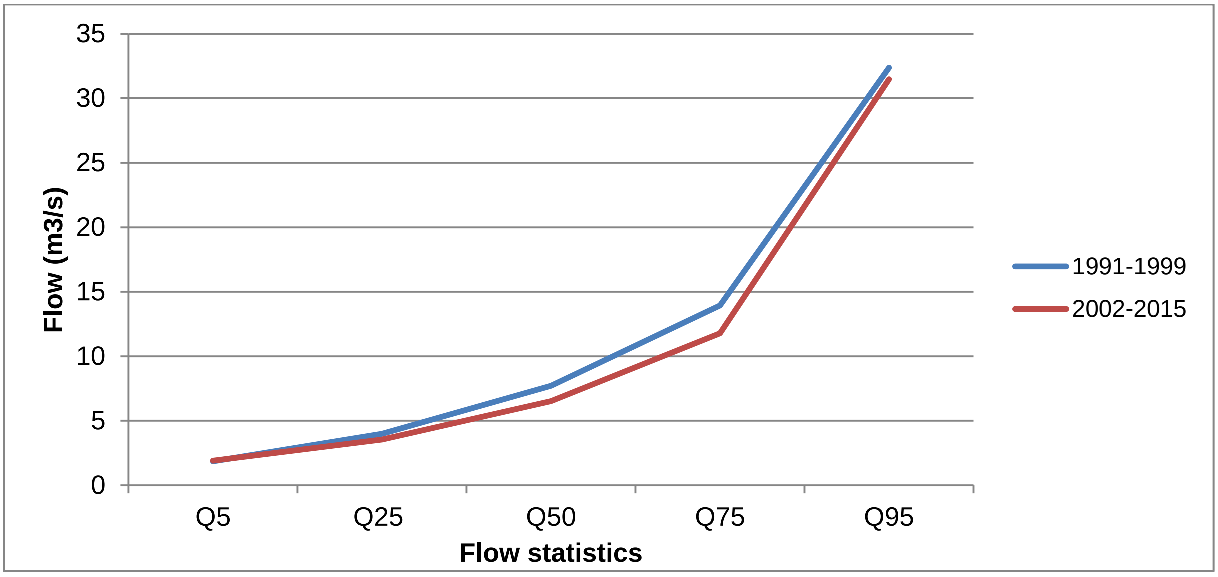


Figure 13 - Flow statistics for the Ashley/Rakahuri River before and after the WIL irrigation scheme

5.2.2 Ashley River/Rakahuri

Smith (2012) states that groundwater levels around Rangiora were noted to be in decline over the preceding decade. Smith (2012) investigated this trend for flows in the Ashley River/Rakahuri, given that the Ashley River/Rakahuri loses a large amount of its flow around Rangiora.

Smith plotted annual mean flows from the Ashley at Gorge recorder (**Figure 14**). Using a five-year running mean, Smith noted that since the mid-1980s mean flows have been relatively constant but appeared to have declined preceding that period.

McKerchar et al (2010) analysed flows in a range of catchments north of Christchurch and identified a number of wetter than normal years from 1974 to 1980, followed by exceptionally dry conditions from 2001 to 2007. This corresponds with the pattern Smith (2012) identified in the Ashley River/Rakahuri data.

This analysis suggests that groundwater levels around Rangiora are, in part, a result of lower flows within the Ashley River/Rakahuri. Importantly, this also flags an important consideration in the discussion around drying reaches of the Ashley River/Rakahuri, as it suggests the period from 2001 to 2007 would be more susceptible to channel drying than the preceding period. Consideration of how this might contribute towards the real and/or perceived effects of abstraction on the river is required.

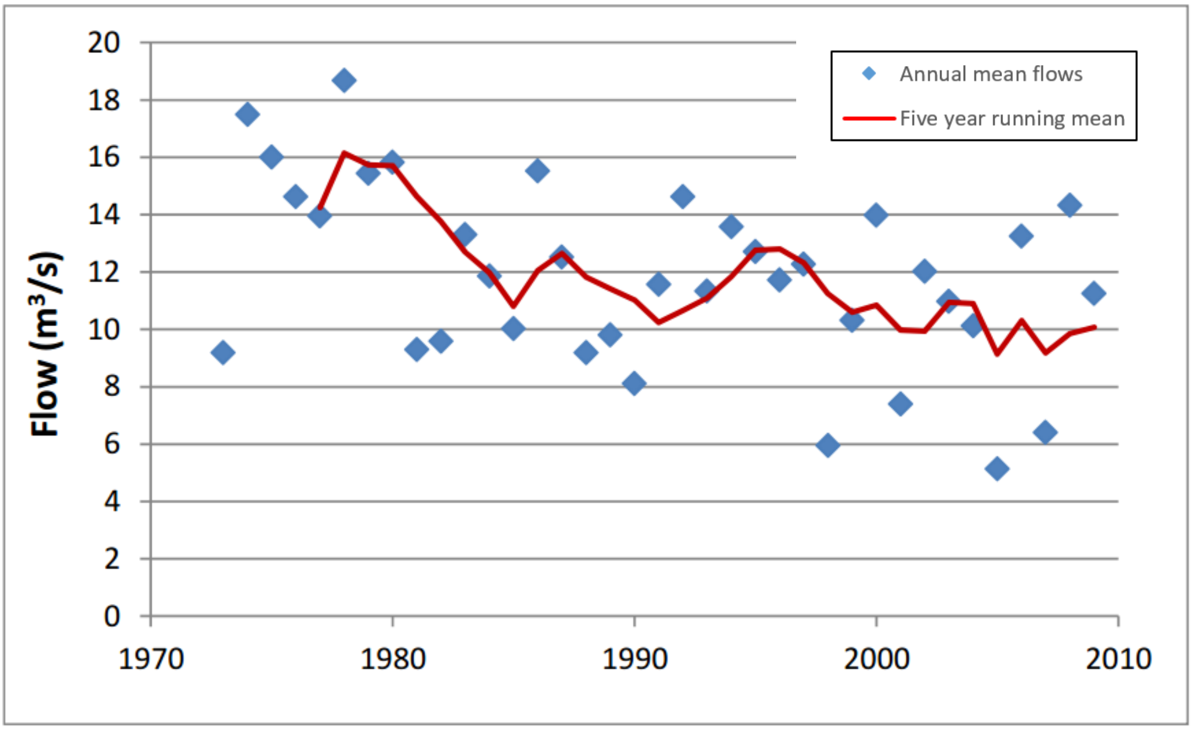
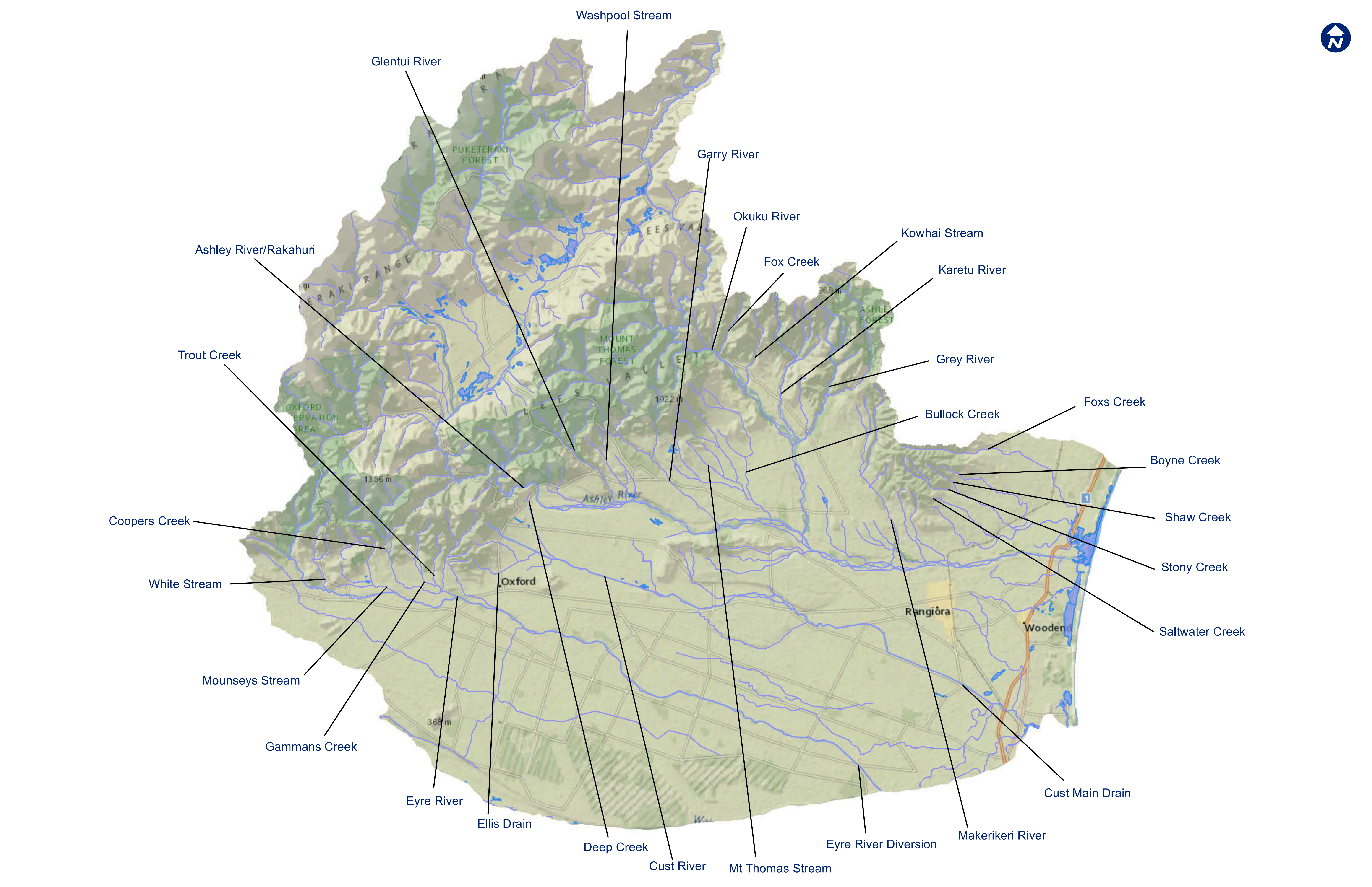


Figure 14 - Ashley at Gorge annual mean flows (Smith, 2012)



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Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **Main Watercourses - Hill-fed**

Scale: 1:250,000 (A3 size)

2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 13** | Rev. 1

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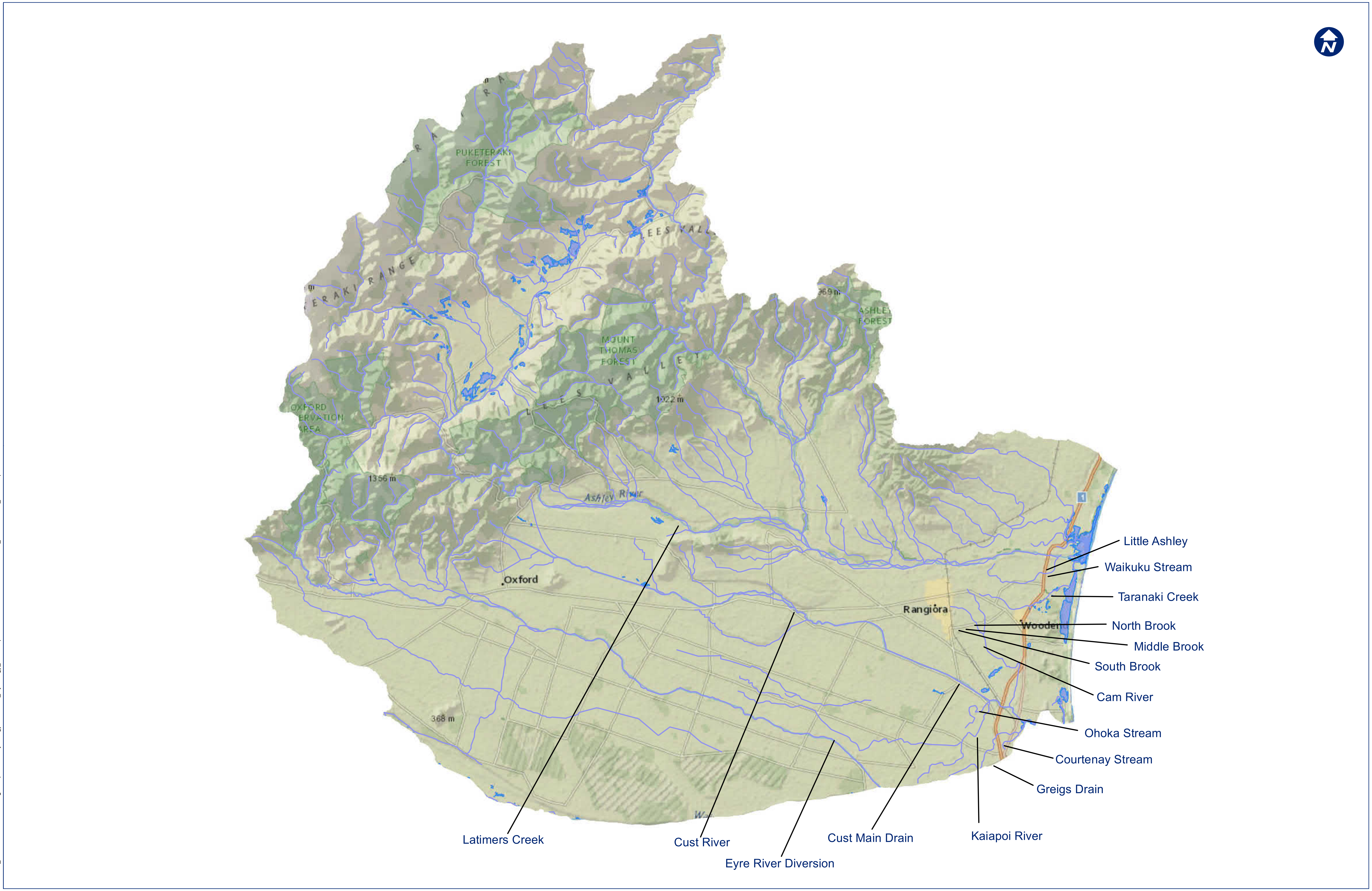

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Environment Canterbury Regional Council
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Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **Main Watercourses - Lowland**

Scale: 1:250,000 (A3 size) 2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 14** | Rev. 1

6 Watercourse losses and gains

Within the Waimakariri Zone, as for much of Canterbury, gains and losses from surface water begin to occur where the foothills give way to the alluvial deposits that make up the Canterbury Plains. Losses and gains to and from the underlying gravels influences river flow in different ways as the water makes its way across the plains. The flow losses and gains in the Waimakariri Zone have been identified and estimated across multiple studies (**Map 15**).

Flow loss and gain rates can vary significantly depending on the flow within a channel. For this work we identified that low flows are the most relevant to consider. They are also generally the most stable situations, which allows us to define losses and gains with some degree of certainty. Farrow (2016) provides loss and gains at mean flow, Chater (2004) uses MALF7d, and we have used these along with several other studies to characterise the loss and gain patterns.

6.1 Ashley River/Rakahuri

From the extensive investigations undertaken to characterise the Ashley River/Rakahuri (Bowden (1982), Horrell (1995), Chater (2004), Smith (2012), Farrow (2016)) it is clear that there is a complex pattern of loss and gain.

Chater (2004) quantified the loss and gain pattern at MALF7d (**Figure 15**); Smith (2012) continued the work and characterised the gains and losses in the Ashley River/Rakahuri. Smith (2012) split the river into six reaches and assessed 18 concurrent gauging runs between 2008 and 2011 (**Figure 16, 17**)

