TECHNICAL REPORT Science Group

Current state of surface water hydrology in the South of the Orari, Temuka, Opihi and Pareora Zone

Report No. R16/47

ISBN 978-0-947511-73-9 (print)
978-0-947511-74-6 (web)
978-0-947511-75-3 (cd)

Current state of surface water hydrology in the South of the Orari, Temuka, Opihi and Pareora Zone

Report No. R16/47

ISBN 978-0-947511-73-9 (print)
978-0-947511-74-6 (web)
978-0-947511-75-3 (cd)

Michael Exner-Kittridge

November 2016

Environment Canterbury
Regional Council
Kaunihera Taiao ki Waitaha

Report No. R16/47
ISBN 978-0-947511-73-9 (print)
978-0-947511-74-6 (web)
978-0-947511-75-3 (cd)

200 Tuam Street
PO Box 345
Christchurch 8140
Phone (03) 365 3828
Fax (03) 365 3194

75 Church Street
PO Box 550
Timaru 7940
Phone (03) 687 7800
Fax (03) 687 7808

Website: www.Environment Canterbury.govt.nz
Customer Services Phone 0800 324 636

Summary

Background:

Covering an area of approximately 893 km^2 of which the Pareora is 540 km^2, south Orari-Temuka-Opihi-Pareora (OTOP) covers a significant portion of the total OTOP Canterbury Water Management Strategy (CWMS) Zone (22%). Only 7% of the total allocated surface water in the OTOP zone is in south OTOP, and supports the livelihood for many people residing in the area. The Pareora River has the lowest mean daily flow (4.22 m^3/s) of the three major rivers in the OTOP zone (i.e. Pareora River, Opihi River, and Orari River).

What we did:

In this report, the major surface water catchments and allocation zones in south OTOP are assessed for the historic and current state of the surface water hydrology and the water abstractions from the surface waters. Surface water allocations were analysed to determine the total allocation by the type of use per year. The minimum flow conditions and the associated reliability of water supply assess when and how frequently allocation blocks and bands were under restriction. The actual water usage is presented to indicate what the consent users actually took from the rivers given the allocation volumes and the minimum flow restrictions. Flow statistics are presented on both the recorded flows and the naturalised flows. And finally, the Pareora River net losses and gains were determined from the many concurrent flow gaugings within the Pareora catchment.

What we found:

The Timaru District Council (TDC) has historically been the largest surface water abstractor in the Pareora catchment (Upper Pareora) and currently has nearly half of the total surface water allocation in the Pareora catchment. The remainder is used for irrigation and most of that occurs in the Lower Pareora. The other south OTOP catchments have about 15% of the allocation of the Pareora and 90% of that is allocated in the Levels and Seadown Plains catchment. Most of the allocated surface water in the other south OTOP catchments is used for irrigation. The Huts recorder on the Pareora River is the only minimum flow site in south OTOP and has two allocation blocks (A and B). Contrary to other catchments of the OTOP zone, the 2014/2015 water year did not see significant minimum flow restrictions, but rather the 2015/2016 water year saw much more restrictions across both allocation blocks. Most of the total allocated volume have meters with available data installed in the Pareora catchment (82%), and approximately 60% of the allocated surface water volume was actually abstracted in the 2014/2015 water year.

The recorder on the Pareora River at Huts (site number 70105) has over a 30 year record, while the only other recorder with a flow estimate is the Pareora River at SH1 (site number 70103) with about 6.5 years of a flow record. Although SH1 has a higher mean flow (4.22 m^3/s) compared to Huts (3.69 m^3/s), SH1 has a much larger seasonal flow range compared to Huts. SH1 has gone dry in the 2009/2010 and 2014/2015 water years, while Huts has never recorded zero flow. According to the stream losses and gains analysis for the Pareora catchment, the lower section of the Pareora River has had reaches become progressively more losing to groundwater between 2000 and 2008. This coincides with a sharp increase in surface water takes during this period.

What does it mean?:

In the Pareora catchment, two gauges represent the two major differences in the geologic contribution to the surface water flow. The Huts recorder which funnels all flow through a bedrock confined gorge and the SH1 recorder which is near the mouth across the lowlands area where surface water flow can be distributed into a groundwater aquifer to be discharged directly into the sea. Surface water flow will not accumulate as quickly within the lowlands as compared to the hills and mountains and may even

have a net loss of surface water near the mouth. Water abstractions can also affect the surface water losses especially for the summer low flows. The results from the naturalisation and the stream reach gains and losses indicate that water abstractions have a significant effect on the summer river flows when natural flows are at their lowest and irrigation demand is at their highest. The naturalisation analysis indicates that the Pareora River at SH1 would not run dry if there were less upstream water abstractions.

Table of contents

List of Figures

List of Tables

Acronyms, abbreviations and definitions

Pareora Catchment	The hydrological catchment of the Pareora River
OTOP Zone	The area managed by Section 15xx of the Canterbury Land and Water Regional Plan, including the Orari, Temuka, Opihi, and Pareora catchments.
SH1	State Highway 1
DOC	The Department of Conservation
LTR	Long term recorder – A recorder with at least 30 years of flow record.
VCSN	Virtual Climate Station Network
ET	Evapotranspiration
PET	Potential Evapotranspiration
NIWA	National Institute of Water and Atmospheric Research
SWAZ	Surface Water Allocation Zones
WAP	Water Abstraction Point
TDC	Timaru District Council
7DMALF	7 day mean annual low flow
Fre3	Frequency of flows greater than three times the median

1 Introduction

1.1 Study area

1.1.1 Catchment description

The south of the Orari-Temuka-Opihi-Pareora (OTOP) zone includes the Pareora River and several smaller surrounding areas (Levels and Seadown Plains, Washdyke Creek, Saltwater Creek, Pig Hunting Creek, and Lyalldale Creek) (Figure 1-1). The topography ranges from coastline to steeplands in the upper Pareora catchment with Te Huruhuru at 1,590 metres above sea level (masl) being the highest point in south OTOP.