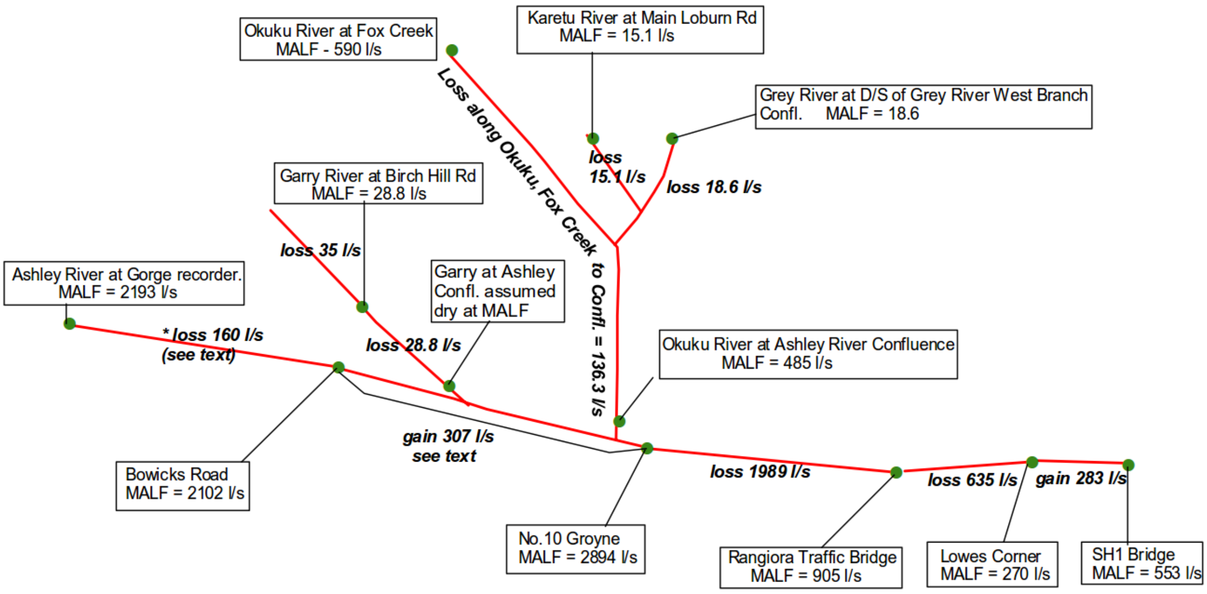


Figure 15 - Chater (2004) loss-gain pattern

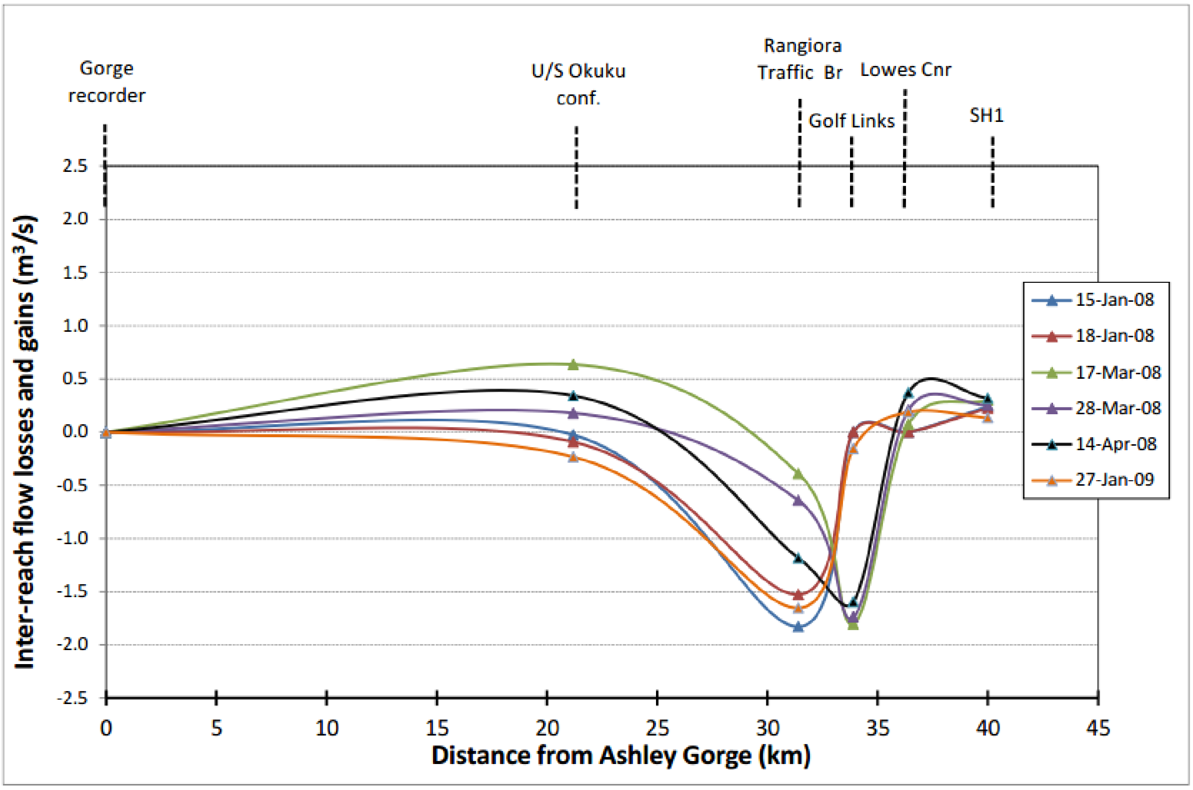


Figure 16 - Smith (2012) loss-gain pattern 2008

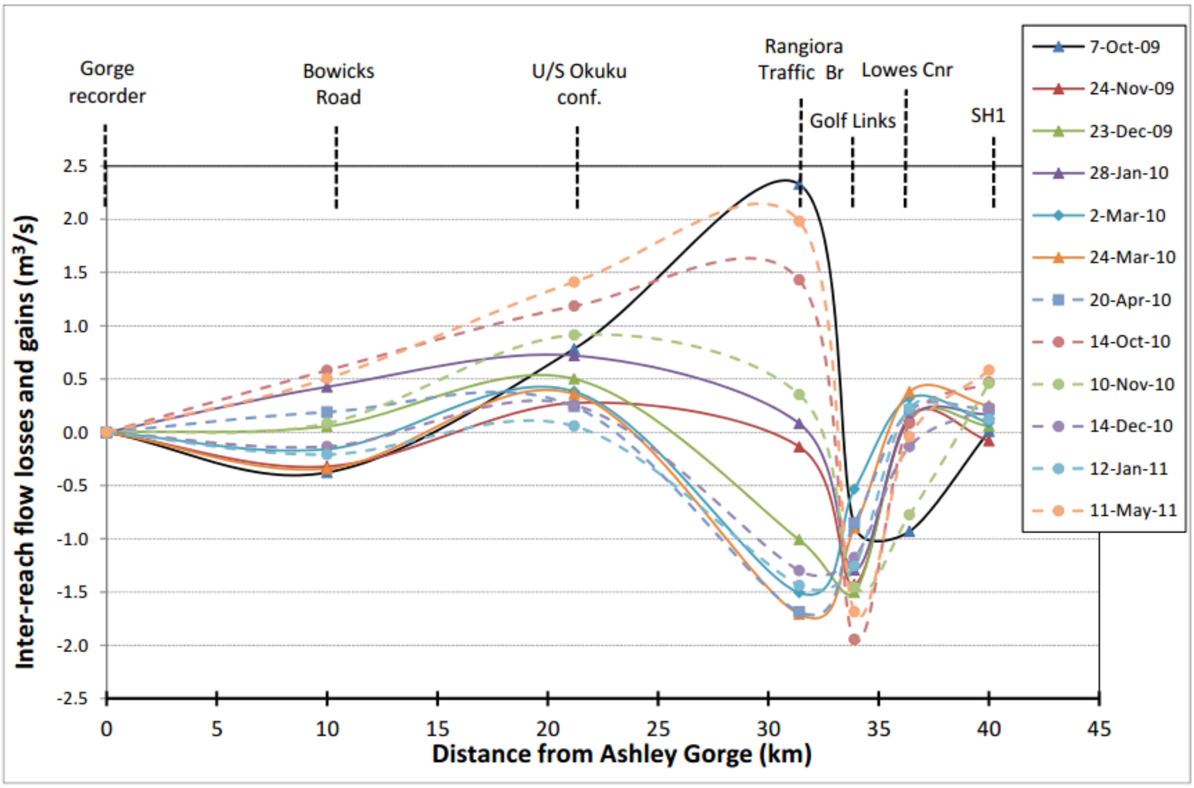


Figure 17 - Smith (2012) loss-gain pattern 2009-2011

Smith (2012) plotted average flows and gains/losses as means from the concurrent gauging data collected between 2009 and 2011 (**Figure 17**). This analysis (**Figure 18**) shows that between the Gorge and Bowicks Road loss and gain is negligible. Chater (2004) considers this reach to be losing, but not significantly so. From Bowicks Road to upstream of the Okuku Confluence a flow gain is noted by Smith (2012). Below this point however, flow losses increase to the Golf links, and after this flow recovers back towards SH1. This broadly reflects the pattern and, to a lesser extent the flux, noted by Chater (2004)

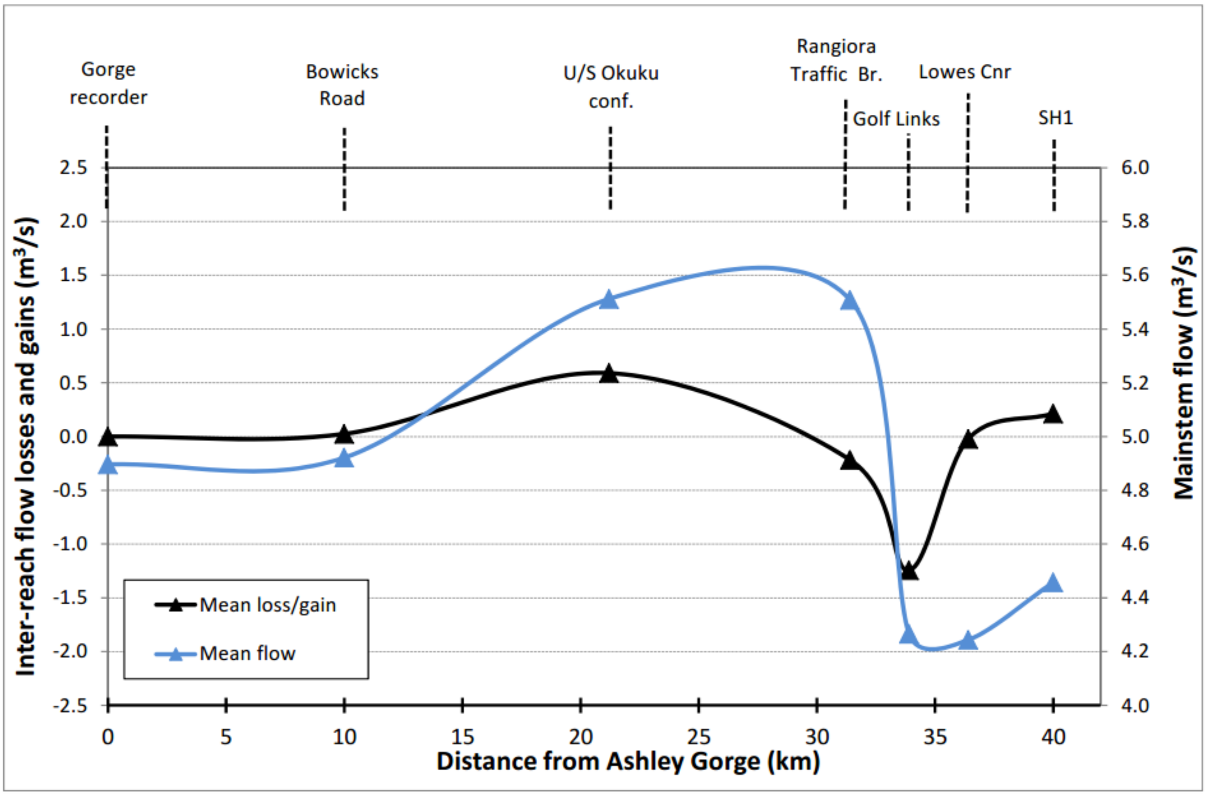


Figure 18 - Smith (2012) mean loss-gain pattern

Farrow (2016) used Chater (2004) and Smith (2012) as the basis for analysis, and therefore generally came to the same conclusion around loss and gain patterns (**Map 15**).

6.2 Eyre River and Eyre River Diversion

The Eyre River has been determined to lose flow to ground along its entire length over the alluvial gravels of the Plains (**Map 15**). The exception to this is its numerous headwater streams, which maintain their flow on the hillslopes of the foothills (Davey G and Smith E, 2005). As soon as these headwater streams cross onto the alluvial materials they lose water at a significant rate; in particular Coopers Creek loses at a rate of 66.4 L/s/km.

The Eyre River is generally dry by Oxford. Farrow (2016) suggests that a flow of <141 L/s at Trigpole Road will result in the river being dry by Depot Gorge Road Bridge, and that a flow of <292 L/s will result in the river being dry by Steffens Road.

Smith (2012) quotes anecdotal evidence that the Eyre River Diversion, into which the Eyre River discharges before meeting the Waimakariri River, flows on average once every two years in response to large rainfall events.

6.3 Cust River and Cust Main Drain

Farrow (2016) has classified the Cust River as gaining along its whole length (**Map 15**). Although the Cust River takes its water from hill-fed catchments it rarely flows with sufficient vigour to incise its fairway (Dodson *et al.,* 2012) suggesting that flows are not significant.

Dodson *et al*. (2012) classifies the Cust River as ephemeral above Carleton Road Bridge and this is supported by site inspections (Dodson 2014). It was also noted at the same site inspections that there is typically always flow in the Cust River at Bennets Road. Farrow (2016) relates this to the historically swampy area at this location.

The upper reaches of the Cust River have little recorded data but piezometric contours suggest that these reaches are on average gaining. Visual observation surveys support these claims when observations taken from 2012 to 2013 suggest the upper reaches are typically gaining (Dodson, 2014).

Further downstream, the river has been noted to run dry at Swannanoa Road during dry periods. Despite running dry at this location, Farrow (2016) estimated that overall the river continues to gain between Swannanoa Road and Threlkelds Road.

As the river transitions into the Cust Main Drain gains continue until the confluence with the Kaiapoi River (Farrow, 2016). Although there are no concurrent gaugings available to characterise this reach, the presence of spring fed rivers such as the Cam River and the Ohoka River that emerge to the west of Kaiapoi suggest that most of the lowland rivers are gaining in this area (Dodson *et al*., 2012).

6.4 Okuku, Grey, Garry, and Karetu Rivers

Chater (2004) undertook a concurrent gauging exercise to characterise the Okuku, Grey, Garry and Karetu Rivers during MALF7d conditions.

From isohyd mapping Chater (2004) estimated that the Garry River loses flow before reaching the Ashley River/Rakahuri, as it flows over the alluvial deposits. The MALF7d estimated by Chater (2004) assumes the Garry River is dry at the Ashley River/Rakahuri confluence during low flows.

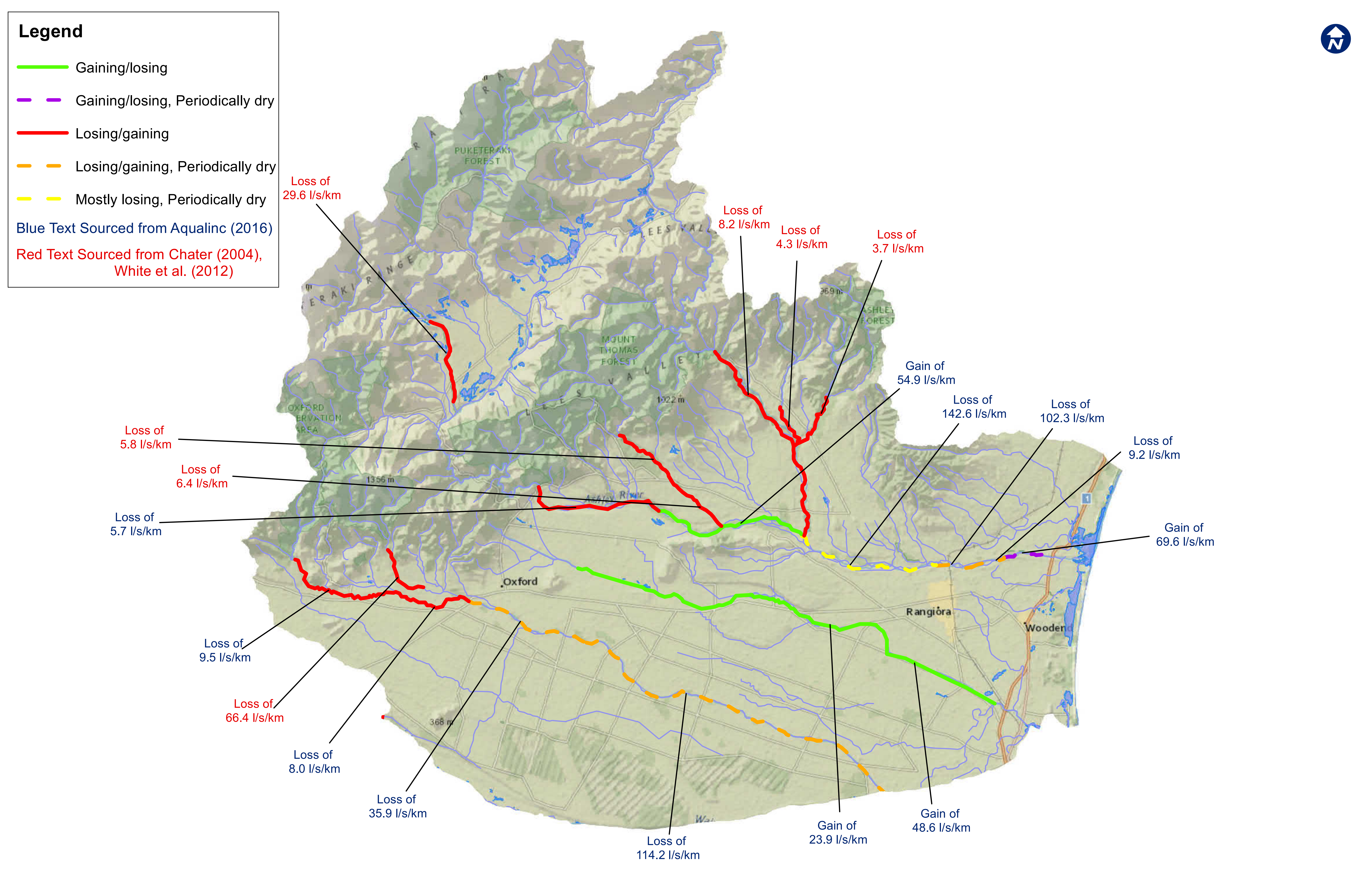
Similarly, Chater (2004) determined (from visual observation), that the Grey River loses all its flow by the time it reaches Main Loburn Road and that the Karetu River loses all its flow by the time it reaches the Grey River confluence.

On the basis of the estimated MALF7d for Okuku River at Ashley confluence, there is a loss of 137 L/s between Okuku River at Fox Creek and Okuku River at Ashley confluence. This is comprised of a 105 L/s evident flow loss, plus 31 L/s which is gained through isoydal integration from Fox Creek to the Ashley confluence (excluding the Karetu and Grey catchments where flow losses are already accounted for) (Chater, 2004).

6.5 Lowland streams

The lowland streams located near the coast are all classified gaining streams. They derive the majority of their flow from springs and also receive land-surface runoff to a greater or lesser extent. As such the estimated flow statistics (**Table 6, 7**) for each of these streams represents the amount of gain in flow.

As we noted earlier in this report, the majority of these streams gain water primarily with groundwater sourced from land surface recharge. The exception to this is Silverstream that is partial fed in its upper reach by water from the Waimakariri River.



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Rev.	By	App.	Description	Date
1	SH	MM	Final	20/12/16
A	SH	MM	Draft for review	9/07/16

Notes: Losses and gains calculated from simultaneous stream gaugings as in Chater (2004) and Farrow (2016). Naturalised flows used to determine losses and gains were sourced from the studies: Chater (2004) and White et al. (2012). Gains and losses measured in low flow conditions (Farrow, 2016).

Printed	04 Oct 2016 13:10		
Drawn	SH	Date	15/07/2016
Checked	MM	Date	15/07/2016
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File Name	Map 15		

Map features depicted in terms of NZTM projection.

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Waimakariri land and water solutions programme

Project: Current State Reporting - Hydrology

Title: Losses and gains

Scale: 1:250,000 (A3 size)

2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 15** | Rev. 1

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7 Standing waterbodies/wetlands

There are no large natural lakes within the zone, although there are a number of wetlands, coastal lagoons and artificial lakes (**Map 16**). All wetlands are considered to be wāhi taonga given that they are mahinga kai habitat, support cultural well-being, maintain and improve water quality, and provide for natural flood protection (Jolly et al., 2013). There is a policy (WM13.4) in the Mahaanui Iwi Management Plan (2013) to advocate for plans that lead to a net gain of wetlands, as well as no loss of remaining natural wetlands.

TAN3.3 (p145) states that environment flow and water allocation regimes must protect the cultural and ecological value of coastal wetlands, estuaries and hāpua. The coastal wetlands were historically well known as food baskets of Ngai Tahu, however the extent and cultural health of these areas has declined significantly (Jolly et al., 2013)

Historically there were extensive wetlands throughout the zone (Bowden, 1983), in particular around the Kaiapoi-Rangiora area (**Figure 19**). These wetlands have been progressively drained to allow for agricultural and urban land-uses and now only remnants remain (**Map 16**).

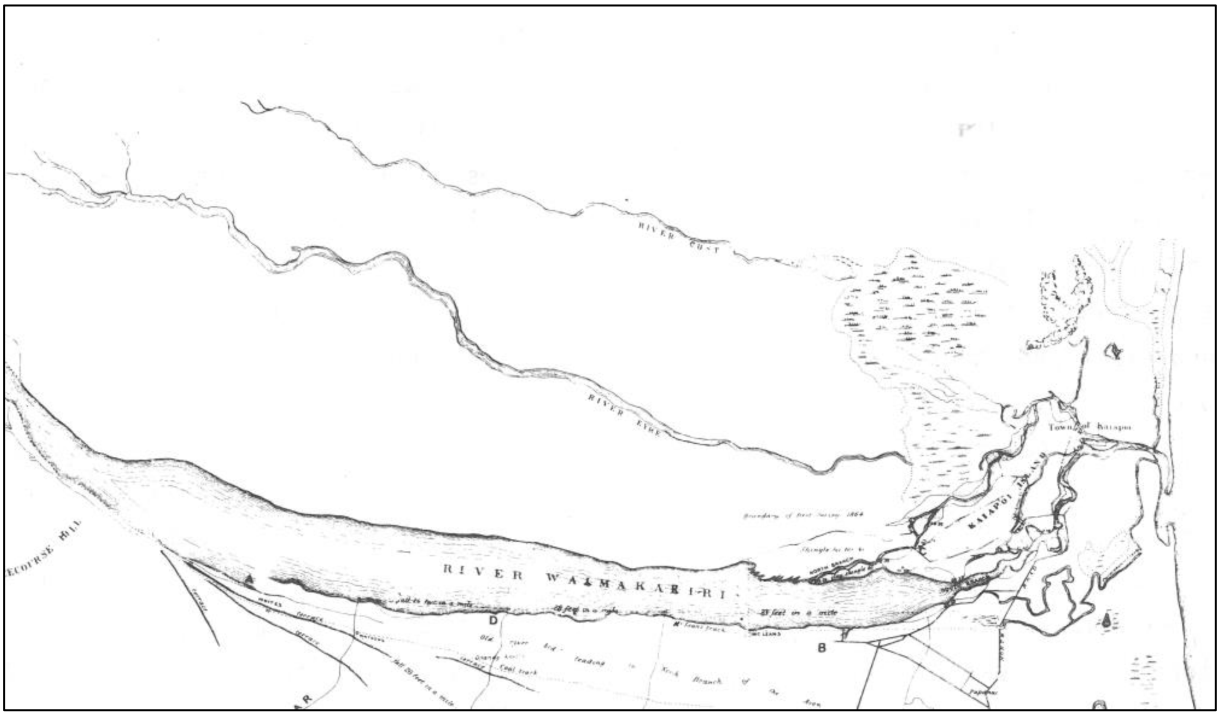


Figure 19 - 1865 swamp extent around Rangiora/Kaiapoi

Each remnant area of wetland or lagoon will have a sensitive water balance that maintains its current character (Winter, 1998). In most cases this will be a combination of direct rainfall, surface inflow (through floods and/or baseflow), groundwater and potentially water delivered by infrastructure. The precise balance of these sources will determine each wetland's vulnerability to change. In general only limited information is available on the water balance for remnant wetlands.

There are a significant number of very small remnant wetlands and marshes throughout the zone, but not all are documented and where Environment Canterbury does hold information, the details around supporting hydrology are very limited. **Table 8** lists the main wetland areas for which information was identified.

Significant effort is required to understand the hydroperiod for each feature, and we did not undertake this as part of this work. To allow future effects on these features to be considered, we have listed the main features below, along with what knowledge is held on their character. The wetland summaries presented in this section are based on the wetland record sheets compiled by Environment Canterbury (2004-2016).