The Pareora catchment is the largest catchment in south OTOP and has an aspect generally to the northeast. About one third is steepland and the remainder is hilly to rolling which becomes more subdued towards the coast (Aitchison-Earl *et al.,* 2006). Flat areas are generally alongside stream channels. The Pareora River is the largest and longest river in the study area and the hydrological catchment is approximately 540 km^2. The Pareora River is generally broken into two main segments with the Lower Pareora gorge near Mt Horrible dividing the Upper and Lower Pareora. The constriction at the Gorge brings together the South Branch Pareora River, the Motukaika River, the White Rock River, and the main stem Pareora River. Most of the water in the Pareora River is accumulated in the Upper Pareora from precipitation in the upland headwaters. In the Lower Pareora, the river flows through the lowlands floodplain which is approximately 2-3 km wide. Stopbanks confine the naturally braided river to protect adjacent properties from flooding.

The smaller south OTOP catchments range from 30 to 100 km^2 and are predominantly located nearer to the coast with intermittent lowland streams. The coastal area extending from State Highway 1 (SH1) to the sea includes a number of urban and industrial land uses (including the city of Timaru, Pareora township, Washdyke industrial area, and the Pareora meat processing works). As such, some of the waterways have been modified and / or incorporated into urban drainage networks. Near the coast in the Levels and Seadown plains catchment, the Seadown Drain that runs along the coast has historically drained the surrounding wetland areas.

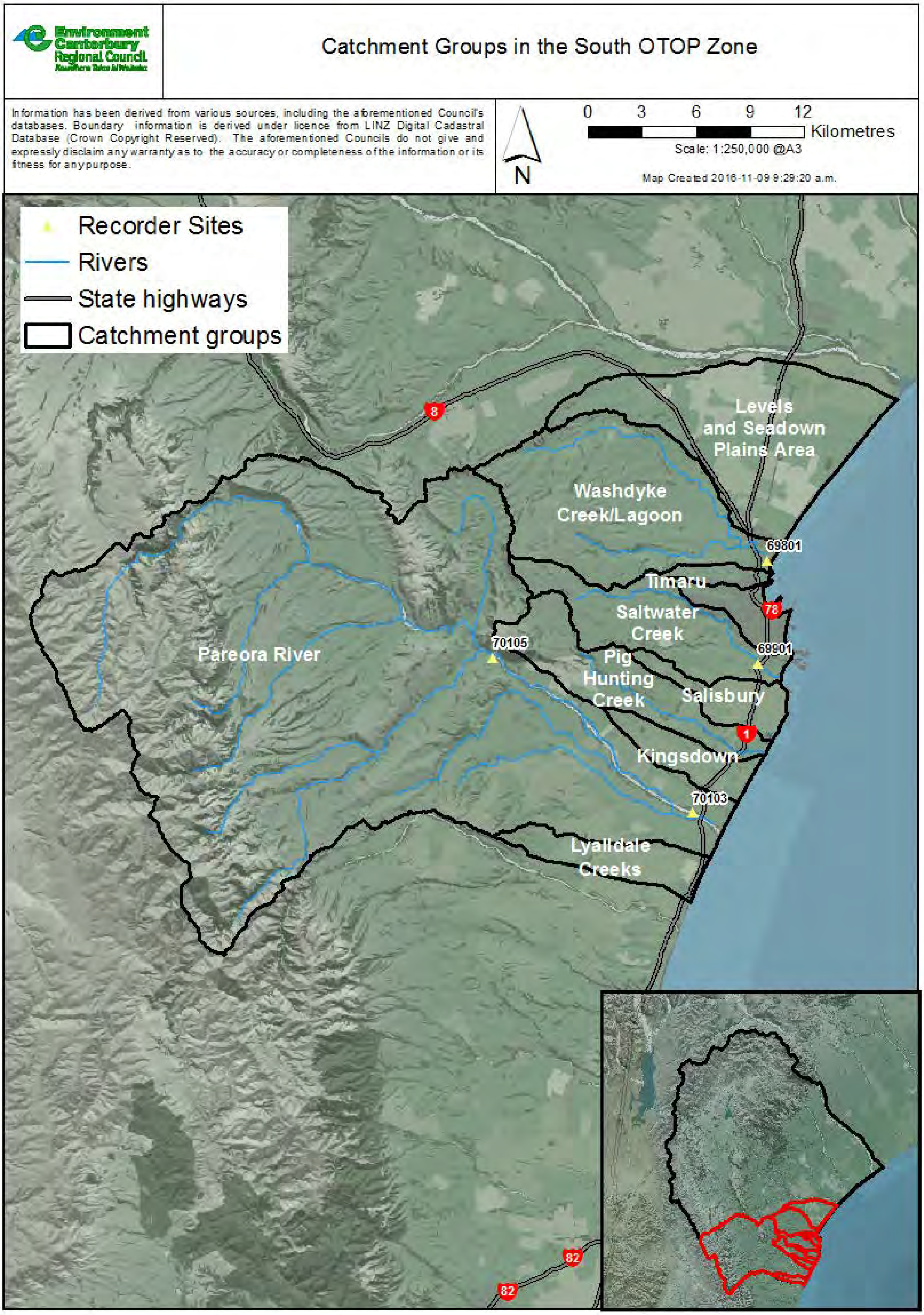

Figure 1-1: Hydrological catchments in the South OTOP Zone

1.1.2 Land use and land cover

Land use and land cover in the South OTOP area ranges from extensive pastoral areas to urban and is depicted in **Error! Reference source not found.** and . Of interest is the broad land cover and its effect on water runoff rates and volumes. The Upper Pareora includes part of the Department of Conservation (DOC) Hunter Hills Conservation Area. Table 1-1 provides a breakdown of broad land cover (New Zealand Land Cover Database 2015).

Land use information initially came from AgriBase. AgriBase is a national scale spatial database from Asure Quality containing information about farm location, type, size, stocking rate, and planting areas for crops. Further information about Agribase can be found in Sanson and Pearson (1997) or on the Asure Quality website.

AgriBase information was ground-truthed by members of the Orari-Temuka-Opihi-Pareora (OTOP) catchment groups. The catchment groups consist of community volunteers with an interest in the management of their local river.

Table 1-1: Land cover in South OTOP in hectares

Catchment	Artificial Surfaces	Bare or Lightly Vegetated Surfaces	Cropland	Forest	Grassland, Sedge and Saltmarsh	Scrub and Shrubland	Water Bodies
Kingsdown	< 0.1	9.5	835.7	20.6	728.7	< 0.1	< 0.1
Levels and Seadown Plains Area	348.9	53.3	3858.7	71	4867.7	< 0.1	3.7
Lyalldale Creeks	27.5	15.6	1367	16.2	690.5	< 0.1	< 0.1
Pareora River	104.2	636	3016.3	1969.8	43932.3	5009.9	97.5
Pig Hunting Creek	14.1	5.4	837.5	202.8	2991.6	54.1	5.9
Salisbury	2.4	5.9	1160.2	16.2	358.6	< 0.1	3.1
Saltwater Creek	480.1	6.5	472.6	221.4	4008.6	3.9	23.6
Timaru	1133.5	8.8	< 0.1	1.1	88.1	< 0.1	0.8
Washdyke Creek/ Lagoon	144.5	20.9	294.8	295.4	8964	105.8	29.2

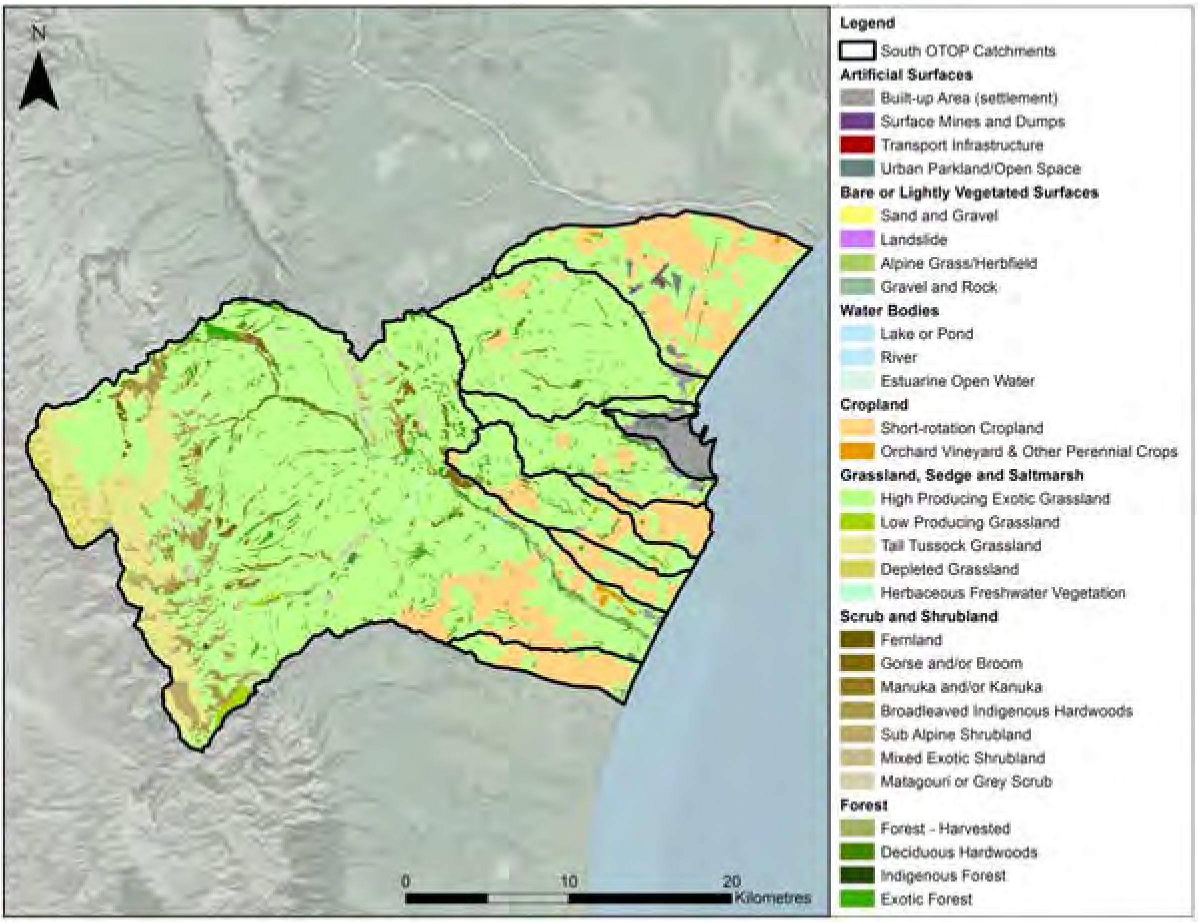

Figure 1-2: Land cover in the South OTOP Zone

1.2 Previous work

Reference	**Description**
Pareora Catchment Environmental Flow and Water Allocation Regional Plan 2012.	The report establishes the water resource management objectives, policies, and methods and sets limits on the groundwater and surface water allocation and minimum flows in the Pareora catchment.
Waugh, J R (Ed); 1987: Pareora Catchment Water and Soil Resource Report 1987.	The report describes the Pareora catchment, the water resources, the water usage, and the land use.
de Joux, 2000: The North Branch Pareora River hydrology and water quality.	The report describes the state of the surface water quantity and quality in the upper Pareora River.
Aitchison-Earl *et al.,* 2006. Pareora - Waihao River Water Resource Summary.	The report describes the state of the groundwater and surface water resources of the Pareora catchment and other nearby catchments in 2006.
de Joux and Scarf, 2010. Review of the Hydrology, Water Allocation and Management of the Pareora Catchment water resources.	The report describes the hydrology and the water use and allocation in the Pareora catchment. Additionally, the report presents modelled effects of different water use scenarios.

2 Monitoring network

2.1 Flow network

Continuous recorders installed in streams and rivers measure water levels at subdaily intervals over a period maintained by Environment Canterbury. To convert water level to flow, manual flow gaugings are conducted at the recorder site to relate the water levels to flows. Flow gaugings are made at a wide range of flow magnitudes over many years to ensure the accuracy of the water level to flow relationships. Most recorder sites are gauged to be able to estimate flow, but some recorders only have water level recorded without an associated water level to flow relationship.

The primary long term recorder (LTR) in the south OTOP zone is the Pareora River at Huts (70105) and is located at the Upper and Lower Pareora divide (Figure 2-1). The LTR has over 30 years of a flow record. The second recorder in the Pareora is at the lower end of the catchment at State Highway 1 (Pareora River at SH1 (70103)) which has a 6.5 year flow record. Both the Huts and SH1 recorders have water level to flow relationships. There are two recorders in south OTOP that do not have water level to flow relationships. These include the Washdyke Lagoon at South End (69801) recorder in the Washdyke Creek catchment and the Saltwater Creek at SH1 (69901) recorder.