Table 8 - Description of standing waterbodies and wetlands in the Waimakariri Zone (Environment Canterbury, 2004-2016)

Site name	Hydrology	Comments	Location
Ashley/Saltwater Creek Estuary	Estuarine	Tidal	Coastal
Tutaepatu Lagoon-Waikuku Wetlands	Palustrine	Groundwater spring fed system	Coastal
Sandhill Road Lakes	Palustrine/Lacustrine. Groundwater/surface water	Artificial lakes dug in old dune slack. McIntosh's drain flows into main lake	Coastal
Kairaki Creek	Estuarine	Tidal	Coastal
Poynters Reserve/Kaiapoi River	Riverine and Estuarine	Tidal freshwater. Salinity <5ppt.	Coastal
Monopoli's Pond	Palustrine	Pond by Waimakariri River	Coastal
Jockey Baker Creek	Estuarine	Tidal. Salinity >5ppt	Coastal
Pines Beach Wetland	Palustrine	Groundwater fed swamp	Coastal
Kairaki Creek	Palustrine and riverine	Ephemeral wetlands: Seasonally ponded low lying farmland	Coastal
Flaxton Swamp	Palustrine	Ephemeral wetland: Seasonally ponded low lying farmland	Coastal
Pegasus Wetlands	Palustrine and lacustrine	A mix of natural, artificial and enhanced wetland and open water habitats	Coastal
Styx-Te Rauakaaka Reserve	Estuarine and Riverine	Tidal. Salinity of lower section >5ppt; upper section <5ppt.	Coastal
Ohoka Swamp	Palustrine	Ephemeral wetland: Seasonally ponded low lying farmland	Coastal
Ashworth ponds	Palustrine and estuarine	Groundwater and seawater intrusion at times	Coastal
Bridgewater swamp	Palustrine	Biodiversity project site	Inland
Astelia grandis swamp	Palustrine	Biodiversity project site	Inland
Baynons-Waimakariri Corridor	Palustrine and riverine	Swamp with periodic surface water flooding from Waimakariri River	Inland
Dog trial Road Wetlands	Riverine and palustrine	Surface water and shallow groundwater from Waimakariri River	Inland
Springvale Flaxland	Palustrine and riverine	Groundwater and surface water (irrigation race inflow).	Inland
Germans Road Wetlands	Groundwater and seasonal surface water	Spring fed swamp with Carex secta, raupo, open pools, willow and Juncus edgariae lower downstream.	Inland
Rampaddock Road swamp forest	Palustrine	Groundwater springs. Remnant kahikatea and pokaka swamp forest	Inland
Birch Hill Wetland	Palustrine	Springs and seepage from terrace above	Inland
Hammonds Wetlands	Palustrine and riverine	Springs and surface runoff from surrounding land into depression.	Inland
Yaxleys Road Swamp	Shallow groundwater from Okuku River	Spring input and surface water outflow	Inland
Okuku River Wetlands (Pig Flat)	Palustrine and riverine	-	Inland
Punanui Stream Wetland	Palustrine	-	Inland
Okuku Downs Stream Wetlands	Palustrine	-	Inland
Duck Creek Wetlands	Palustrine	-	Inland
Broom and Kingsdown Stream Wetlands	Palustrine and riverine	-	Inland
Whistler River Wetlands	Palustrine	Hill runoff and springs	Inland
Snowdale Wetlands	Palustrine	-	Inland
Ashley River Wetlands (Lees Valley)	Palustrine and riverine	-	Inland
Whistler River Wetlands	Riverine	Shallow groundwater and floodwater inputs from the Whistler River	Inland

Site name	Hydrology	Comments	Location
Waimakariri Corridor wetlands	Riverine and palustrine	Surface water and shallow groundwater from Waimakariri River	Inland
Morrison Road Wetland-Waimakariri Corridor	Riverine and palustrine	Surface water and shallow groundwater from Waimakariri River	Inland
Sanctuary Swamp	Palustrine and riverine	Groundwater input from the Waimakariri River.	Inland
Cust River Wetlands	Palustrine and riverine	Ephemeral wetlands: Seasonally ponded low lying farmland	Inland

7.1 Remnant coastal wetlands

Ashley River/Rakahuri - Saltwater Creek Estuary
This wetland, the estuary of the Ashley River/Rakahuri and Saltwater Creek, consists of river delta mud and sand flats and saltmarsh behind a sand dune barrier. The majority (>75 %) of the wetland area is un-vegetated. Of the vegetated wetland area, 94 % is estuarine saltmarsh habitat, with small areas of adjoining riverine and palustrine freshwater wetland habitats.

The sources of water for this area are river water from Ashley River/Rakahuri, Saltwater Creek, and Taranaki Creek (fresh), and seawater ingress during each tidal cycle (saline).

The wetland is currently rated as **high** ecological significance with a **moderate** threat level.

Jockey Baker Creek
Located on the lower reaches of Baker Creek and its confluence with Waimakariri River, this approx.. 15 ha wetland is characterised by palustrine swamp (70%), riverine marsh (20%) and estuarine tidal saltmarsh habitat (10 %).

It is noted that the current wetland is as a result of installed stop banks, flood gates and drains. Despite this it would be expected that the hydrology of the saltmarsh and riverine areas is relatively stable. No information is available regarding the hydrology of the palustrine swamps.

The wetland is currently rated as **moderate** ecological significance with a **moderate** threat level.

Pines Beach Wetland
This wetland is classified as a dune slack wetland in late stages of transition from estuarine to palustrine hydrology. Relic saltmarsh species are scattered within mainly freshwater vegetation. There is a limited catchment area and water levels fluctuate depending on groundwater and rainfall inputs.

The wetland is currently rated as **moderate** ecological significance with a **moderate** threat level. Hydrology pressures from some local drains and groundwater abstraction contribute to this rating .

Kairaki Creek
This site is between the Jockey Baker Creek site and the coast. It is classified as tidal, estuarine and is a tributary of the Waimakariri River. It has been assessed as 36 % estuarine grassland, shrubland, rushland and reedland, 30 % open water, 22 % riverine treeland and 12 % palustrine forest.

The creek drains the Pines Beach Wetland system and therefore the hydrology of the Kairaki Creek site is largely dependent on that of the upstream wetland. This area is considered to rely heavily on local land surface runoff as a source of water.

The wetland is currently rated as **moderate** ecological significance with a **moderate** threat level. Hydrology pressures from vegetation clearance, drainage, flood control structures and river engineering and groundwater/surface water abstractions contribute to this rating.

Tutaepatu Lagoon-Waikuku
Located between Pegasus township and the coast, this is wetland-lagoon complex is comprised of approximately 88 % palustrine grassland, rushland and forest, 5 % terrestrial herbfield/grassland, 5 % lacustrine open water and 2 % riverine treeland and open water.

As with Pines Beach Wetland it appears that there is a limited catchment area and water levels fluctuate depending on groundwater and rainfall inputs.

The wetland is currently rated as **high** ecological significance with a **high** threat level. Hydrology pressures from vegetation clearance, drainage, farm and urban development and groundwater abstraction contribute to this rating.

Sandhill Road Lakes
Sandhill Road Lakes are artificial lakes dug in old dune slack south of Woodend. MacIntosh's Drain flows into the main lake. The lakes are classified as palustrine and lacustrine with aspects of groundwater and surface water hydrology affecting the lakes.

Poynters Reserve/Kaiapoi River
Poynters Reserve is located at the mouth of the Kaiapoi River so is classified as riverine and estuarine with tidal and Kaiapoi River inputs.

Monopoli's Pond
Monopoli's Pond is located near the mouth of the Waimakariri River upstream of Poynters Reserve and Styx-Te Rauakaaka Reserve. The pond is classified as palustrine.

Flaxton Swamp
Located north of Kaiapoi, Flaxton Swamp is an ephemeral wetland that seasonally ponds in low-lying farmland. The swamp is primarily fed by groundwater and is classified as palustrine.

Pegasus Wetlands
Located within the Pegasus township, these wetlands are comprised of a mix of natural, artificial, and enhanced wetlands and open water habitats. The wetlands are classified as a combination of palustrine and lacustrine.

Ohoka Swamp
Located north of Kaiapoi, Ohoka Swamp is an ephemeral wetland that seasonally ponds in low-lying farmland. The swamp is primarily fed by groundwater and is classified as palustrine.

Ashworth Ponds
Located north of the Ashley River/Rakahuri, these ponds are fed by groundwater with saltwater intrusion occurring at times. The classification for these ponds are a combination of palustrine and estuarine.

7.2 Remnant inland wetlands

Germans Road – Ashley Gorge
This palustrine marsh is remnant *Juncus edgariae* rushland in an area of developed pasture. Drainage, vegetation clearance and pasture development have significantly reduced the size of this wetland habitat. The wetland is currently rated as **moderate** ecological significance with a **high** threat level.

Springvale Flaxland
This palustrine swamp and marsh are fed from ground and surface water, and located on an alluvial terrace of the Ashley River/Rakahuri. The core of the wetland is permanently wet swamp with seasonally-wet marsh on the margins. The wetland is currently rated as **moderate** ecological significance with a **moderate** threat level.

Hammonds Wetland
Located on the alluvial material below the Mt Thomas foothills, this relatively large wetland is located in a depression that collects surface runoff from the surrounding land. Classified as both palustrine and riverine the wetland is also fed by groundwater springs. This wetland is located within an ecological district that has <5 % of its original indigenous vegetation remaining. The overall ecological significance of this wetland is **moderate**.

Birch Hill Wetland
This palustrine wetland is located near the confluence of Washpool Stream and the Ashley River/Rakahuri. It's primarily spring fed, and seepage from the terrace above also flows into the wetland. The wetland is currently rated as **high** ecological significance.

Bridgewater swamp and Astelia grandis swamp
Located between Rangiora and Kaiapoi these swamps are palustrine and groundwater fed, and form a biodiversity project site.

Waimakariri corridor wetlands
Along the length of the Waimakariri River there are a number of wetlands fed by surface water and shallow groundwater from the river.

These palustrine and riverine wetlands include the Morrison Road wetland, the Baynons wetland, the Dog Trail Road wetlands, and many others within the Waimakariri River corridor.

Rampaddock Road swamp forest
Located in the Eyre foothills, this is a palustrine swamp fed by groundwater springs. The wetland is a remnant Kahikatea and Pokaka forest and swamp.

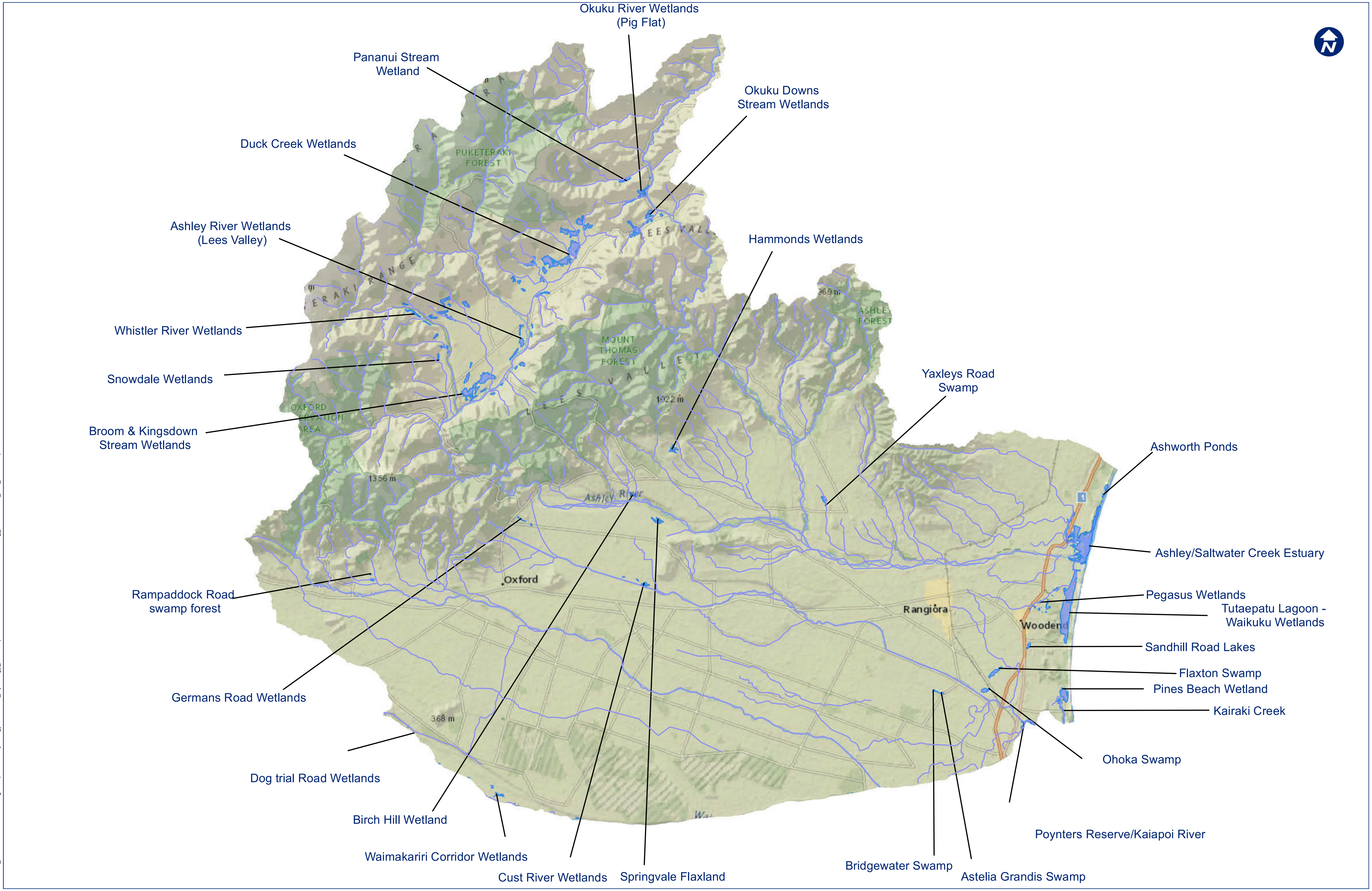
Yaxleys Road Swamp
Located near the Okuku River this swamp is spring fed with surface water outflow. The swamp is linked to shallow groundwater from the nearby Okuku River.

Lees Valley Wetlands
There are a large number of wetlands in the Lees Valley, within the headwaters of both the Ashley River and the Okuku River. The classifications of the large majority of the wetlands are palustrine with some riverine wetlands fed by hill runoff.

The Lees Valley is home to the Okuku River Wetlands, the Duck Creek Wetlands, the Ashley River wetlands, and numerous more.

Sanctuary Swamp
Located on the banks of the Waimakariri River, the swamp is fed by groundwater input from the Waimakariri River and classified as palustrine and riverine.

Cust River Wetlands
Located on the Cust River, east of oxford, the Cust River Wetlands are ephemeral wetlands that seasonally pond in low-lying farmland. The wetlands are primarily fed by groundwater and are classified as palustrine.



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This map is confidential and shall only be used for the purposes of this project.

Rev.	By	App.	Description	Date
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Map features depicted in terms of NZTM projection.

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **Standing waterbodies and wetlands**

Scale: 1:250,000 (A3 size) 2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 16** | Rev. 1

8 Surface water allocation regime

8.1 Introduction

The allocation regime in the Waimakariri Zone is governed by two documents: the Land and Water Regional Plan (LWRP) and the Waimakariri River Regional Plan (WRRP), incorporating Plan Change 1. This creates a geographical split in the allocation regime (**Map 17**). The LWRP applies to all areas of the zone, except where the WRRP applies, in which case the WRRP is the applicable document. One exclusion to this is where the LWRP seeks to address earthquake related issues, but we have not considered this.

Regardless of the applicable plan there are two key aspects to the allocation regimes which are important for this work: minimum flow and allocation limit.

The minimum flow is the flow at a designated point on a watercourse that must be exceeded before those with a permit to take water can start abstracting water. This is normally set to ensure sufficient water is available in a watercourse to protect the values associated with that watercourse; the minimum flow is typically set to protect ecological health.

The allocation limit is the total amount of water, split between permit holders, that can be abstracted above the minimum flow. Methodologies for determining the allocation limit are varied but are generally focused on preserving the values of the watercourse. Some consents also include a maximum allocation volume per time period, usually per day, season or year.

In some watercourses there are several minimum flow and allocation blocks used, normally where water demand is high in relation to the water available. In this case, the first permits granted collectively form the ‘A’ block. Water in the ‘A’ block is the most reliable water available. Subsequent permits granted form the ‘B’, and sometimes ‘C’ blocks. Water in these blocks is increasingly less reliable as abstraction cannot commence until a much higher minimum flow has been reached and usually watercourses quickly drop below the minimum flow after rainfall so abstractions under these blocks must cease.

In addition to the usual framework, on the Waimakariri River an ‘AA’ block has been established. This block includes water used for reticulated potable supply and stock water and is intended to ensure the ongoing supply to critical users even during periods of very low flow.

8.1.1 WRRP

The Waimakariri River Regional Plan, incorporating Plan Change 1, became operative in 2011, replacing the previous version of the Waimakariri River Regional Plan. The changes of note were:

1. Change of minimum flow monitoring point from Old Highway Bridge to Otarama
2. Creation of an ‘AA’ block of 5 m^3/s
3. Reduction of ‘A’ block allocation by 5 m^3/s
4. Creation of ‘B’ block allocation limit of 27 m^3/s
5. 1:1 flow sharing regime for all ‘B’ block permits

The ‘AA’ block was created as a ‘secure’ block to service reticulated community supplies and stockwater. This was not ‘new’ water, but rather was part of the original ‘A’ block hence the ‘A’ block allocation was reduced by 5 m^3/s. This water is generally protected against restrictions during low flow periods because of its importance for human and stock wellbeing. Below the minimum flow for the ‘A’ block, some restrictions do apply.

The ‘B’ block had existed in the original plan, however, had no maximum allocation. This is because at the time of the plan’s inception, the ‘B’ block water was considered so unreliable that there would never be significant demand that would require it to be controlled by an allocation limit. In recent years, the use of large-scale storage as part of flood-harvesting schemes has made this water much more important. The creation of a ‘B’ block limit is a response to flood-harvesting to ensure its effects are controlled.

The implementation of Plan Change 1 did not change the regime on any other river within the Waimakariri River Regional Plan area.

Table 9 summarises the current allocation regime on each river, and **Map 17** shows the distribution of minimum flow sites within the Waimakariri Zone and specifies the sites linked to allocation regimes.

8.1.2 LWRP

In the Land and Water Regional Plan the Ashley River/Rakahuri allocation regime is split into three blocks; ‘A’, ‘B’ and ‘C’. The ‘A’ block allocation has been calculated using a combination of the actual rate of surface water abstractions and the calculated stream depletion effects (SDEs) caused by groundwater abstractions. The methodology used for the ‘B’ and ‘C’ block allocations has not been confirmed.

The LWRP also includes allocation regimes for the Taranaki Creek, Waikuku Stream, Little Ashley Creek and Saltwater Creek. These allocations only have ‘A’ block allocations, which were calculated using the average method which uses the sum of the consented abstraction volumes, averaged over the stated period of take. The average rate of take for each consent is summed and combined with the SDEs to form the allocation limit.

Table 9 summarises the current allocation regime for each river. **Map 17** shows the distribution of minimum flow sites within the Waimakariri Zone and specifies the sites linked to allocation regimes.

8.2 Overview of current regime

8.2.1 Objectives

There are currently 26 minimum flow sites in the Waimakariri Zone. Eleven are within the WRRP area (**Table 9**), five are within the LWRP area (**Table 9**), and ten are used within consent conditions, but do not appear in either Plan (**Table 10**). Minimum flows have been set to achieve objectives set out in the applicable plan. Objectives in the LWRP and WRRP are very similar in scope.

Within the Land and Water Regional Plan, minimum flows are set to achieve Objective WQN1:

Enable present and future generations to access the region's surface and groundwater resources to gain cultural, social, recreational, economic and other benefits, while:

(a) safeguarding their existing value for efficiently providing sources of potable water for people and for stock;
(b) safeguarding the life-supporting capacity of the water, including its associated aquatic ecosystems, significant habitats of indigenous fauna, and areas of significant indigenous vegetation;
(c) safeguarding their mauri and existing value for providing mahinga kai for Ngāi Tahu;
(d) protecting wāhi tapu and other wāhi taonga of value to Ngāi Tahu;
(e) preserving the natural character of lakes and rivers and protecting them from inappropriate use and development;
(f) protecting outstanding natural features and landscapes from inappropriate use and development;
(g) protecting significant habitat of trout and salmon; and
(h) maintaining, and, where appropriate, enhancing amenity values.

Within the Waimakariri River Regional Plan, minimum flows are set in order to achieve Objective 5.1:

Enable present and future generations to gain cultural, social, recreational, economic, health and other benefits from the rivers, lakes and wetlands in the Waimakariri River Catchment, and from hydraulically connected groundwater while:

(a) safeguarding their existing value for efficiently providing sources of drinking water for people and their animals;
(b) safeguarding the life-supporting capacity of the water, including its associated: aquatic ecosystems, significant habitats of indigenous fauna, and areas of significant indigenous vegetation;
(c) safeguarding their existing value for providing mahinga kai for Tangata Whenua;
(d) protecting wahi tapu and other wahi taonga of value to Tangata Whenua;
(e) preserving the natural character of rivers, lakes and wetlands and protecting them from inappropriate use and development;
(f) protecting outstanding natural features, and landscapes from inappropriate use and development;
(g) maintaining and enhancing amenity values; and
(h) protecting the significant habitat of trout and salmon.

8.2.2 Minimum flows

A lack of separation is present between the existing ‘A’ and ‘B’ allocation blocks on all of the watercourses within the Waimakariri sub-region (excluding the Waimakariri River). This restricts the natural flow variability of the watercourses. This affects the zones ability to achieve the LWRP objectives.

The LWRP provides a default minimum flow that is applied to all areas that do not already have a specific sub-regional regime. It is based on a percentage of the MALF7d, commonly 50%, and has been set to achieve increased aquatic ecosystem health. We have compared the current minimum flows with the MALF7d's calculated in Section 5 to show the difference between the minimum flows set based on the LWRP requirements and the allocation requirements. **Table 11** shows that most of the available minimum flows are greater than 50% of the MALF7d. The Waikuku Stream is the only minimum flow that falls under the LWRP default value. This is because it was understood that reducing the minimum flow in the Waikuku Stream would have minimum impact as long as a flushing flow was achieved during the weekends (Glennie, 2004).