In the Pareora catchment, there are 48 gauging sites that have 5 gaugings or more throughout the gauging record with the Huts recorder site which has the highest number with 645 gaugings. The smaller catchments in the south OTOP zone only contain 5 gauging sites that have 5 gaugings or more.

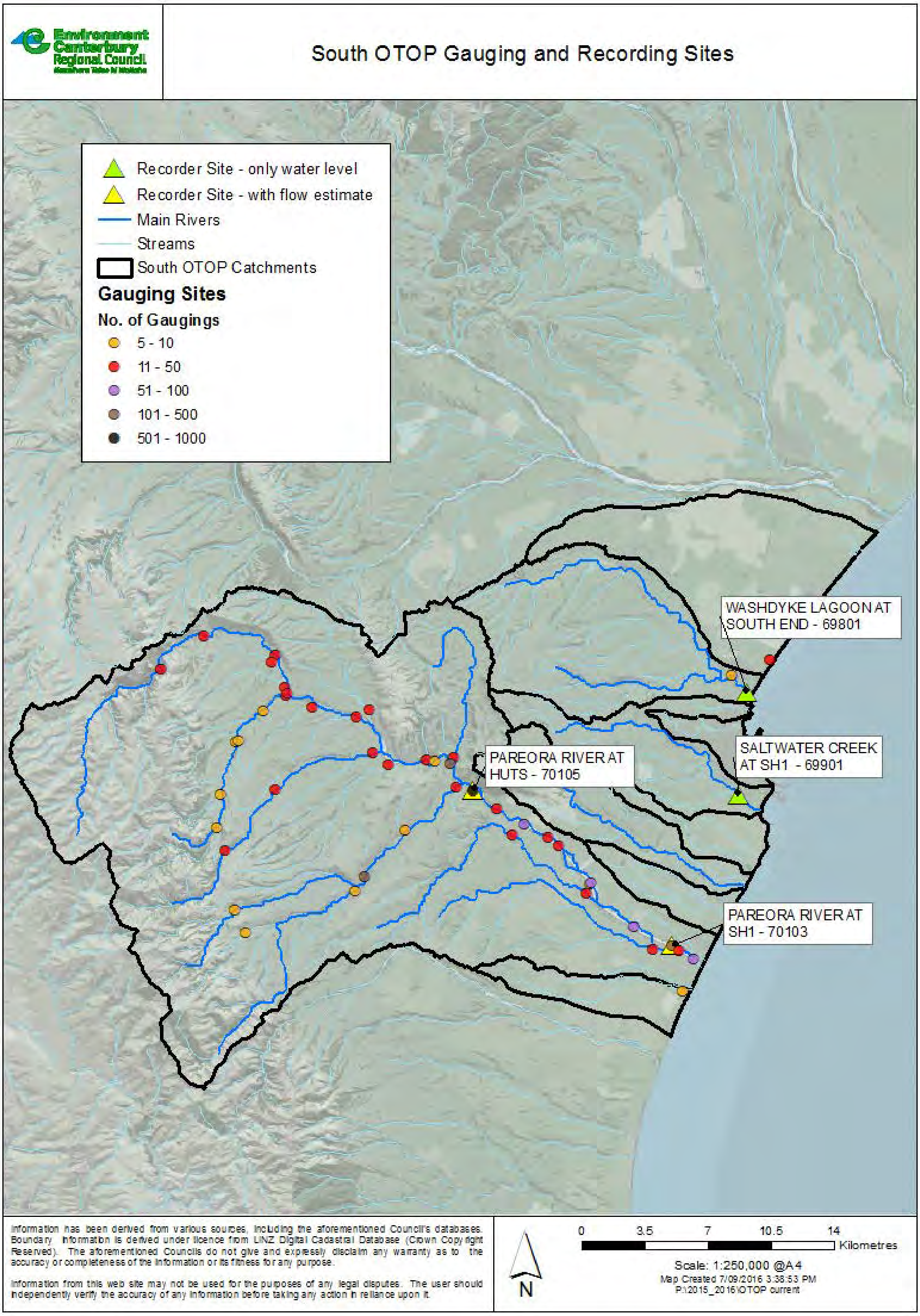

Figure 2-1: Recorder and gauging sites in south OTOP

2.2 Climate stations and the virtual climate station network (VCSN)

There are six precipitation stations within or in close proximity to the south OTOP catchments (Figure 2-2). Four are within the catchments and include a MetService weather station. The other two, Otaio at Bluecliffs and Rocky Gully at Rocky Gully, are in adjacent catchments. The Timaru weather station maintained by MetService is the closest multi-parameter weather station near the Pareora catchment and measures a suite of micrometeorological parameters, which is used in the estimation of potential evapotranspiration (PET) and interpolated into the National Institute of Water and Atmospheric Research (NIWA) VCSN data (Tait and Woods, 2007). PET represents evapotranspiration (ET) from a short grass crop that is not water limited. This method is used because PET can be estimated from only meteorological parameters, while actual ET requires additional information about crop type and soil moisture conditions. Consequently, PET will typically be the upper limit of actual ET and generally represents the seasonal patterns of temperature and incoming solar radiation.

We have used data from NIWA's Virtual Climate Station Network (VCSN) in our analysis for this report. Standard VCSN data are estimated using daily spatial interpolation for the whole of New Zealand on a 0.05° latitude/longitude grid (approximately 5 km) using the MetService weather stations (Tait and Turner, 2005; Tait *et al.,* 2006). The VCSN provides long-term daily climate estimates, including precipitation (from January 1960) and PET (from January 1972), at a relatively high spatial resolution.

Since the VCSN is interpolated on a national scale, we assessed the validity of VCSN data within the OTOP zone catchment by comparing VCSN estimates with observations from local rain gauges and weather stations. Precipitation data from the VCN were compared to data from the Environment Canterbury rainfall recorders in the OTOP zone. These data are independent since the Environment Canterbury rainfall sites are not included in the interpolation for the standard VCSN. PET data were compared to the records from the weather stations at Timaru and Orari estate, which are included in the VCSN interpolation.

We found that the VCSN precipitation data correlate poorly with site data for rain gauges in the foothills at the top of the Opihi catchment. This is consistent with the Tait *et al.* (2012) suggestion of using VCSN data in areas above 500 m elevation with caution. Because of this, NIWA has provided Environment Canterbury with an alternate version of the VCSN dataset (dating back to 1972) that includes data from Environment Canterbury's rainfall gauges in the interpolation. We used this dataset to produce mean annual rainfall contours for the OTOP zone.

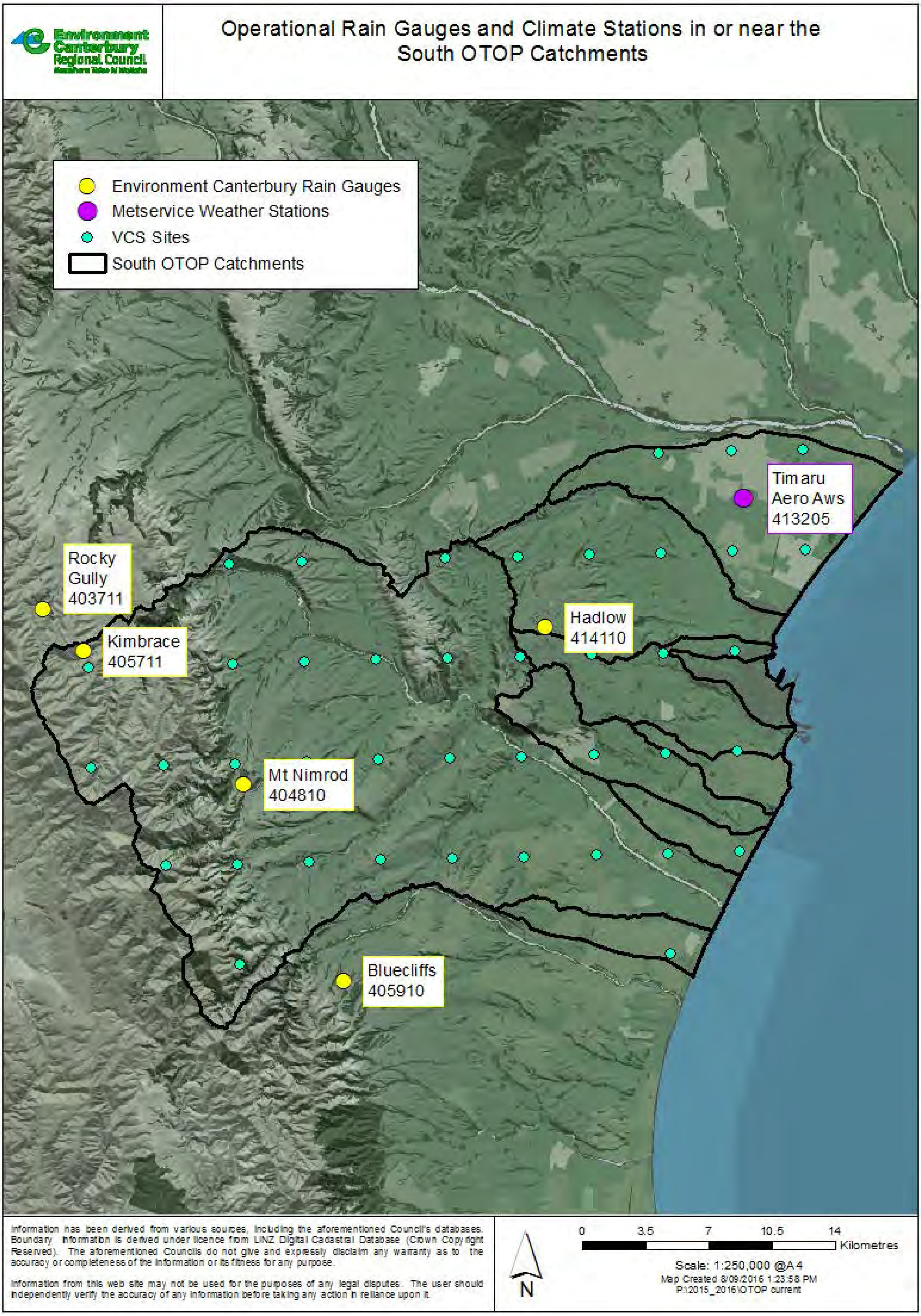

Figure 2-2: Environment Canterbury precipitation gauges, MetService weather station, and VCSN grid locations

3 Climate

3.1 Precipitation

Precipitation is a term that includes both rainfall and snowfall. The precipitation in the Pareora catchment is relatively consistent throughout the year with slightly more precipitation occurring during the summer months as compared to the winter months (Figure 3-1). Mean precipitation from 1970-2015 is 585 mm/year, the minimum is 330 mm/year (2015), and the maximum is 966 mm/year (2013) (Figure 3-2). The coefficient of variation (standard deviation divided by the mean) is 0.26.