Table 9 - Plan allocation regimes

	Watercourse	Minimum flow site location	Site no.	A block allocation		B block allocation		C block allocation	
				Min flow	Allocation limit	Min flow	Allocation limit	Min flow	Allocation limit
Land and Water Regional Plan	Ashley River/Rakahuri	Ashley River/Rakahuri at Gorge	66204	2500 L/s Jan-Jul 4000 L/s Aug-Nov 3000 L/s Dec	700 L/s	3200 L/s Jan-Jul 4700 L/s Aug-Nov 3700 L/s Dec	500 L/s	6000 L/s	3000 L/s
	Taranaki Creek	Taranaki Creek, Kaipohia monument	390	120 L/s	61 L/s	181 L/s	No Limit	No C block	No C block
	Waikuku Stream	Waikuku Stream, Waikuku Beach Road	389	100 L/s Mon-Fri 150 L/s Sat-Sun	460 L/s	560 L/s Mon-Fri 610 L/s Sat-Sun	No Limit	No C block	No C block
	Little Ashley Creek	Ashley River/Rakahuri at SH1	66201	50 L/s 30 L/s for 4 days each month	172 L/s	222 L/s	No Limit	No C block	No C block
	Saltwater Creek	Saltwater Creek, Toppings Rd	253	100 L/s	408 L/s	508 L/s	No Limit	No C block	No C block
Waimakariri River Regional Plan	Waimakariri River *below Woodstock*	Otarama	-	N/A – Some restrictions apply below 46,000 L/s	'AA' block of 5,000 L/s	-	-	-	-
	Waimakariri River *below Woodstock*	Otarama	-	46,000 L/s	17,000 L/s	68,000 L/s	27,000 L/s 1:1 sharing	No C block	No C block
	Courtenay Stream	Main North Road	-	260 L/s	140 L/s	400 L/s	No Limit	No C block	No C block
	Greigs Drain	Greigs Drain Road	-	150 L/s	70 L/s	220 L/s	No Limit	No C block	No C block
	Kaiapoi River	Neeves Road	-	600 L/s	1000 L/s	1600 L/s	No Limit	No C block	No C block
	Cust Main Drain	Threlkelds Road	-	230 L/s	690 L/s	920 L/s	No Limit	No C block	No C block
	Cust River	Rangiora-Oxford Road	-	20 L/s	290 L/s	310 L/s	No Limit	No C block	No C block
	No.7 Drain	Main Drain Road Culvert	-	60 L/s	130 L/s	190 L/s	No Limit	No C block	No C block
	Ohoka Stream	Kaiapoi River confluence	-	300 L/s	500 L/s	800 L/s	No Limit	No C block	No C block
	Cam River	Youngs Road	-	1000 L/s	700 L/s	1700 L/s	No Limit	No C block	No C block
	North Brook	Marsh Road	-	530 L/s	200 L/s	730 L/s	No Limit	No C block	No C block
	Middle Brook	Marsh Road	-	60 L/s	30 L/s	90 L/s	No Limit	No C block	No C block
	South Brook	Marsh Road	-	140 L/s	100 L/s	240 L/s	No Limit	No C block	No C block

Table 10 - Non-plan minimum flows

	Watercourse	Minimum flow site location	Take	-	
				Min flow	Consent
Non-plan	Pancake Stream	-	SW	50 L/s	CRC020522
	Latimers Creek	-	SW	45 L/s	CRC158093 CRC158094
	Okuku River	Fox Creek	SW	543 L/s	CRC142908
	Washpen Stream	-	SW	No minimum	CRC141168
	Saltwater Creek	Factory Road	SW	150 L/s, with at least 100 L/s d/s of abstraction	CRC147644
	Topps Creek	-	SW	20 L/s d/s of abstraction	CRC000762 CRC980228 CRC050028 CRC136743
	Veiwhill Creek	-	SW	No minimum	CRC092949
	Waikuku Stream	-	SW	151 L/s	CRC971090.1 CRC168133 CRC971041.3
	No.7 Drain	-	SW	20 L/s	CRC990749
	Mounseys Stream	Island Road Bridge	SW	72 L/s	CRC141168

Table 11 - Minimum flows with available MALF7d comparison

Plan	Watercourse	Minimum Flow	MALF7d	% of MALF7d
Land and Water Regional Plan	Ashley River/Rakahuri	2500 L/s Jan-Jul	2040 L/s	123%
		4000 L/s Aug-Nov	2040 L/s	196%
		3000 L/s Dec	2040 L/s	147%
	Taranaki Creek	120 L/s	101 L/s	119%
	Waikuku Stream	100 L/s Mon-Fri	355 L/s	28%
		150 L/s Sat-Sun	355 L/s	42%
Waimakariri River Regional Plan	Courtenay Stream	260 L/s	332 L/s	78%
	Greigs Drain	150 L/s	60 L/s	250%
	Cust Main Drain	230 L/s	492 L/s	47%
	Ohoka Stream	300 L/s	505 L/s	59%
	Cam River	1000 L/s	1194 L/s	84%
Non-plan	Okuku River	543 L/s	446 L/s	122%
	Waikuku Stream	151 L/s	355 L/s	43%

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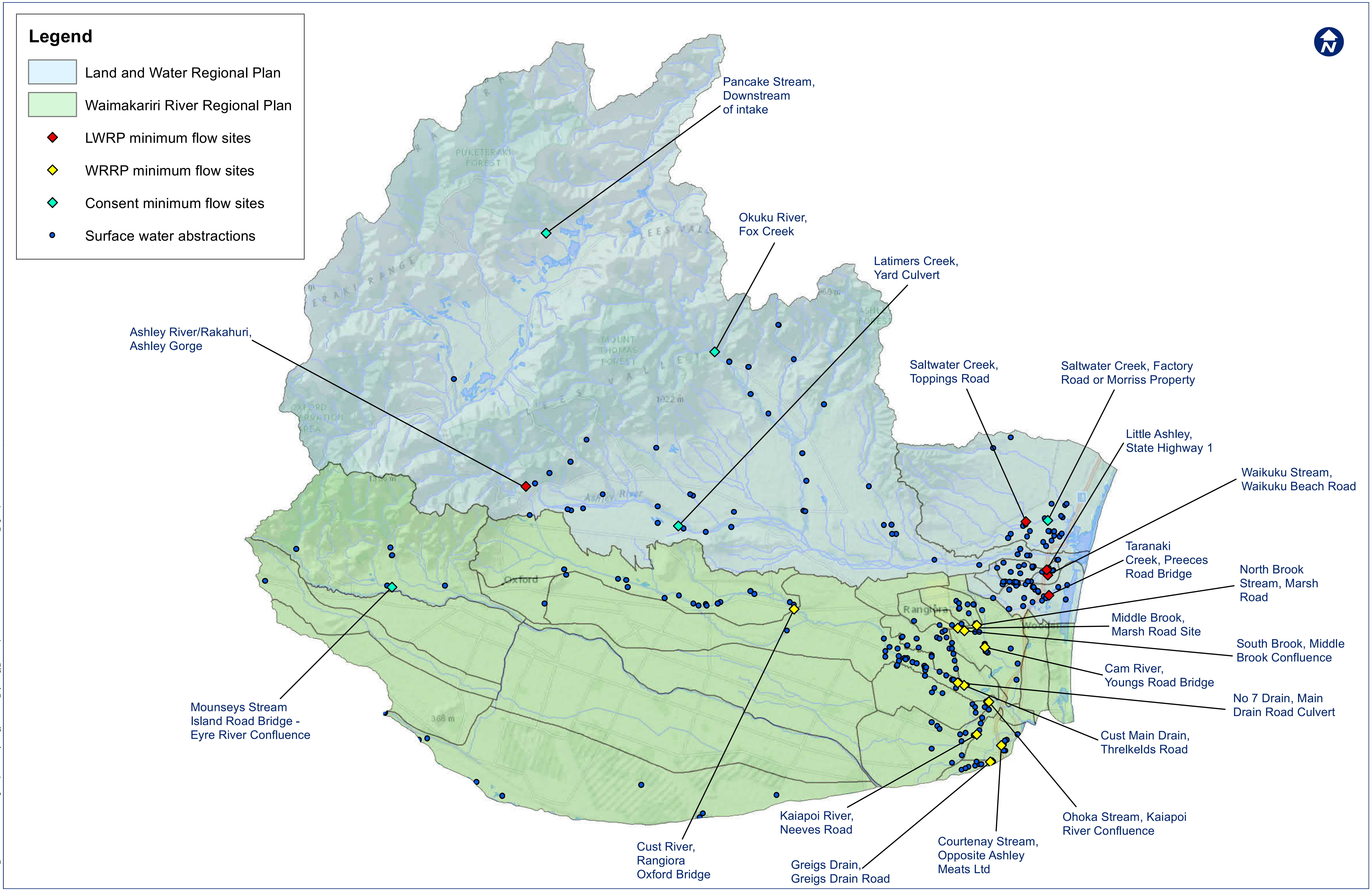

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This map is confidential and shall only be used for the purposes of this project.

Rev.	By	App.	Description	Date
1	SH	MM	Final	20/12/16
A	SH	MM	Draft for review	9/07/16

Notes:

Printed	04 Oct 2016 14:25		
Drawn	SH	Date	19/07/2016
Checked	MM	Date	19/07/2016
Approved	MM	Date	19/07/2016
File Name	Map 17		

Map features depicted in terms of NZTM projection.

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **Allocation regime**

Scale: 1:250,000 (A3 size) 2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 17** | Rev. 1

8.3 Details of current allocations

8.3.1 Summary of surface water allocation

In this section we have provided a summary of the allocated surface water based on consent volumes. This is presented as allocation data in the LWRP area (**Figure 20**), the WRRP area (**Figure 21**), and then the zone as a whole (**Figure 22**).

To estimate the annual allocation volumes for all consents regardless of consent stipulations (e.g. limits to instantaneous rate of take, daily volume abstracted, and/or annual volume abstracted across one or multiple water abstraction points) made certain assumptions, as follows:

- If an annual allocation volume was provided in the consent, then that value was used.
- If a daily or multi-day maximum was provided, then that value was converted to a daily volume (if necessary) and extrapolated to the entire year.
- If only an instantaneous rate of take was provided, then that value was extrapolated to the entire year.

The annual extrapolation was based on water usage type: if the usage type was irrigation, then 212 days of usage was assumed, while 365 days of use was assumed for all other usage types (i.e. stockwater, public water supply, industrial, and other). These 'extrapolation days' provided for internal consistency in consent comparisons.

Prior to 2013 almost all of the water abstracted within the LWRP surface water allocation zones (SWAZs) was used for irrigation (**Figure 20**). The 'other' uses for water after 2013 mainly consist of private farm consents, which include dairy shed wash-down, stockwater, storage and irrigation. Although there is less allocated surface water in the LWRP SWAZs they have a significant allocation volume with between 17 and 20 million m^3 allocated in the water years 2011 to 2015.

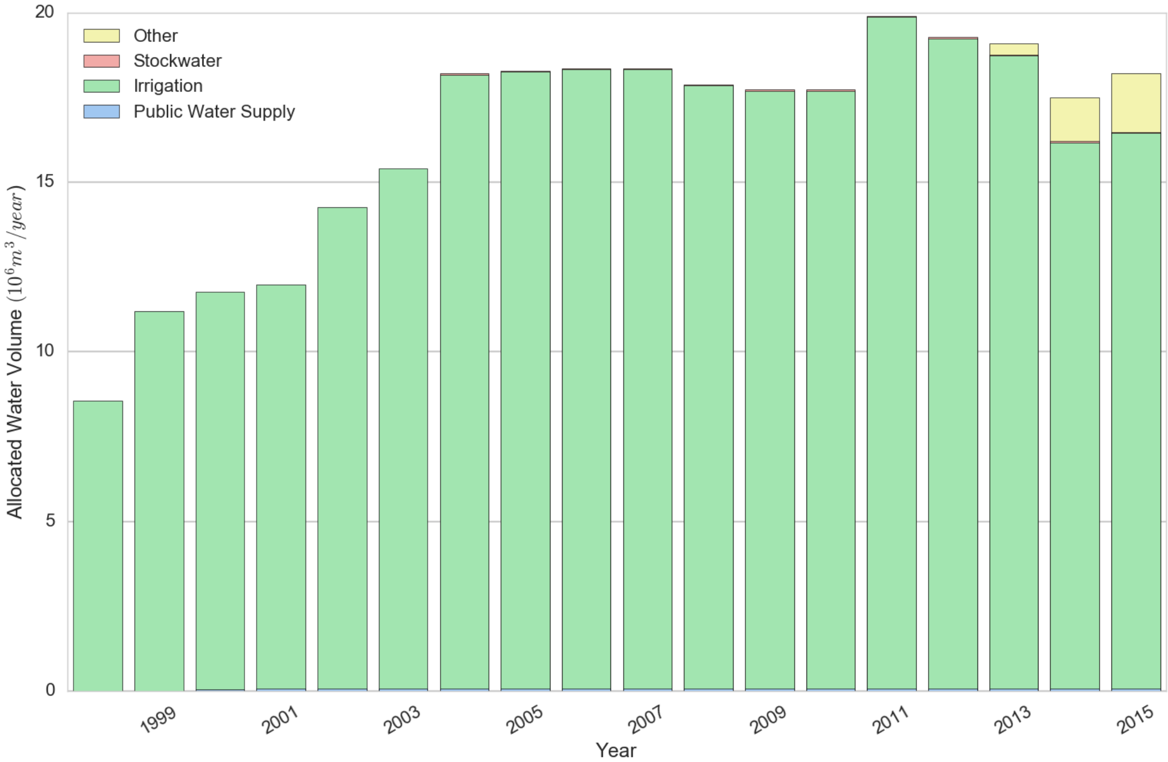


Figure 20 - Total allocated water in the LWRP SWAZ stacked by water type from 1998 to 2015

The volume of allocation used for irrigation increased dramatically following the establishment of the WIL irrigation scheme in 1999 (**Figure 21**). In the 2014/2015 water year, the allocated water volume for irrigators in the WRRP SWAZs was around 470 million m^3. Most of the allocated water in the WRRP SWAZs, with approximately 85 % in the 2014/2015 water year, is consented for irrigation use.

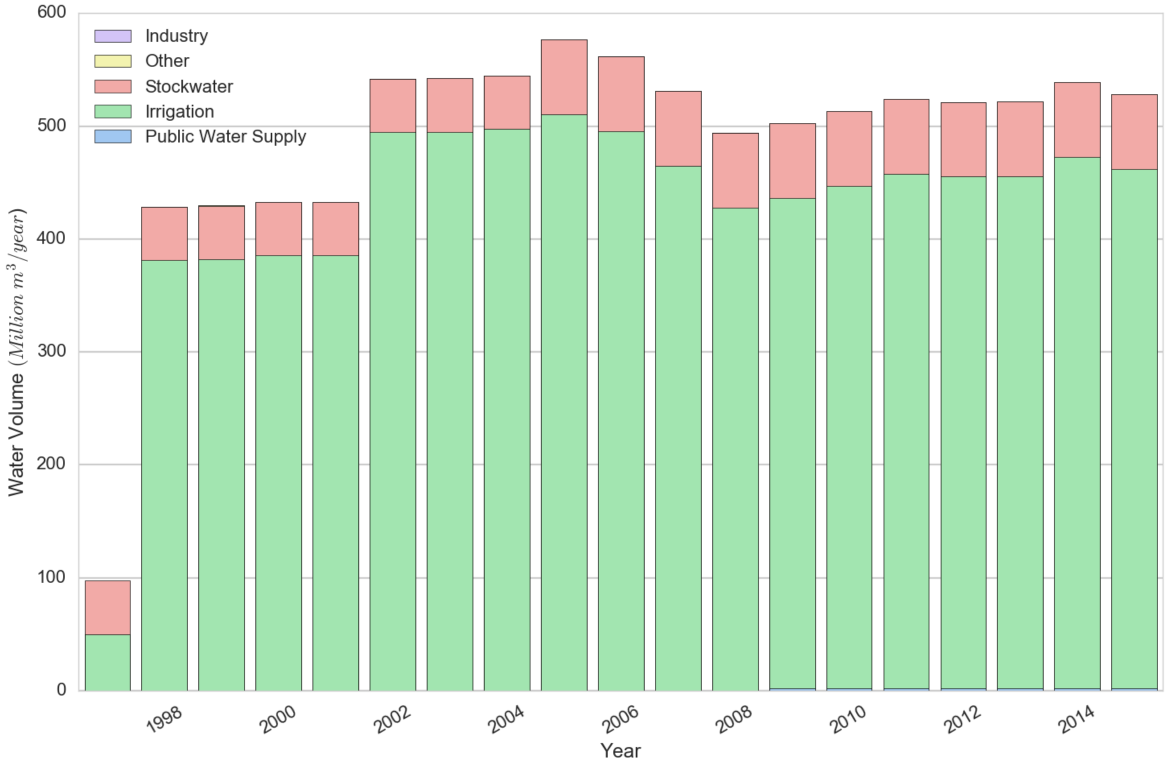


Figure 21 - Total allocated water in the WRRP SWAZ stacked by water type from 1997 to 2015

Because of the relatively small abstractions made in the LWRP SWAZs, the total allocation on the Waimakariri Zone follows the same trends as the WRRP SWAZs (**Figure 22**); over 85 % of the allocated volume within the Waimakariri Zone is consented for irrigation use.

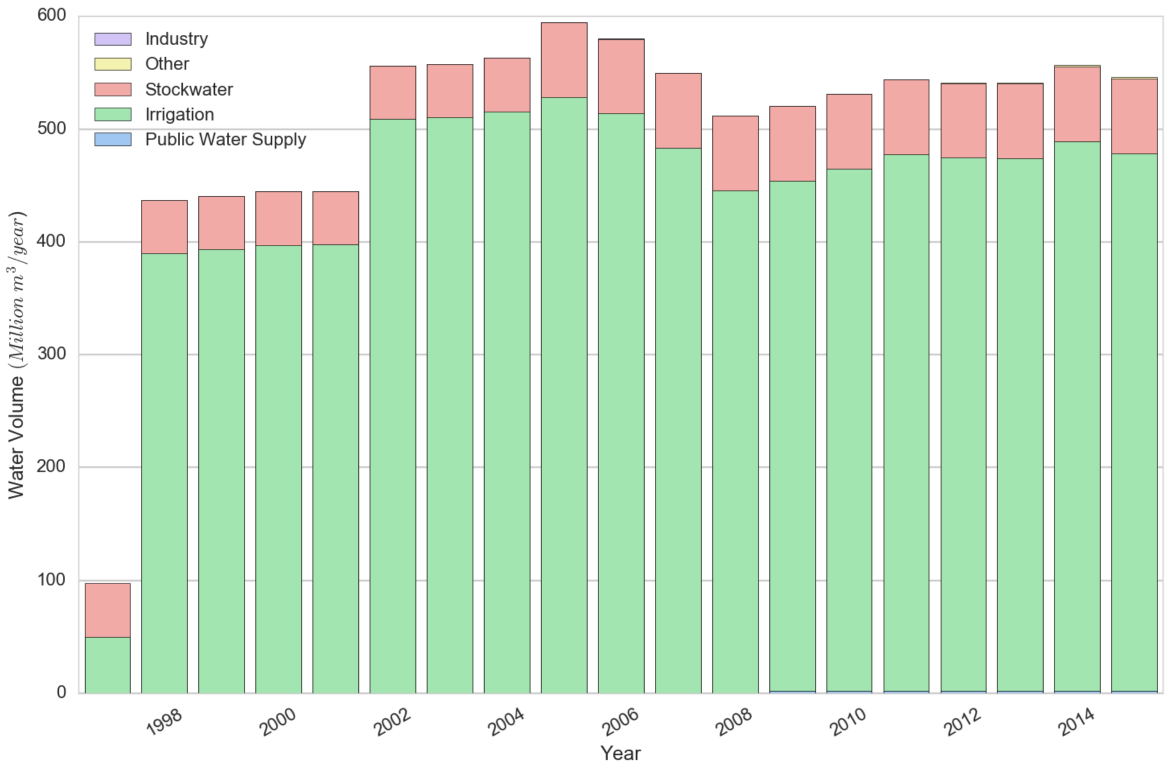


Figure 22 - Total allocated water in the Waimakariri Zone stacked by water type from 1997 to 2015

8.3.2 Ashley/Rakahuri River (LWRP)

The allocation regime of the Ashley River/Rakahuri is managed under the LWRP and is a three block system: ‘A’, ‘B’ and ‘C’ blocks.

The ‘A’ block contains 700 L/s. This was based on all surface water takes and stream depleting groundwater takes granted prior to 1 January 2002 (Environment Canterbury, 2010). Under the Natural Resources Regional Plan (NRRP), and subsequently the LWRP, no new permits were to be issued for the ‘A’ block and relinquished water would not be reallocated.

The minimum flow for the Ashley River/Rakahuri ‘A’ block was set to protect the river environment during critical months, reducing the chance of the Ashley River/Rakahuri running dry. The chosen minimum flow regime was determined to be the most appropriate option for achieving Objective WQN1 of the NRRP.

Initially in the NRRP process a 2.5 m^3/s minimum flow <u>throughout the year</u> was proposed (Mosley, 2001). Through the hearing process the expert advice of ornithologists at Advisory Group meetings led to the recommendation of a variable flow regime to better reflect the flow patterns needed for birds to successfully breed on the open gravel of the braided river bed (Glennie, 2004).

Following the setting of higher minimum flows to address bird breeding, there appears to have been limited objection from involved parties to the minimum flows set in the NRRP process, with the exception of the 2.5 m^3/s minimum flow set for January.

This flow was proposed because flow gauging work showed at this level, a continuous flow from mountain to sea could be maintained, with the pinch point being Lowes Corner where 300-400 L/s would still be present. With irrigation having ceased by that point, a dry river could be attributed to natural effects, and upstream and downstream of Lowes Corner flows would be greater than 300-400 L/s giving better flow conditions for instream values.

The Department of Conservation is noted as supporting the 2.5 m^3/s minimum flow, but they sought a 1:1 flow sharing regime. There was a concern from Ngai Tūāhuriri participants at the Advisory Group that 2.5 m^3/s would not be sufficient for flow continuance and they preferred 5 m^3/s (Tau, 2003).

A minimum flow of 3 m^3/s was estimated to give around five extra days flow at potentially drying sites following each rainfall event. Considering the balance of interests in the process, this was not considered significant.

The 'B' block of 500 L/s was set as a small volume to ensure that a situation did not develop where numerous abstractors are competing for a resource that occurs only occasionally during the period of greatest demand (Environment Canterbury, 2010).

The 'C' block of 3 m^3/s was set so as not to reduce the frequency of freshes required to flush the river (Environment Canterbury, 2010).

The allocation regime for Ashley River/Rakahuri is managed using flow recorded on the Ashley River/Rakahuri at Ashely Gorge (Site No.66204).

Non-plan consents
Mosley (2004) states that CRC147037 (226 L/s) and CRC971656.1 (226 L/s), located north of Waikuku, are no longer used, as groundwater now supplies demand. However, they were not relinquished and it appears these were included in the original estimate of the allocation block.

Mosley (2004) estimated 536 L/s of stream depletion for the Ashley River/Rakahuri. This includes a WDC take of 300 L/s for community supply. This has now been terminated and is therefore no longer contributing to flow patterns of Ashley River/Rakahuri. At the time (2002), there was 536 L/s of stream depletion and 263 L/s of surface water giving a total abstraction of 799 L/s. Removing the WDC take this gives 522 L/s.

We reviewed the current surface water and stream-depleting groundwater takes on the Ashley River/Rakahuri and identified a number of active consents that are tied to minimum flows that differ from those stated in the LWRP (**Table 12**). Four consents were tied to minimum flows of 1.7 m^3/s for February and March. Active consents totalling 214.4 L/s are tied to this lower minimum flow, which includes 41.8 L/s of stream depleting groundwater, from a 49 L/s consented maximum rate (Smith M, internal Environment Canterbury assessment).

Table 12 - Non-plan consents

Watercourse	Source	Max rate (L/s)	Min flows (L/s)
CRC020874	Ashley River /Rakahuri	31.6	Jan: 2200 Feb-Mar: 1700 Apr: 2200 May – Nov: 4200 Dec: 3200
CRC147037	Ashley River /Rakahuri	226	Jan: 2200 Feb-Mar: 1700 Apr: 2200 May – Nov: 4200 Dec: 3200
CRC971656.1	Ashley River /Rakahuri	226	Jan: 2200 Feb-Mar: 1700 Apr: 2200 May – Nov: 4200 Dec: 3200
CRC980737	Gary River	76	Jan: 2200 Feb-Mar: 1700 Apr: 2200 May – Nov: 4200 Dec: 3200 (on Ashley + 40 L/s min flow on Garry)
CRC970989	Okuku River	65	Jan: 2200 Feb-Mar: 1700 Apr: 2200 May – Nov: 4200 Dec: 3200
CRC151956	Ashley River /Rakahuri	49 L/s consent, 41.8 L/s (stream depletion estimate)	Jan: 2200 Feb-Mar: 1700 Apr: 2200 May – Nov: 4200 Dec: 3200

8.3.3 Ashley River/Rakahuri lower tributaries (LWRP)

Independent allocation regimes exist for each of the lower tributaries associated with the Ashley River/Rakahuri. Each is managed under the LWRP and is a two block system.

Minimum flows
Minimum flows were set on a watercourse by watercourse basis.

For **Taranaki Creek** the minimum flows were established using a technical panel approach to provide adequate protection to instream values (Environment Canterbury, 2004).

For **Waikuku Stream**, during the NRRP process (the outcomes of which are fully reflected in the LWRP), there was a request to reduce the minimum flow from 50 L/s to 30 L/s. The NRRP technical panel indicated that the minimum flow could be reduced subject to a technical report investigating potential for bed sedimentation effects on aquatic fauna. The Waikuku Water Users Group advocated for the minimum flow being reduced on weekdays only, retaining the higher minimum flow on weekends to aid flushing. The technical report suggested sedimentation would not be an issue at low flows however the proposal was adopted to provide added protection (Environment Canterbury, 2004).

For **Little Ashley Stream**, during the NRRP process (the outcomes of which are fully reflected in the LWRP), it was proposed to increase the minimum flow from 30 L/s to 50 L/s to allow adequate depth of flow for native fish species. It was noted that flow shallowing was occurring through bank collapse induced channel widening. At the time a border dyke irrigator (170 L/s) stated that a change from 30 L/s to 50 L/s would compromise his ability to irrigate. The irrigator's scheme had been in place for 30 years (at 2004) and operated on average four days per month. To balance these competing demands an allowance was therefore made to preserve the 30 L/s regime on four days per calendar month to allow abstraction, and additional riparian planting was proposed to mitigate any effects of the lower flow on the four days. The higher minimum flow was to apply at all other times (Glennie, 2004).

Within **Saltwater Creek** the A block minimum flow was set by a technical panel to provide adequate protection to instream values (Environment Canterbury, 2004).

Block allocation
The size of the A block (**Table 13**) was determined by the sum of all takes granted prior to 1 January 2002. The 'sum of all takes' was estimated as the average rate of take for all surface water takes plus the calculated stream depletion effects of stream depleting groundwater abstractions (Glennie, 2004). It was the intention that all relinquished takes not be reallocated until the total (not the average) rate of take falls below the A block allocation (Hayward and Lawrence, 2015).

The allocation limits in **Table 13** can be exceeded because the average rate of take is used to define the allocation block, but maximum rates of take are specified in consents. In some cases the allocation block could be exceeded by 100 % if all consents were to be fully active at the same time. As stated above, there is no separation between the minimum flows for 'A' and 'B' allocation blocks, which means 'B' block takes are able to commence before the 'A' block allocation has been fully used. This has the potential to affect Community Outcome 1 and 2 and should be considered when developing solutions.

Table 13 - A block allocations

	Size of A block (average rates L/s)	Maximum instantaneous rates (L/s)
Taranaki Creek (Min flow site Kaiapohia Monument 390)		
Stream depleting groundwater	31	31
Surface abstraction	30	118
Total	**61**	**149**
Waikuku Stream (Min flow site Beach Road 389)		
Stream depleting groundwater	176	176
Surface abstraction	284	655
Total	**460**	**831**
Little Ashley Stream (Min flow site State Highway 1 66201)		
Stream depleting groundwater	113	113
Surface abstraction	59	231
Total	**172**	**344**
Saltwater Creek (Min flow site Toppings Road 253)		
Stream depleting groundwater	245	245
Surface abstraction	163	172
Total	**408**	**417**

8.3.4 Waimakariri River (below Woodstock) (WRRP)

The allocation regime of the Waimakariri River is managed under the WRRP (2011). The Waimakariri River flow regime does not fall under the remit of the Waimakariri Zone for the purposes of the LWRP sub-regional process. The Waimakariri River flow regime is included in a future sub-regional chapter that covers all of the alpine rivers. Notwithstanding this, the Waimakariri River is an important source of water for activities undertaken in the Waimakariri Zone, and is a potential receiving water for the effects of such activities. Therefore the Waimakariri River must be considered to some extent.

The allocation regime on the Waimakariri River is a three block system: 'AA', 'A', and 'B' blocks (**Table 9**).

Historically there was no limit placed on 'B' block water as it was considered that the water was so unreliable that it would never be in high demand. In recent times, large flood-harvesting storage schemes have become technically and economically viable, this potentially places great demand on the 'B' block and as such an allocation limit was introduced to control use.

The allocation regime for Waimakariri River is managed using flow recorded on Waimakariri River at Otarama (Site No.66403).

8.3.5 Waimakariri River lower tributaries (WRRP)

Minimum flows for the Waimakariri River lower tributaries were set as part of the Waimakariri River Regional Plan process in 2001. In general these minimum flows were set to ensure the passage of migratory fish to spawning grounds in these watercourses (**Table 14**). The intent was that if sufficient water depth can be provided over critical riffles for the widest-bodied fish then this will ensure protection and support for all other fish species. Fish surveys were undertaken for this work and the appropriate value was related to the fish found in the survey.

Table 14 - Instream values

Tributary	Instream value				
	Juvenile trout	Adult trout	Adult salmon	Effluent dilution	Canoe passage
Courtenay Stream	Expert panel approach used				
Greigs Drain		✓			
Kaiapoi River			✓		✓
Cust Main Drain		✓			
Cust River	✓				
No.7 Drain		✓			
Ohoka Stream			✓		
Cam River				✓	✓
North Brook			✓		
Middle Brook	Expert panel approach used				
South Brook			✓		

In addition to fish passage, an allowance in the minimum flows was also made for effluent dilution and recreational canoe passage (**Table 14** and **15**) where appropriate.

Table 15 - Basis of assessment

Assessment criteria	Depth of Water Required (m)
Adult salmon	0.25
Adult trout	0.15
Juvenile trout	0.1
Canoeing	0.2

No ‘critical riffles’ were identified for **Courtenay Stream** and **Middle Brook** and therefore the above methodology was not used. Rather, the minimum flows already in place were adopted, these having been determined by an expert panel approach.

At the time, the **Cam River** received treated effluent from Rangiora wastewater treatment plant (WWTP), hence the minimum flow was set to ensure dilution. Dilution of ammonia was the key parameter used, assessed against the USEPA (1986) water quality criterion to support salmonids at 20°C and a pH of 8.0. This was 0.93 g/m^3 total ammonia or 0.76 g/m^3 total ammonia-nitrogen. The maximum ammonia-nitrogen level in the discharge was assumed to be 16 g/m^3 (Hickey *et al.* (1989).

The Rangiora WWTP no longer discharges to the Cam River (Golder, 2009), and therefore the requirement to account for dilution no longer applies. The minimum flow estimated to support fish passage at the time was 670 L/s.

No supporting information could be identified for the setting of allocation block(s) for these watercourses.

In 2009, the suitability of the 2001 minimum flows was assessed (Golder, 2009). This study recommended that some minimum flows be amended (**Table 16**), although these currently have no statutory standing.

Table 16 - Recommendations for minimum flows

Site	MALF7d (L/s)	WRRP minimum flow (L/s)	Golder (2009) recommendation (L/s)	Justification
Courtenay Stream	293	260	350	Additional protection to cover adult brown trout, large longfin eels and other native fish
Greigs Drain	302	150	230	Additional protection to cover adult and juvenile brown trout
Kaiapoi River	1,273	600	1,000	900 L/s required for salmonids, 1000 L/s would protect adult brown trout, large eels and other native fish
Cust Main Drain	325	230	No change	Current MF provides a good level of protection for juvenile brown trout and native fish.
Cust River	140	20	120	Current MF provides very limited habitat. Suggested flow provides for juvenile trout
No.7 Drain	67	60	No change	Provides suitable depth and adequate protection of native and salmonid species
Ohoka Stream	526	300	365	Slight increase required to protect salmonid and native fish habitat
Cam River	1,022	1,000	890	Lower MF provides a high level of protection for adult brown trout
North Brook	622	530	No change	Reasonable high protection of instream values (salmonids/eels)
Middle Brook	31	60	30	Generally impractical to have MF higher than MALF7d, which is the naturally occurring limit to aquatic habitat
South Brook	171	140	120-140	Based on trout protection a small reduction would not change outcomes. If Salmonid use was identified her a MF of 210 L/s would be required

9 Reliability of Supply

9.1 Background and methodology

The allocation blocks and bands put restrictions on water abstraction during periods when flows fall below minimum flow limits. The restrictions can be either partial or full depending on the flow conditions. Because of these restrictions, the total water abstraction volume for a consent may be lower than the originally allocated volumes.

For each band within each minimum flow site, there are a number of assigned consents. Combining the water allocation with the minimum flow band restrictions, the amount and frequency of the restrictions can be estimated for all consents for all bands with restrictions. Minimum restrictions have been recorded since the 2006/2007 water year.

9.2 Zone Summary

Table 18 shows the number of days that each allocation block and band was on restriction. Since the Waimakariri Zone can be split into two regional plan jurisdictions (**Map 18**) we analysed the reliability of supply separately for each plan (**Figure 23 and 24**). Each graph presents the surface water allocation in the blue bars with shading showing the available allocation due to water restrictions. This is replicated for the volume of water monitored giving the total allocation and the total available allocation following restrictions. The red bars show the actual metered usage of water.

In the LWRP SWAZs the 2014/2015 water year had significant restrictions. In the Ashley River, restrictions have remained significantly higher than previous year during both the 2014/2015 and 2015/2016 water years (**Table 18**).

In the WRRP SWAZs the minimum flow restrictions were consistent with the previous year's restrictions. Full restrictions are not common in the WRRP SWAZs except on the Cam River and North Brook, where full restrictions increased in frequency during the 2014/2015 and 2015/2016 water years (**Table 18**).

To analyse the entire Waimakariri Zone, we combined the WRRP and LWRP analyses to give zone wide information (**Table 17, Figure 25**). The restricted allocation volumes are similar for most years.

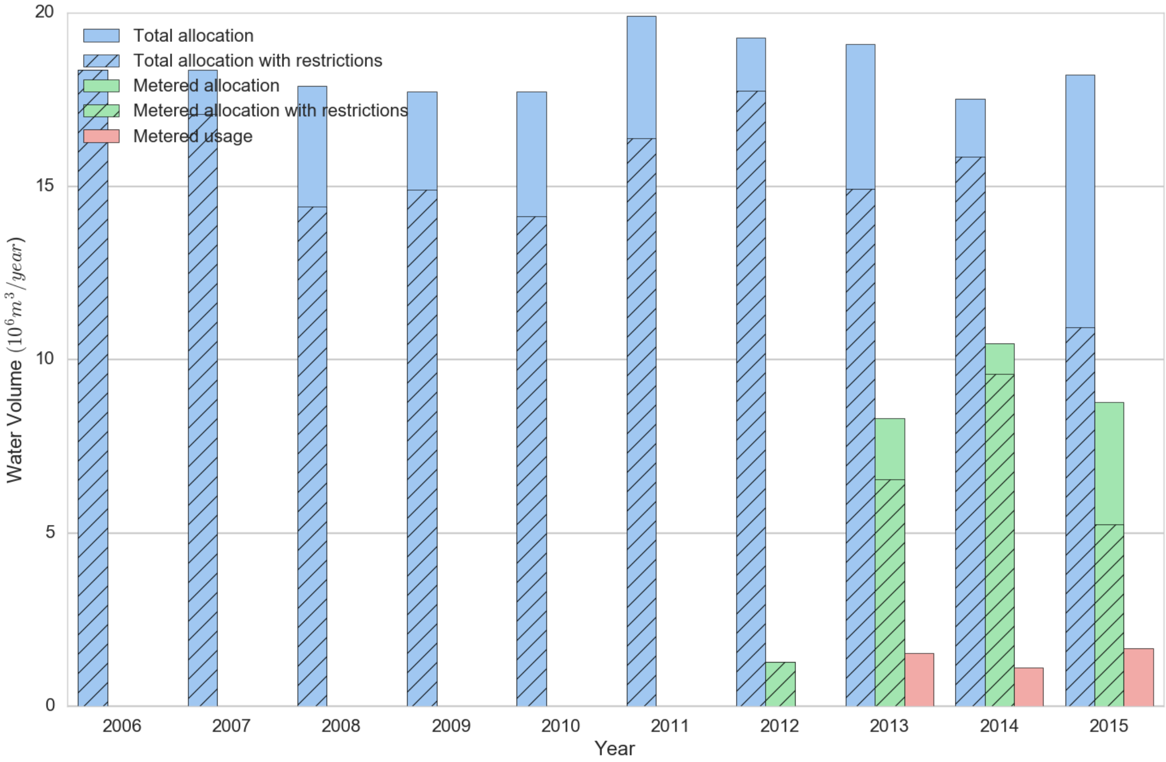


Figure 23 - Water use and allocation for the LWRP SWAZs

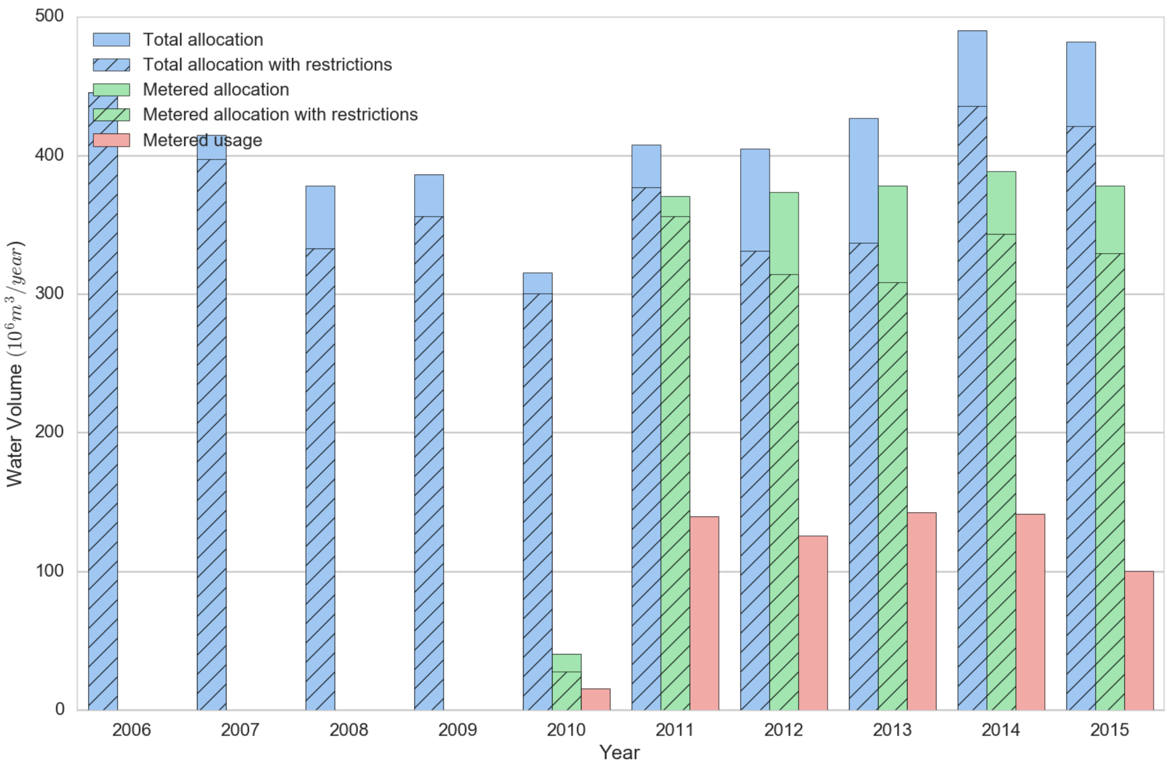


Figure 24 - Water use and allocation for WRRP SWAZs

Table 17 - Water use and allocation for the Waimakariri Zone

Year	Total allocation (million m^3)	Total available allocation (after restrictions) (million m^3)	Percentage restricted	Metered allocation (million m^3)	Available metered allocation (after restrictions) (million m^3)	Percentage restricted	Metered usage (million m^3)
2010	333	315	5 %	37	27	27 %	15
2011	427	393	8 %	389	360	7 %	140
2012	424	349	18 %	389	320	18 %	126
2013	445	352	21 %	390	310	21 %	144
2014	507	451	11 %	397	355	11 %	143
2015	500	432	14 %	387	331	14 %	102