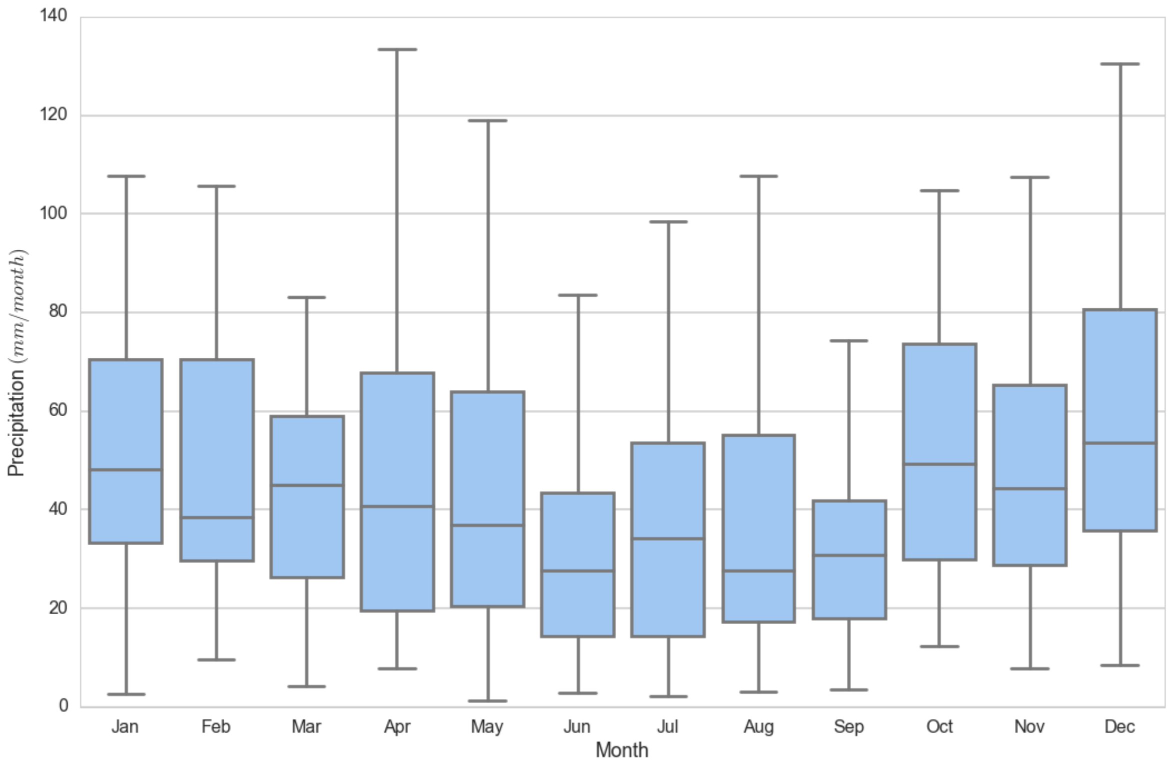

Figure 3-1: Mean monthly precipitation totals from the VCSN data for the Pareora catchment

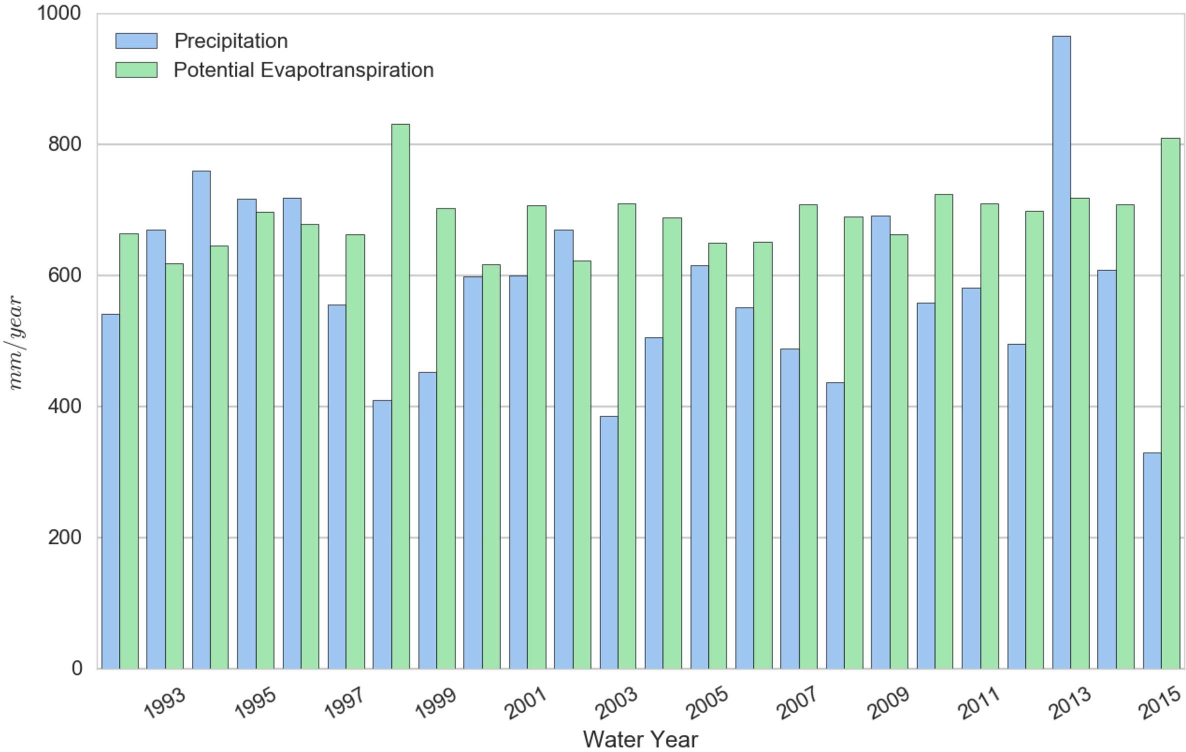

Figure 3-2: Yearly totals of precipitation and PET from 1992 to 2015 from the VCSN data for the Pareora catchment. The years shown on the x-axis are the end of the water year. For example, 2015 is the 2014/2015 water year

3.2 Potential evapotranspiration

Due to the methodology of calculating PET as described in Section 2.2, the yearly PET totals are relatively consistent from 1992-2015 as compared to precipitation (Figure 3-2). From 1992-2015, the mean is 691 mm/year, the minimum is 617 mm/year (2000), and the maximum is 832 mm/year (1998). The coefficient of variation is 0.07. The PET has a clear seasonal pattern of high in the summer and low in the winter representing temperature and incoming solar radiation seasonality (Figure 3-3).