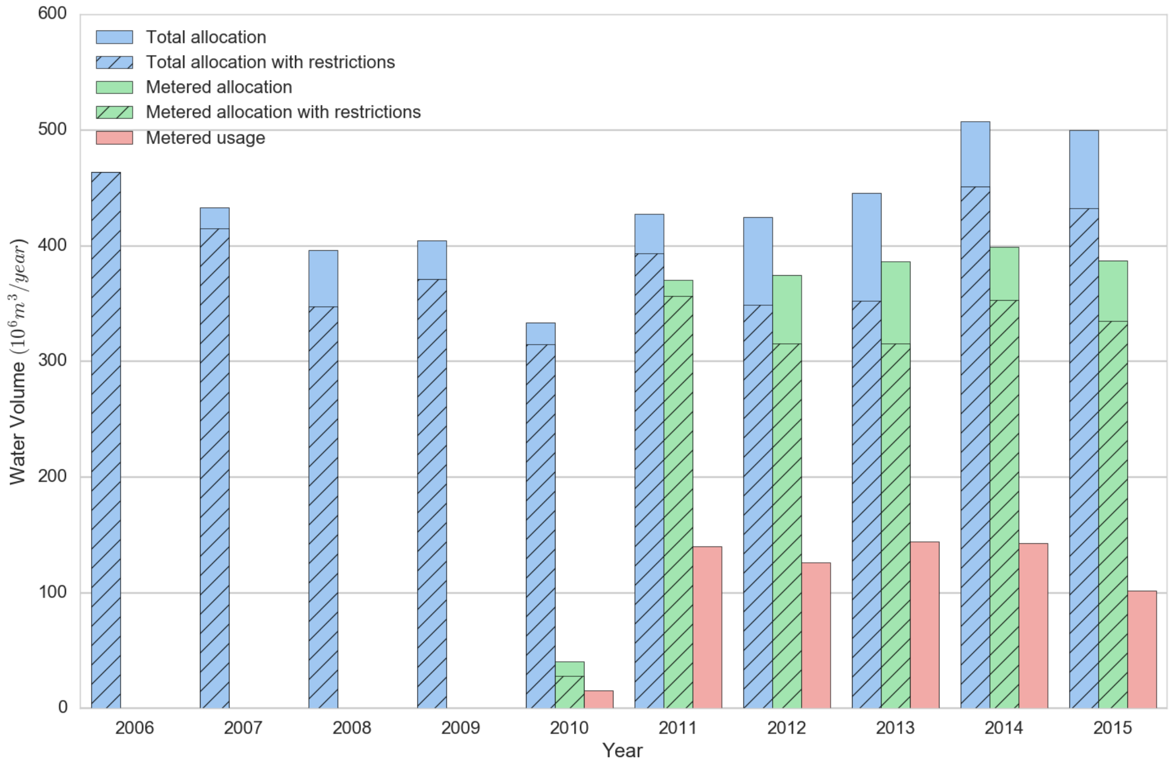


Figure 25 - Total water use and allocation for the Waimakariri Zone SWAZs

Table 18 – Number of days each allocation band is on restriction

	Minimum Flow Site	Allocation Block	Allocation Band	2012/ 2013 Full	2012/ 2013 Partial	2013/ 2014 Full	2013/ 2014 Partial	2014/ 2015 Full	2014/ 2015 Partial	2015/ 2016 Full	2015/ 2016 Partial
Land and Water Regional Plan	66204 Ashley River	A	Band 1	42	54	4	36	119	58	79	82
			Band 4	92	8	42	8	144	8	150	26
			Band 5	26	0	-	-	-	-	-	-
			Band 7	91	1	40	2	143	1	145	5
		B	Band 8	0	94	0	40	0	175	0	27
			Band 9	102	0	51	0	154	0	30	0
		C	Band 11	100	3	49	3	150	5	156	4
			Band 13	-	-	-	-	149	14	225	38
	253 Saltwater Creek	A	Band 1	0	22	0	1	0	50	0	45
	389 Waikuku Stream	A	Band 1	-	-	-	-	60	0	-	-
			Band 2	0	85	0	81	60	95	0	195
			Band 3					59	16	0	18
	66215 Taranaki Creek	A	Band 1	0	91	0	88	65	113	0	193
			Band 2	-	-	-	-	67	68	13	128
	387 Little Ashley Stream	-	Band 2	0	104	-	-	-	-	-	-
Waimakariri River Regional Plan	66417 Cust Main Drain	A	Band 5	0	48	0	2	0	104	0	89
			Band 7	0	48	0	2	0	104	0	89
			Band 8	0	48	0	2	0	104	-	-
			Band 9	0	47	0	2	0	102	0	88
			Band 10	0	48	0	2	0	104	0	89
			Band 11	0	48	0	2	0	104	0	89
			Band 12	0	48	0	2	0	105	0	91
			Band 14	-	-	-	-	0	104	0	89

	Minimum Flow Site	Allocation Block	Allocation Band	2012/ 2013 Full	2012/ 2013 Partial	2013/ 2014 Full	2013/ 2014 Partial	2014/ 2015 Full	2014/ 2015 Partial	2015/ 2016 Full	2015/ 2016 Partial
		B	Band 15	-	-	-	-	0	137	0	105
Waimakariri River Regional Plan	270 Cust River	A	Band 2	0	17	0	0	0	60	0	23
			Band 3	0	55	0	1	0	99	0	89
	66409 Cam River	A	Band 1	0	16	0	5	0	140	0	102
			Band 3	17	99	7	228	164	136	104	255
			Band 4	0	62	0	16	0	185	0	110
			Band 5	0	116	0	235	0	300	0	359
	361 Kaiapoi River	A	Band 1	-	-	-	-	38	0	0	136
			Band 2	-	-	-	-	38	0	0	136
			Band 4	-	-	-	-	0	38	0	262
	343 No.7 Drain	A	Band 1	0	112	0	0	0	0	0	21
	370 Ohoka Stream	-	Band 2	0	112	0	0	0	38	-	-
			Band 3	0	112	0	0	0	105	-	-
			Band 4	0	112	-	-	-	-	-	-
			Band 5	0	112		-	-	-	-	-
			Band 6	0	112	0	0	0	105	-	-
	279 North Brook	A	Band 1	0	104	0	139	38	94	63	60
			Band 2	0	104	0	139	0	132	0	123
			Band 3	0	104	0	139	0	132	0	63
	1115 Middle Brook	A	Band 1	104	0	68	0	132	0	209	0
Non-plan	166405 Eyre River	-	Band 1	0	15	-	-	-	-	-	-
	1516 Mounseys Stream	-	Band 1	65	9	0	0	19	2	90	35
	66213 Okuku River	-	Band 2	-	-	-	-	74	25	71	38

10 Water use

10.1 Background

Environment Canterbury has collected data on actual water usage by water consent holders over the past decade through the installation of flow meters at the water abstraction points (WAPs). However, water usage data prior to 2012 is sparse and generally describes use for only a small proportion of the consented abstractions.

10.2 Zone Summary

We have presented below the available water use data for the Waimakariri Zone. This is also presented in Section 9 as all water use data in the LWRP area (**Figure 23**), the WRRP area (**Figure 24**), and then the zone as a whole (**Figure 25**).

The volume of water metered in comparison to the allocated surface water in the LWRP SWAZ is low, with approximately 42 % of allocated volume capture by consents with flow meters (**Figure 23**). Of the metered volume, approximately 30 % of the allocated water was used. The volume consented in the LWRP SWAZs is less than 5 % of the allocated water within the Waimakariri Zone.

Of the allocated surface water volume in the WRRP SWAZs, nearly 80 % was captured in consents with flow meters (**Figure 24**). About 30 % of the metered allocations were actually used by volume.

About 78 % of the allocated surface water volume for all consents was captured in the consents with flow meters (**Figure 25**). Of the metered consents, about 30 % of the allocated water was actually used by volume, which is lower than the overall Canterbury usage of approximately 60 %.

10.3 Major water users

Water use in the Waimakariri Zone is primarily for irrigation and stockwater. We have summarised the major water users for the zone in **Table 19**. Additional information is described in the following sections.

Table 19 - Consent information for major water users in the zone

Consent Holder	Consent Number	A block abstraction (m^3/s)	B block abstraction (m^3/s)	Maximum volume ($m^3/year$)	Minimum flow	Expiry date	Abstraction Location
WIL	CRC166677	11.041	-	-	WRRP - **Table 20**	2031	Waimakariri River at Browns Rock
	CRC144253	0.2	-	4,016,301	WRRP - **Table 20**	2033	Waimakariri River at Browns Rock
	CRC000585.9	10.5 + 1.5 for groundwater augmentation	-	57,100,100	WRRP - **Table 20**	2031	Waimakariri River at Browns Rock
Ngai Tahu	CRC169707	2.12	3.36 (less A block abstraction)	41,310,700 (irrigation) 1,064,186 (stock water/dairy shed)	WRRP - **Table 20**	2031	Waimakariri River at Browns Rock
Claxby	CRC152927	1.609	-	-	WRRP - **Table 20**	2033	
WDC	CRC133965	2.1	-	-	No minimum flows apply to this consent	2039	Waimakariri River at Browns Rock
Loburn	CRC970989	0.065	-	1,576,800 (4,320 m^3 per day)	**Table 21**	3032	Okuku River adjacent to Yaxleys Road

Table 20 – Flow regime for the Waimakariri River

Flow regime	Flow (L/s)
A Block	
Abstractions cease	41,000
Water sharing regime between A block allocations	41,000–63,000
Maximum A block abstractions allowed	63,000
B Block	
Abstractions cease	63,000
Water sharing regime between B block allocations	63,000–63,000+B1
Maximum B block abstractions allowed	63,000+B1 (B permits within 'First Priority Band')

10.3.1 WIL

The consent granted to WIL in mid-2016 (CRC166677; expires 2031) has not been activated as of July 2016. This leaves the primary consent for WIL abstractions being from the consent granted in 1999, CRC000585.9.

WIL also hold consent CRC952571.1 which allows for the discharge of 3 m^3/s from their race system to augment flows within the Eyre River. This flow was intended to assist in river augmentation trials on the Eyre River and is not routinely used.

10.3.2 Loburn

Loburn Irrigation Company Limited consent is the only irrigation scheme within the Waimakariri Zone that abstracts from the Okuku River. The minimum flow for the Loburn Irrigation Company abstraction is set based on flows measured at the Ashley River gorge recorder (**Table 21**).

Table 21 - Loburn Irrigation Company minimum flow requirements

Month	Ashley River minimum flow (L/s)
January	2,200
February - March	1,700
April	2,200
May - November	4,200
December	3,200

11 Recreation

11.1 Introduction

There are numerous recreational uses of the zone's rivers and standing waterbodies, as detailed in the Waimakariri Sub-regional Plan: Recreational/Social Current State Report (Sparrow, 2016). Each of these activities rely on the characteristics of the surface water body at which the activity takes place. Any changes to the hydrology of the surface water body could by extension change the ability of users to recreate in the way that they currently do. Our main focus here is the in-stream recreational users on the main rivers of the zone (**Table 22, Map 18**).

Table 22 - Main instream recreation activities by water body

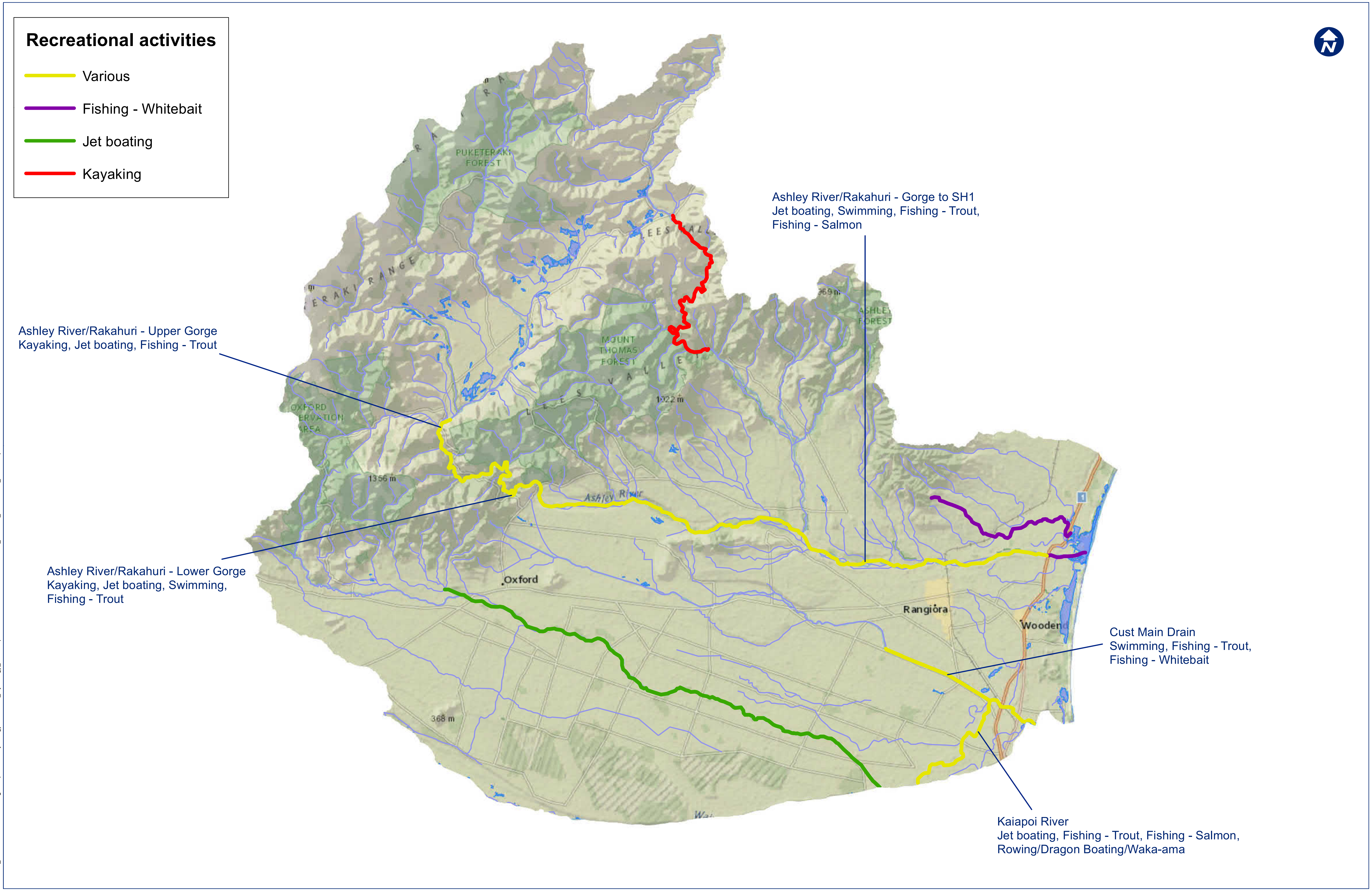
Activity	Location			
Swimming	Ashley Gorge above Bridge	Ashley Gorge below bridge	Ashley at Rangiora	Lower Main Drain
Rowing/dragon boating/waka-ama	Kaiapoi River at Kaiapoi	-	-	-
Kayaking	Ashley River	Okuku River	-	-
Jet Boating	Ashley River	Kaiapoi River	Eyre River	-
Fishing (whitebait)	Ashley lower reaches	Saltwater Creek	Kaiapoi River/main Drain	-
Fishing (salmon)	Kaiapoi River	Ashley River	-	-
Fishing (trout)	Ashley River	Cust main drain	-	-

An analysis of the hydrological characteristics that support the identified uses is presented below. We have attempted to distil the uses of a wide variety of users, each of which have their own skill and comfort levels (which itself changes as that person progresses in a sport) in a way that can be compared to a benchmark and by which change can be assessed in a scientific manner.

The methods used to undertake this analysis is the opportunity window approach. By using flow duration curves (FDCs) and an understanding of the flow bands in which activities occur, the window of opportunity that exists for users to undertake their chosen activity can be identified (**Appendix B**). The opportunity window is a somewhat blunt analysis, and so this is backed up by a further set of statistics that aims to indicate the temporal occurrence of flow bands (**Table 23**).

Table 23 - Temporal statistics to define recreation bands

Label	Description	Unit
Opportunity window	From FDC - % time flow band occurs	%
Window occurrence $_{average}$	Average occurrence of distinct flow band events per year	No.
Window duration $_{average}$	Average duration of flow band events	Days
Period between window $_{average}$	Average period between flow band events	Days



This map is confidential and shall only be used for the purposes of this project.

Rev.	By	App.	Description	Date
1	SH	MM	Final	20/12/16
A	SH	MM	Draft for review	9/07/16

Notes:

Printed	04 Oct 2016 15:30		
Drawn	SH	Date	19/07/2016
Checked	MM	Date	19/07/2016
Approved	MM	Date	19/07/2016
File Name	Map 18		

Map features depicted in terms of NZTM projection.

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Waimakariri land and water solutions programme

Project: **Current State Reporting - Hydrology**

Title: **Main instream recreational activities**

Scale: 1:250,000 (A3 size) — 2.5 1.25 0 2.5 5 Kilometres

Status: Final | Map No. **Map 18** | Rev. 1

11.2 Swimming

Swimming has been identified as important during the summer months at the Ashley Gorge camp site. AECOM (2011) presents an upper flow limit of 5 m^3/s for swimming at this location; no lower bound was presented. We have chosen a lower bound of 2 m^3/s for the site because, while it may create a flow too shallow to swim, there will be occasional pools that will continue to provide recreation opportunities. Flow statistics to define opportunity windows were not available for any other sites but if additional information arises we will use this in the scenario assessment.

The opportunity window analysis (**Appendix B**) was undertaken from 1st October to 31st April, this being the period during which swimming is most likely to occur due to warmer water temperatures. This period has an average opportunity value of 37 %. Temporal statistics for swimming use at Ashley Gorge camp site were also determined (**Table 24**).

Table 24 - Swimming opportunity statistics for the Ashley Gorge

Statistic	Ashley Gorge
Opportunity window (%)	37
Window occurrence $_{average}$ (per season)	9
Window duration $_{average}$ (days)	8
Period between window $_{average}$ (days)	14

11.3 Jet boating

Jet boating is an iconic form of recreation on New Zealand waters. It also forms a core component of the recreational activity of hunters, angler and others seeking access to relatively remote areas. Most jet boating occurs during the period of October to March (Environment Canterbury, 2016).

A number of key issues affect jet boaters and their ability to enter the water: these are primarily covered in Waimakariri Sub-regional Plan: Recreational/Social Current State Report (Sparrow, 2016). The flows required for jet boating usually need to provide at least 100-150 mm of water, with the route being free of large rocks and/or boulders.

Jet boating on Canterbury Rivers (2015) describes jet boating classes based on skill level and risk (**Table 25**). Each class is assessed according to average flows and a change in classification may be necessary at higher or lower flows.

Table 25 - Jet boating class descriptions

Class	Description
Class 1	Easy boating, suitable for beginners and family boating. Boat damage unlikely. Deep water, braids with fine gravel, shingle, minor rapids only. In different flow conditions can encounter boulders, minor rock gardens, small but lively rapids or very shallow water
Class 2	More advanced, comfortable after 100 hours experience. Contains challenges. Boat damage and risk of injury may result from misjudgements. Medium rapids, shallow water, complicated braids, some boulder/rocks, occasional willows.
Class 3	Adventure boating. Expert skills required. Boat damage/loss probable if mistakes made. Families not recommended. Crew and driver at risk if accident occurs. White water covers recommended. Maximum 2 persons/boat recommended. Challenging rock gardens, boulders, major rapids, chutes, willows and often shallow and flooded conditions.
Class 4	Unlikely to be boated. Impasses, waterfalls, no water.

Greenaway et al. (2015) described the key jet boating sites following the classification described above (**Table 26**). The establishment of useful flow guidelines can be difficult, but flows have been defined for the Ashley River/Rakahuri in relation to the Ashley River at Gorge (66204) flow gauge (Environment Canterbury, 2016).

Table 26 - Jet boating sites

River	Reach	Class	Comments	Required flow (m^3/s)
Ashley River	Gillespies Bridge to Middle Bridge	Class 2	Rocks/gorgy/no access. Gradient: 7.5 m/km	50
	Middle Bridge to Ashley Gorge	Class 3	Rocks/chutes/gorgy/no access Gradient: 8.3 m/km	70
	Ashley Gorge to SH1	Class 2	Shingle/braided/willows Gradient: 5.0 m/km	20
Waimakariri River	Gorge Bridge to SH1	Class 1	Shingle/braided Gradient: 4.4 m/km	Needs high flows (flood)
Eyre River	Waimakariri River to Oxford Bridge	Class 3	Shingle/willows/braided Gradient: 6.3 m/km	Needs high flows (flood)

We have considered jet boating as a year round activity because no restrictions are set on the Ashley River reaches, although it does generally occur in the summer months (October – March). As such we have analysed the opportunity window for jet boating on a full-year basis (**Table 27, Appendix B**).

Table 27 - Jet boating opportunity statistics

Statistic	Ashley Gorge		
	Gillespies Bridge to Middle Bridge	Middle Bridge to Ashley Gorge	Ashley Gorge to SH1
Opportunity window (%)	2	1	13
Window occurrence $_{average}$ (per year)	4	3	13
Window duration $_{average}$ (days)	2	2	4
Period between window $_{average}$ (days)	82	128	25

We did not analyse boating on the Eyre River as use of the Eyre River is a rare occurrence.

11.4 Fishing

Very little information is available regarding suitable flow rates for fishing the watercourses in the Waimakariri Zone. Additional information will be available in future reports covering recreation following collaboration with Fish and Game and additional survey work.

Aqualinc (2011) states that the lower gorge is fishable up to a flow of 5 m^3/s, above which the flow becomes too rapid for fishing. The fishing season for trout above the Ashley Gorge bridge is from the 1st October to 30th April so we have undertaken the opportunity window analysis on a seasonal basis (**Table 28, Appendix A**).