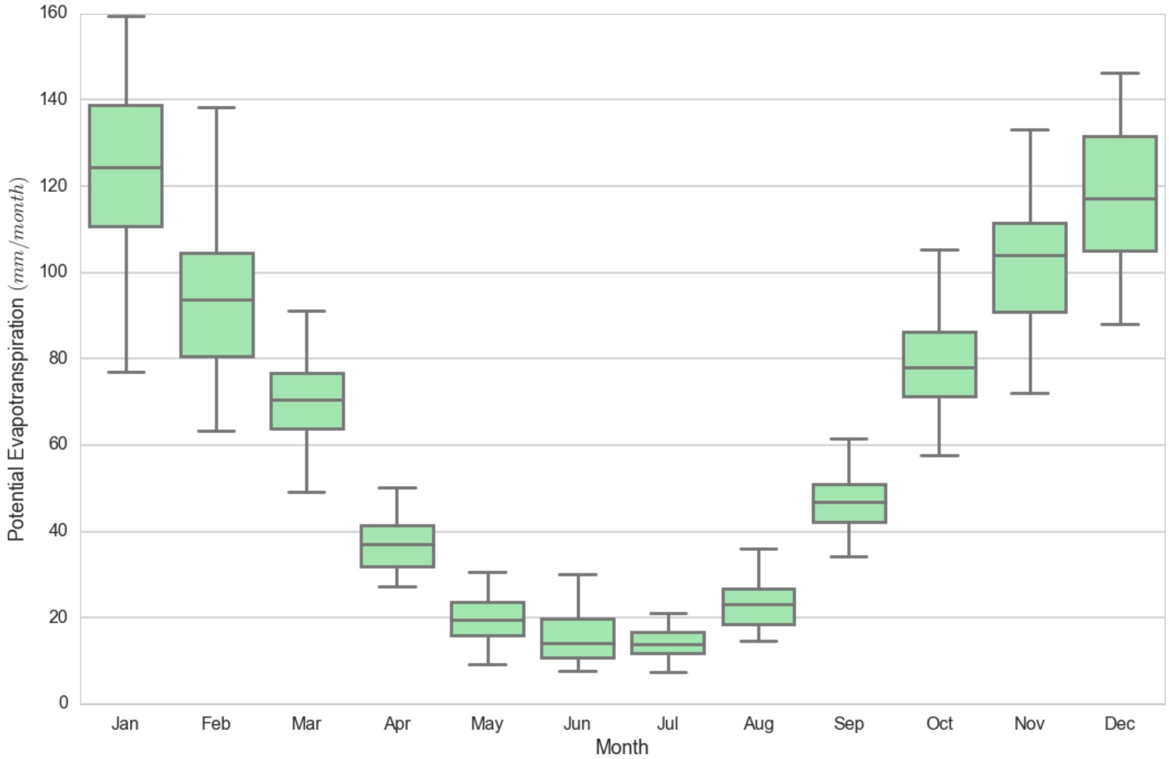

Figure 3-3: Mean monthly PET totals from the VCSN data for the Pareora catchment

3.3 Difference between precipitation and evapotranspiration

Taking the difference between the monthly precipitation and PET values provides insight into the months that would provide recharge to the streams and groundwater compared to months that might be depleting the water stores. Not surprisingly, the winter months with very low PET and moderate precipitation have a positive gain on water, while the summer months with the significantly higher PET removes more water than is supplied (Figure 3-4).

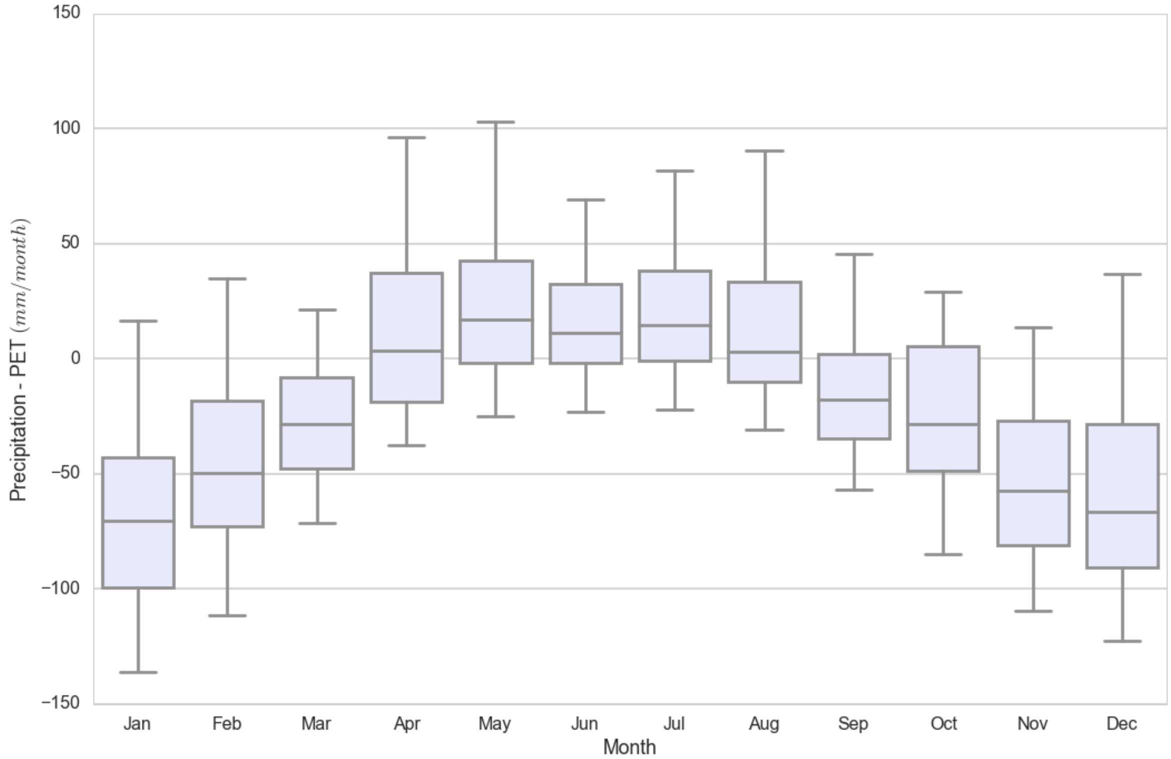

Figure 3-4: Mean monthly difference between precipitation and PET from the VCSN data for the Pareora catchment

4 Surface water allocation

4.1 Background and methodology

The water allocation is summarised by Surface Water Allocation Zones (SWAZs) groups (Figure 4-1). The SWAZ boundaries for the Pareora are defined in the Pareora Regional Plan (2012). The boundaries of the SWAZs mostly follow the hydrologic catchments, but they do not coincide in all cases (Figure 1-1). This is most apparent in the lower boundaries of the SWAZs especially in the Pareora delineation. The Pareora SWAZ group is composed of two individual SWAZs that include the Upper and Lower Pareora.

The smaller SWAZ's in the South OTOP area include Lyalldale Creek to the south and Saltwater Creek, Washdyke Creek, Pig Hunting Creek, and Levels and Seadown Plains in the north (Figure 4-1). Compared to the Pareora, these adjacent SWAZs have less surface water allocation, but are nevertheless important to summarise as they do account for a significant surface water allocation. The Lyalldale Creek SWAZ has no surface water allocation consents.