Table 28 - Fishing opportunity statistics for the Ashley Gorge

Statistic	Ashley Gorge
Opportunity window (%)	48
Window occurrence $_{average}$ (per season)	7
Window duration $_{average}$ (days)	14
Period between window $_{average}$ (days)	16

11.5 Kayaking

A significant amount of supporting research is available regarding the use of Canterbury rivers for kayaking (Rankin *et al*., 2014). This information has been used along with the Waimakariri Sub-regional Plan: Recreational/Social Current State Report (Sparrow, 2016) to identify sites of importance and the ways in which these sites are used.

The key kayaking sites are defined in Rankin *et al*., (2014) (**Table 29**) and follow the classification system of American Whitewater; the International Scale of River Difficulty (https://www.americanwhitewater.org/content/Wiki/safety:start?#vi).

Table 29 - Key kayaking sites

River	Reach	Class	Features/values	Category
Waimakariri	Gorge Bridge to SH1 Bridge	II	**Beginner-intermediate white water**. Beginner - Expert downriver racing. Close to Christchurch	A
Ashley	Gillespies Bridge - Middle Bridge	II (III)	**Developing beginner-intermediate white water.** Wilderness feel. Wild and scenic gorge. Proximity to Christchurch	B
	Middle Bridge - Domain	III+	**Outstanding intermediate-advanced white water.** Wilderness feel. Wild and scenic gorge. Proximity to Christchurch	B
Okuku	Lees Valley - Fox Creek	III+ - IV	**Outstanding advanced-expert white water.** Wilderness feel. Wild and scenic gorge. Proximity to Christchurch	B

'Difficulty' is a subjective metric and depends on an individual's experience, skills and willingness to accept risk. Rankin (2014) provides information on the general level of experience required to undertake a defined difficulty rating in comfort (**Table 30**). Rankin (2014) provides further information around the difficulty ratings undertaken by a person outside their comfort zone, however, we have limited this analysis to 'in comfort' only. Two types of kayaking are considered. White water kayaking occurs on all rivers in the zone, whereas multisport kayaking is restricted to the Waimakariri River. Multisport kayaking is generally focused on fast traverse of relatively flat white water, whereas white water kayaking is focused on traversing and playing with the hydraulic features of a river. The equipment and skill required are very different and we have therefore split these into separate analyses.

Table 30 - Kayaking in-comfort use

Class	In-comfort use	
	White water kayaker	Multisport kayaker
I	Beginner	Beginner
II	Beginner	Intermediate
II+	Beginner	Advanced
III	Intermediate	Expert
III+	Advanced	-
IV	Advanced	-
V	Expert	-

Using the above categorisation, Rankin (2014) has defined the flow requirements of each site and each skill level (**Table 31**).

Table 31 - Kayaking flow requirements

River	Reach	Class	Flow requirement (m^3/s)			
			Beginner	Intermediate	Advanced	Expert
Waimakariri	Gorge Bridge to SH1 Bridge	II	60-200	60-300	60-400	-
		Multisport	60-150	60-200	60-500	60-600
Ashley	Gillespies Bridge - Middle Bridge	II (III)	10-30	10-60	20-100+	-
	Middle Bridge - Domain	III+	-	10-45	20-200	20-250+
Okuku	Lees Valley - Fox Creek	III+ - IV	-	-	10-60	10-100+

We have used these flow requirements and the upper and lower bounds for the opportunity windows in this analysis (**Appendix B**) and to consider the temporal aspects of the opportunities (**Tables 32-36**). Unlike swimming, which is limited by water temperature, and fishing which is limited by open-seasons, we have considered kayaking to be a year-round activity. The Okuku River and Ashley River/Rakahuri in particular require southerly, easterly or northerly storms to give rise to many of the kayak-suitable events and these weather patterns occur year round. On the Waimakariri River the Brass Monkey race series (http://brassmonkey.org.nz/index.html) is held each June/July and is one of the largest of its kind in New Zealand.

As such we have analysed the opportunity window for kayaking on a full-year basis.

Table 32 - White water kayaking for the Ashley Gorge - upper

Statistic	Ashley Gorge - upper			
	Beginner	Intermediate	Advanced	Expert
Opportunity window (%)	31	36	13	-
Window occurrence $_{average}$ (per year)	22	18	13	-
Window duration $_{average}$ (days)	5	7	4	-
Period between window $_{average}$ (days)	12	13	25	-

Table 33 - White water kayaking for the Ashley Gorge - lower

Statistic	Ashley Gorge - lower			
	Beginner	Intermediate	Advanced	Expert
Opportunity window (%)	-	34	13	13
Window occurrence $_{average}$ (per year)	-	20	13	13
Window duration $_{average}$ (days)	-	6	4	4
Period between window $_{average}$ (days)	-	12	25	25

Table 34 - White water kayaking for the Okuku River

Statistic	Okuku River			
	Beginner	Intermediate	Advanced	Expert
Opportunity window (%)	-	-	8	8.4
Window occurrence $_{average}$ (per year)	-	-	10	9
Window duration $_{average}$ (days)	-	-	3	3
Period between window $_{average}$ (days)	-	-	34	36

Table 35 - White water kayaking for the Waimakariri River

Statistic	Waimakariri River			
	Beginner	Intermediate	Advanced	Expert
Opportunity window (%)	72	77	79	-
Window occurrence $_{average}$ (per year)	18	14	12	-
Window duration $_{average}$ (days)	15	20	25	-
Period between window $_{average}$ (days)	6	6	7	-

Table 36 - Multisport kayaking for the Waimakariri River

Statistic	Waimakariri River			
	Beginner	Intermediate	Advanced	Expert
Opportunity window (%)	63	72	80	80
Window occurrence $_{average}$ (per year)	22	18	10	9
Window duration $_{average}$ (days)	11	15	29	33
Period between window $_{average}$ (days)	6	6	8	8

12 Conclusion

In this report we defined the key characteristics of the zone's current surface hydrology, establishing information which is used in the preparation of Current State reports for other disciplines, and in the subsequent scenario and solutions work.

We have covered the current state of hydrology for the Waimakariri Zone in a narrow sense that refers to the surface water found within the zone's flowing watercourses, standing waterbodies and wetlands. However, we have included some assessment of shallow river connected groundwater. This information should guide the Waimakariri Water Zone Committee's recommendation towards their ZIP addendum as part of the Waimakariri land and water solutions programme.

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14 Appendix

14.1 Appendix A - Methodology to derive flow characteristics

Watercoures within the Waimakariri Zone have three levels of monitoring data: flow monitoring site data, flow gauging data and no flow data. Flow monitoring sites measure the flow continuously with rating curves for the site updated regularly or after major flood events. Flow gauging data is gained from manual gaugings at the site but can have as few as one gauging per site.

The flow data used was accepted as accurate in terms of the appropriate application of rating information. Notwithstanding this a high-level assessment for data errors was undertaken using techniques defined in Hydrology Centre (1988) and WMO (2008).

Monitored catchments
Monitored catchments typically have extended periods of data for each location. However, in the Waimakariri Zone there are multiple monitoring sites with very limited data (**Figure 6**). For these sites the flow statistics are calculated using the available data. The Ashley at Gorge (66204) monitoring site has the longest data.

Some available data sets have minor gaps that we had to fill in order that we could use the data set. We filled the gaps by creating regressions between similar catchments. Erroneous values were corrected by performing reality checks such as comparing the filled and unfilled flow statistics and flow duration curves and assessing against rainfall. Having continuous data available allows a range of flow statistics to be drawn from the data to define the characteristics of the watercourse (**Table 4, 6**).

Gauged catchments
There are numerous methodologies by which to derive flow statistics for gauged catchments to allow the character of the watercourse to be defined. There is often a temptation to use very limited data sets in such work, which limits the power of the resulting predictions in the unmonitored catchment. The limitations of the method used are often quickly forgotten as the numbers are taken up and used. To this end we have sought to impose a standard for the use of gauge data to predict flow statistics in unmonitored catchments (**Table 5, 7**).

The current best-practice is the guidelines laid out in Journal of Hydrology NZ 54 (2): 147-152, 2015. Estimation of low flow statistics at unmonitored sites by correlation of concurrent base flow gaugings. In preparing these guidelines the author has used the collective experience in New Zealand since the 1970s, and specifically conclusions given in Henderson *et al*., (2003).

The key guidelines are:
- Use of geometric mean regressions
- A minimum of 10 concurrent gaugings are required to undertaken analysis
- For estimates at, or around the Mean Annual Low Flow (MALF) then data above the median should be excluded from the regression.

For the hill-fed locations this methodology is generally applicable, except for the sites where 10 gaugings were not available (**Map 12**).

However, following the above methodology is difficult for the lowland streams. These streams have a generally stable flow profile which strays away from low flows only during rainfall events which cause runoff in the immediate surrounding area. They react to rising groundwater levels, but in a steady manner with gentle rise and fall. The flow estimates generated through gaugings on these lowland streams are also susceptible to changes in water level resulting from weed growth. The stable nature of the flow means that it is often difficult to obtain measurements across a range of flow values, leaving those collected clustered around the stable flow for the stream. When limiting analysis to only flows below the median this can cause problems with model fit (Allen and Hay 2011).

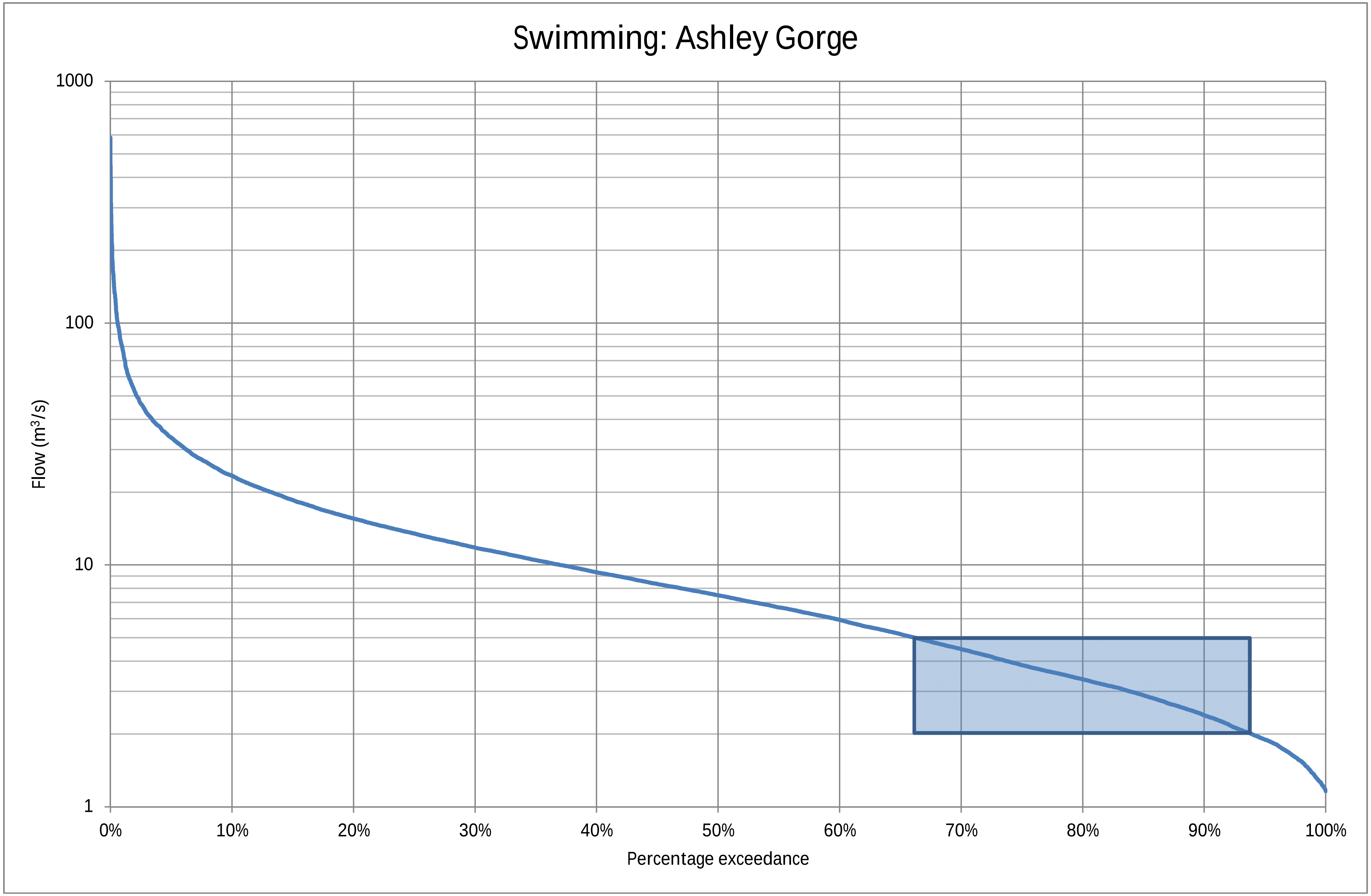
As a result the majority of regression relationships we have developed to provide low-flow statistics for ungauged sites return very poor regressions and generally cannot be relied upon as predictors of low-flows at ungauged sites. This was highlighted in Smith (2013) which felt that regression was in general an inappropriate method to define low-flow regimes at ungauged spring-fed sites. Smith (2015) reiterated this point and demonstrated that collecting more gaugings does not necessarily remedy the problem but can in fact increase data scatter and reduce the power of regressions further.

It is worth bearing in mind that the purpose of defining low-flow statistics, such as the MALF7d is to assist in setting ecological flow requirements. With this in mind, Smith (2015) raised the possibility of achieving this without the use of hydrological statistics, perhaps through dissolved oxygen assessments. We also consider that the indicative MALF7d values provided herein be used only in the context of an expert panel set up to consider the full range of information available in setting appropriate flow regimes on watercourses with abstraction effects.

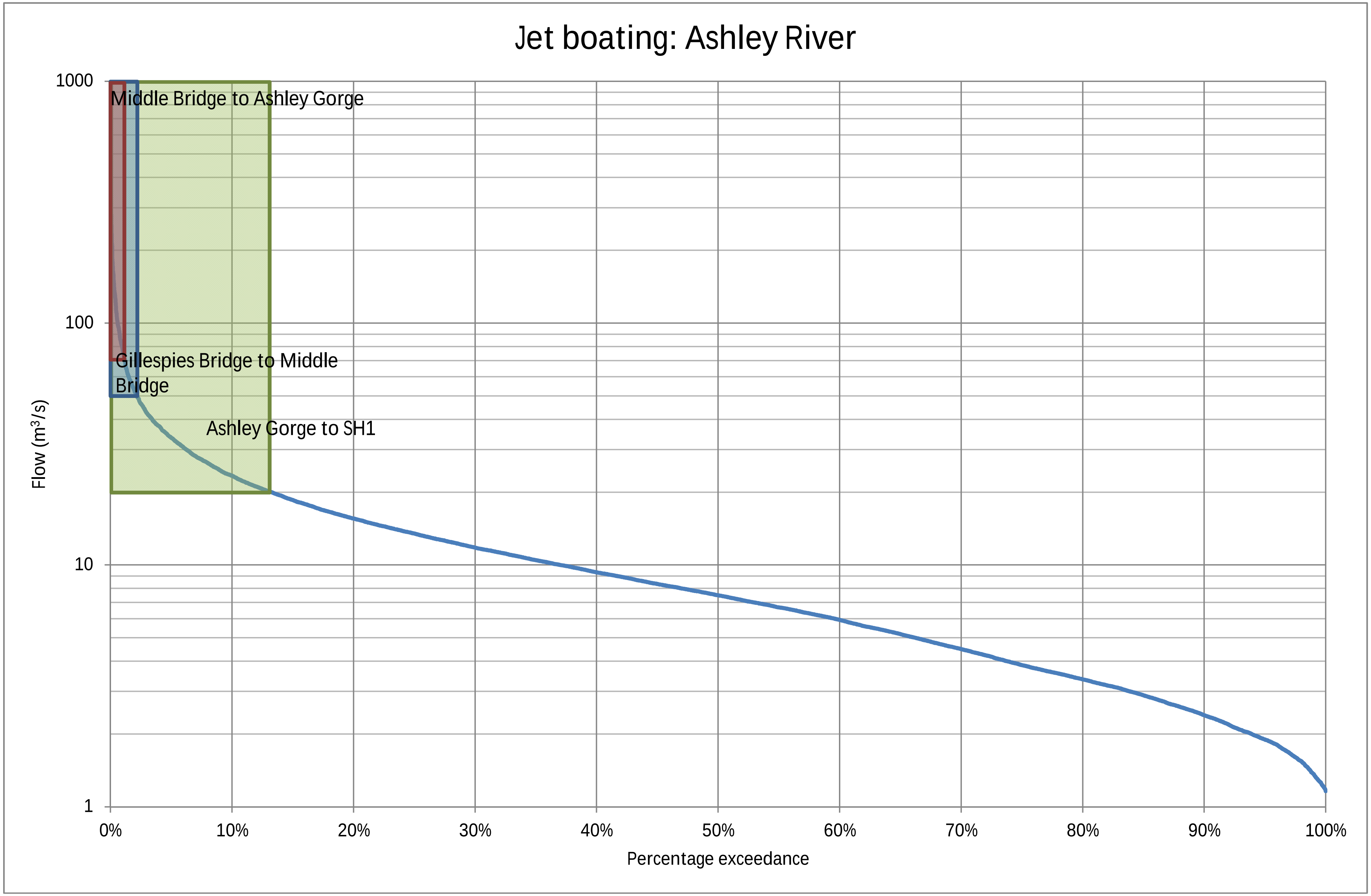
For these sites we have used the full range of available gaugings to derive the low flows as this was the only way to provide a somewhat justifiable regression model. In some locations we have developed statistics at sites where less than 10 concurrent gaugings exist through necessity. Where either of these has been done this will be clearly identified and statistics are presented as indicative only (**Table 5**).

Ungauged catchments
For catchments that have limited or no gauging data an average annual rainfall and area scaling method was used. Each catchment was scaled using catchment area. Rainfall data was obtained from the VCSN and used to also scale the catchments based on average rainfall. This method was only used for hill-fed catchments that were founded on bedrock rather than the gravel deposits located in the Plains, and this was limited to watercourses around Mt Grey.

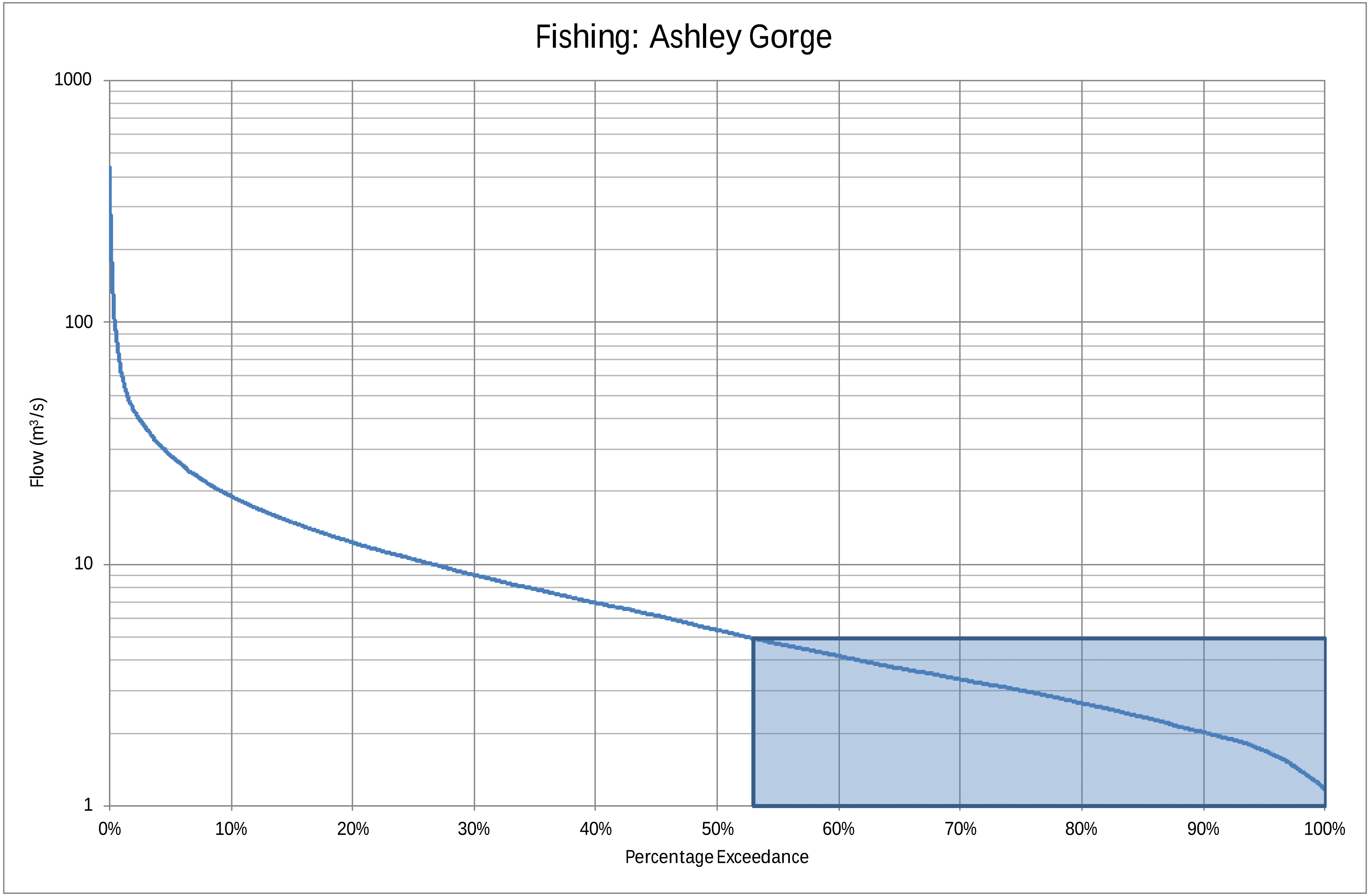
14.2 Appendix B – Recreation opportunity window analysis

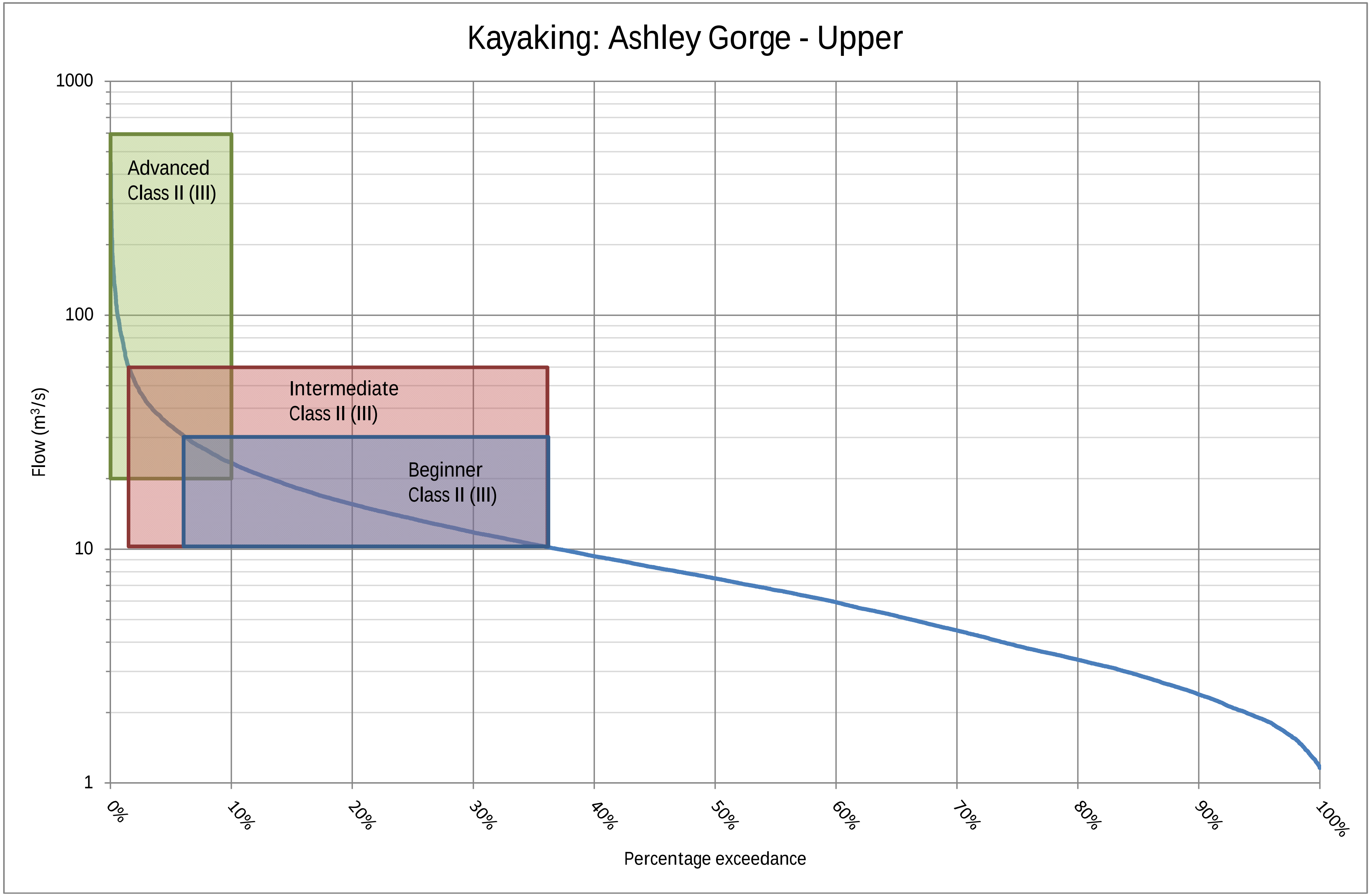


Swimming: Ashley Gorge
1000
100
10
1
Flow (m3/s)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage exceedance

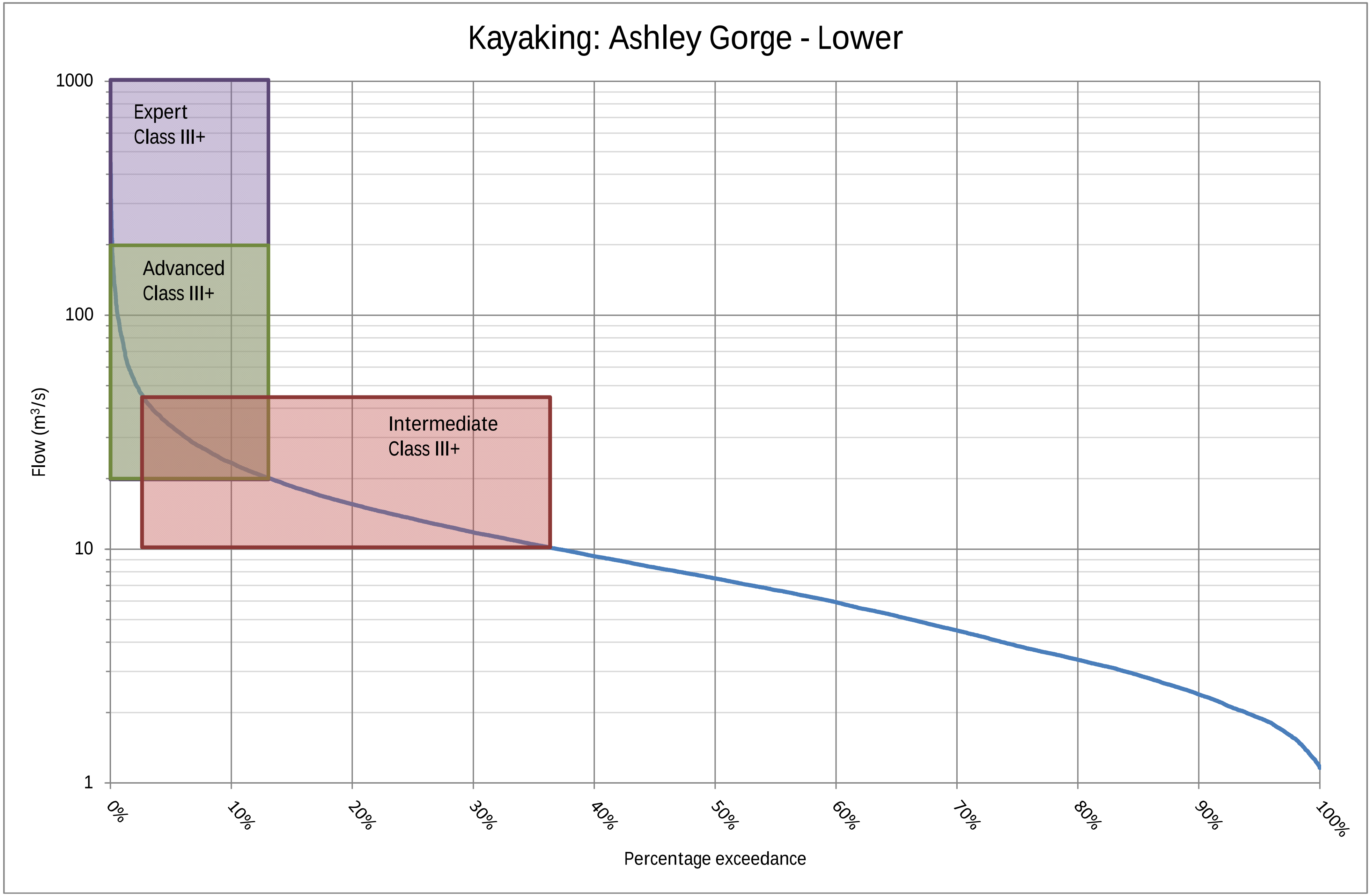


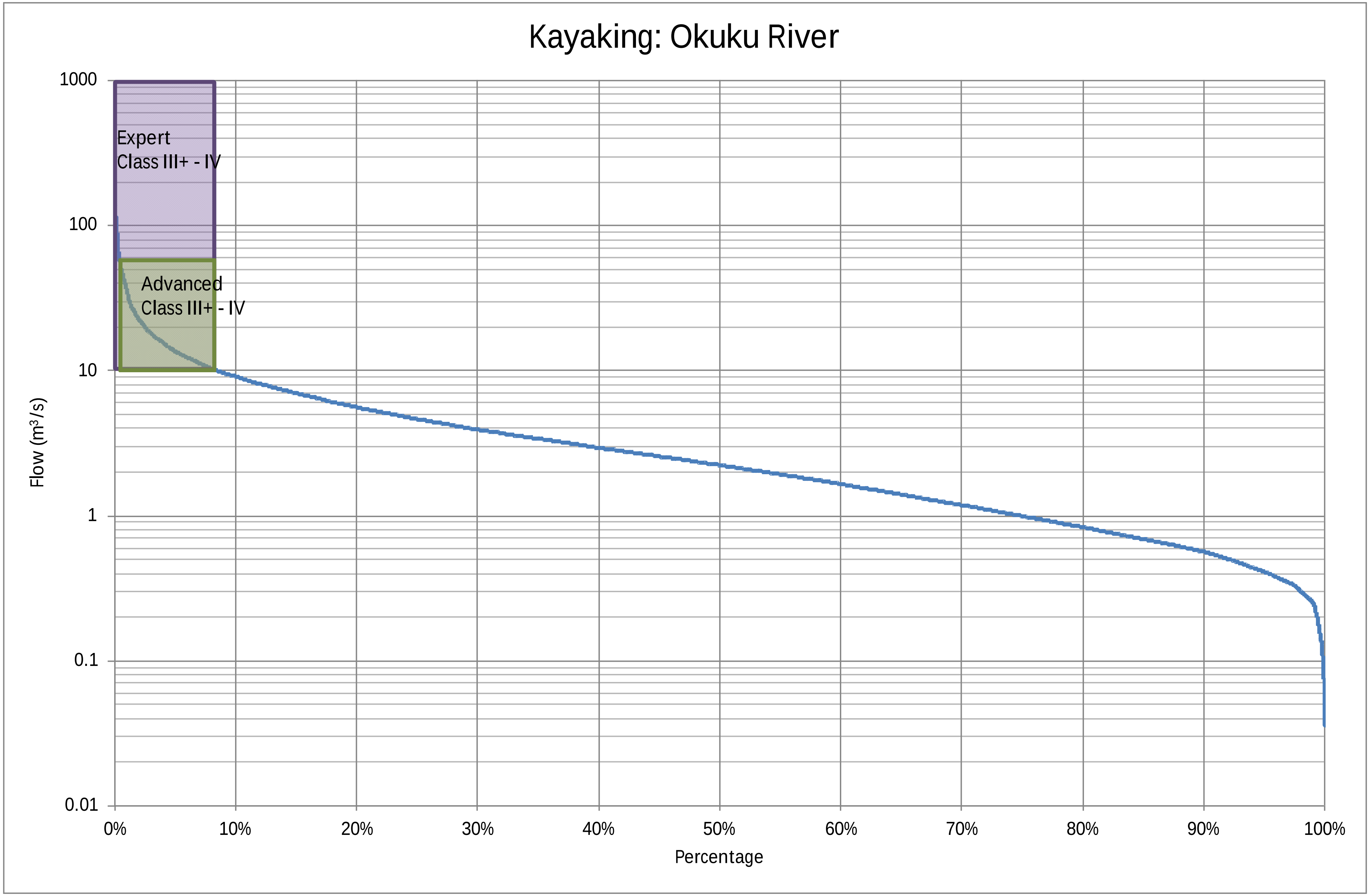
Jet boating: Ashley River
1000
100
10
1
Flow (m³/s)
Middle Bridge to Ashley Gorge
Gillespies Bridge to Middle Bridge
Ashley Gorge to SH1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage exceedance

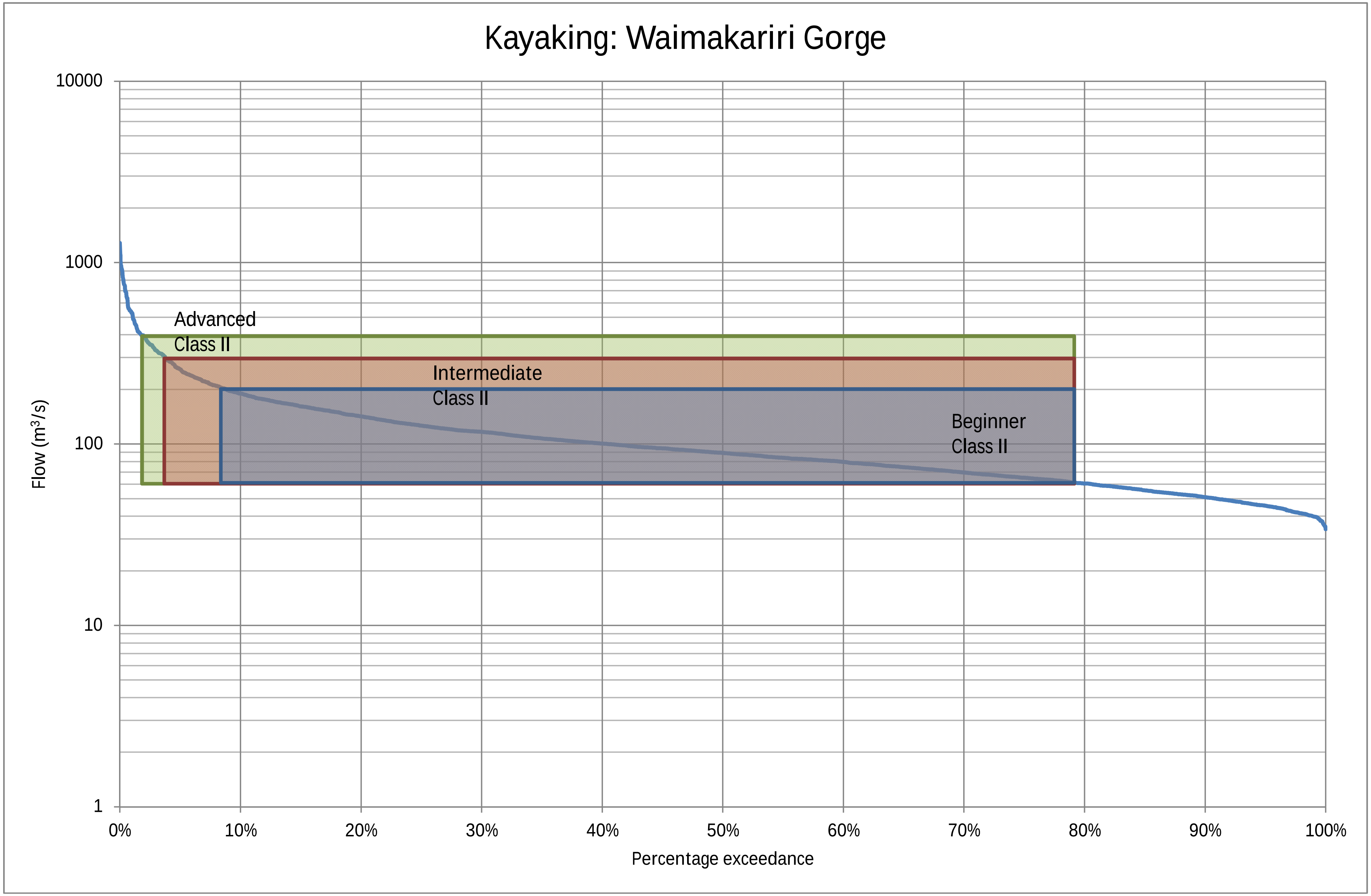

Fishing: Ashley Gorge
1000
100
10
1
Flow (m³/s)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage Exceedance



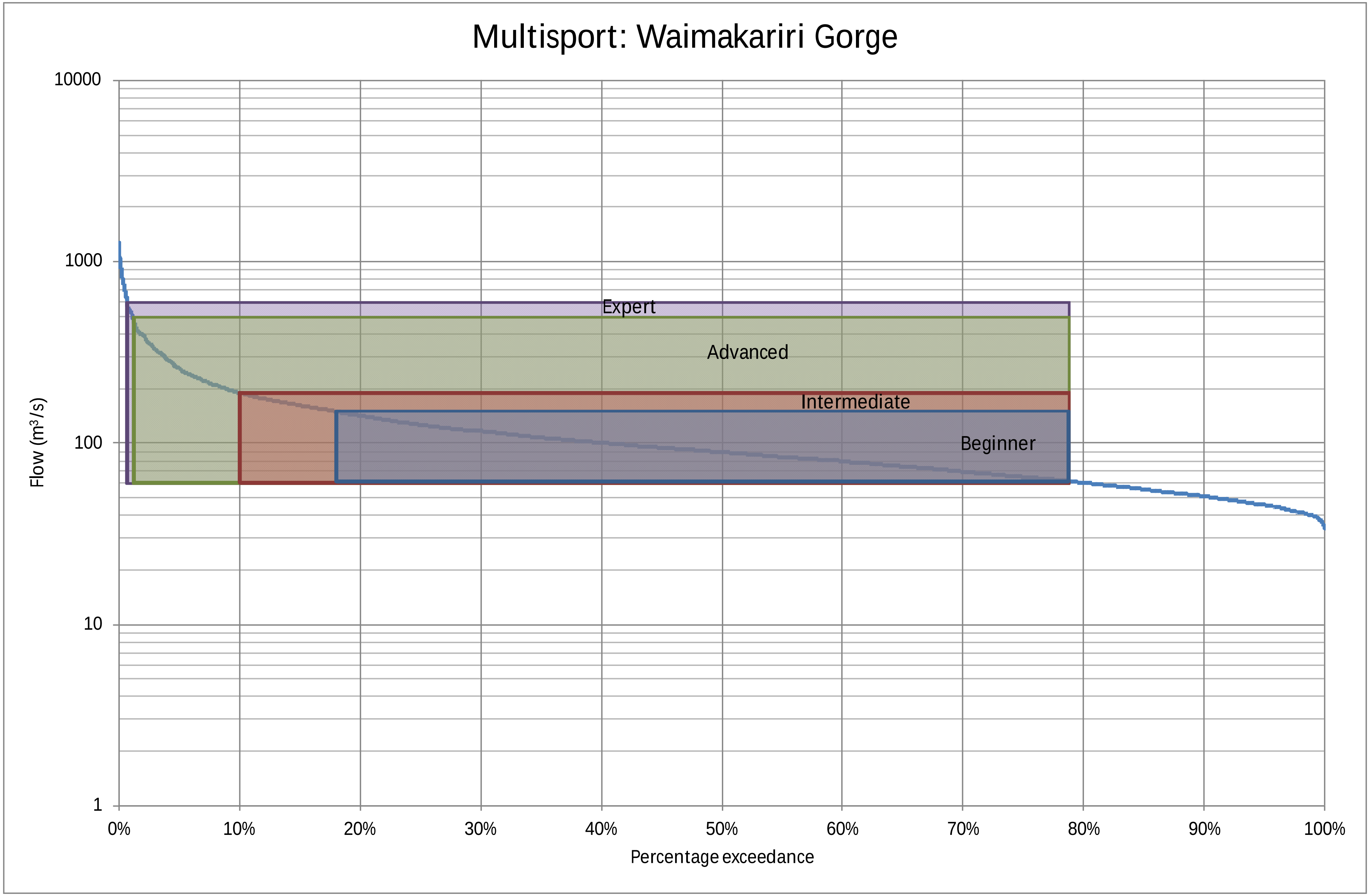
Kayaking: Ashley Gorge - Upper
1000
100
10
1
Flow (m³/s)
Advanced
Class II (III)
Intermediate
Class II (III)
Beginner
Class II (III)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage exceedance


Kayaking: Ashley Gorge - Lower
Expert
Class III+
Advanced
Class III+
Intermediate
Class III+
Flow (m3/s)
1000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage exceedance


Kayaking: Okuku River
Expert
Class III+ - IV
Advanced
Class III+ - IV
1000
100
10
1
0.1
0.01
Flow (m³/s)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage



Kayaking: Waimakariri Gorge
10000
1000
100
10
1
Flow (m3/s)
Advanced
Class II
Intermediate
Class II
Beginner
Class II
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage exceedance


Multisport: Waimakariri Gorge
10000
1000
100
10
1
Flow (m3/s)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage exceedance
Expert
Advanced
Intermediate
Beginner