Water allocation consents have a wide variety of water abstraction requirements which can range from limits on the instantaneous rate of take, daily volume abstracted, and/or annual volume abstracted across one or multiple water abstraction points (WAPs), and even across multiple consents. For our analysis, annual allocated volumes were acquired for each consent from the consents database at Environment Canterbury for comparisons across multiple consents, catchments, and water usage types (e.g. irrigation, public water supply, industrial).

To estimate the annual allocation volumes for all consents regardless of the consent stipulations, certain assumption were made. If an annual maximum allocation volume was provided in the consent, then that value was used. If a daily or multi-day maximum allocation volume was provided, then that value would be 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 would be extrapolated to the entire year. The annual extrapolation was based on the water usage type; if the usage type was for irrigation, then 212 days of usage would be 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 the consent comparisons.

4.1.1 Hunter Downs Irrigation Scheme

The Hunter Downs Irrigation Scheme is proposed to begin construction at the end of 2016 to abstract water from the Waitaki River and distribute this water across 40,000 hectares of farmland stretching from Waimate to Timaru. The included area covers part of the south OTOP zone. Since this irrigation scheme is taking all of its water from the Waitaki River, no additional abstraction will occur in the south OTOP zone, but as a consequence more water will be added to the catchments in the south OTOP zone. If the Hunter Downs Irrigation Scheme is developed, water is expected to be available for use starting in the 2018/2019 water year.

4.2 Pareora SWAZ results

Figure 4-2 provides a plot of water abstraction points in the Pareora catchment. Since 1969, the primary surface water abstraction consent was for the Timaru District Council (TDC) water supply and has had a consistent allocation of 0.216 m^3/s or 6.7 million m^3/year throughout all years (Figure 4-2 and Figure 4-3). A large increase in abstractions occurred during the period from the water years 2009/2010, associated with increased irrigation for dairy farming conversions. The TDC abstracts water from the Upper Pareora, while most of the irrigation abstraction occurs in the Lower Pareora (Figure 4-2). Total allocation in the Pareora SWAZ is approximately 16 million m^3 in the 2014/2015 water year.

Figure 4-1: **Surface water allocation zones (SWAZs) in south OTOP zone**

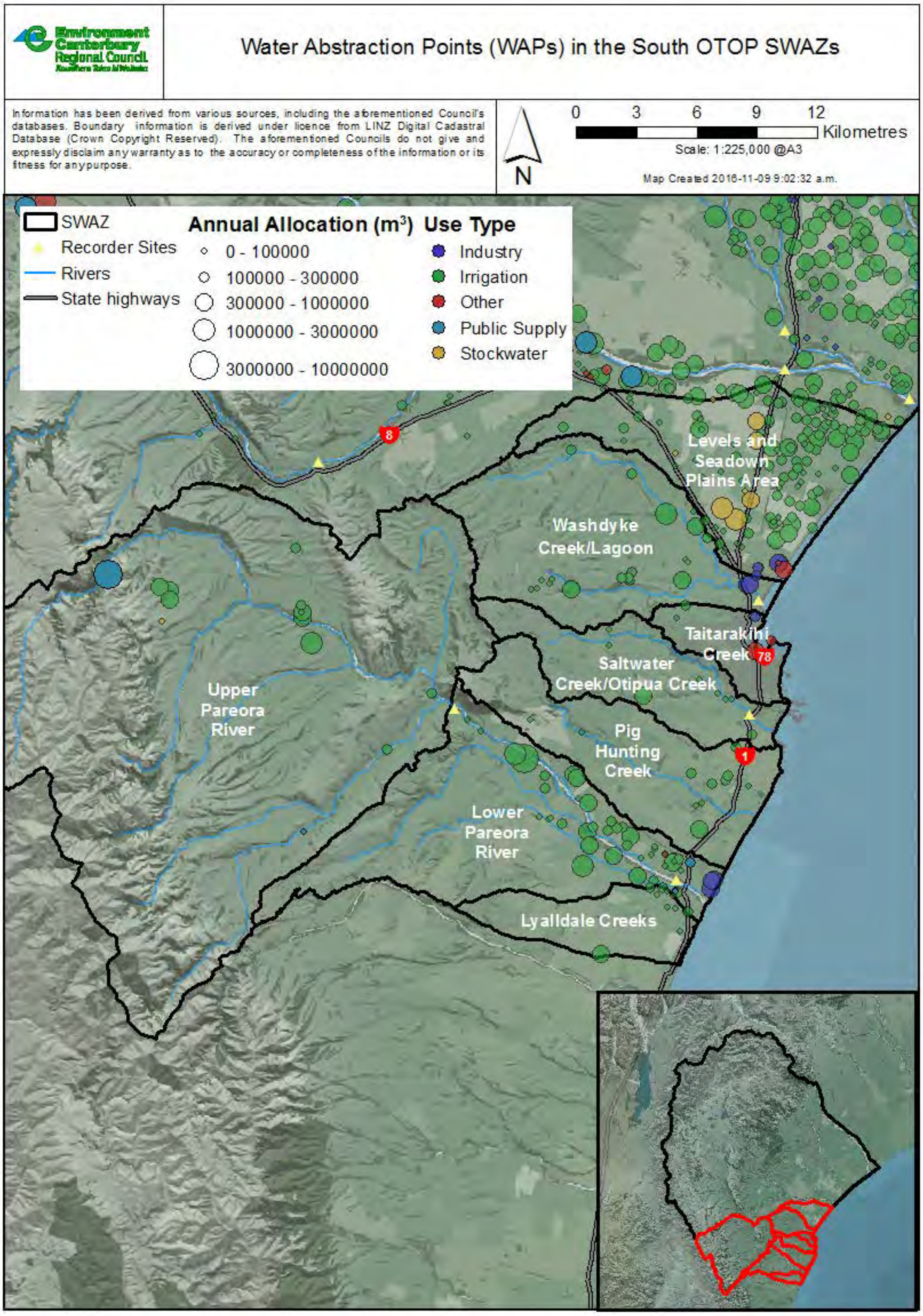

Figure 4-2: **The Pareora SWAZ with all surface water and groundwater abstraction points with the symbol size representing the abstraction volume and the surface water recorders/minimum flow sites**

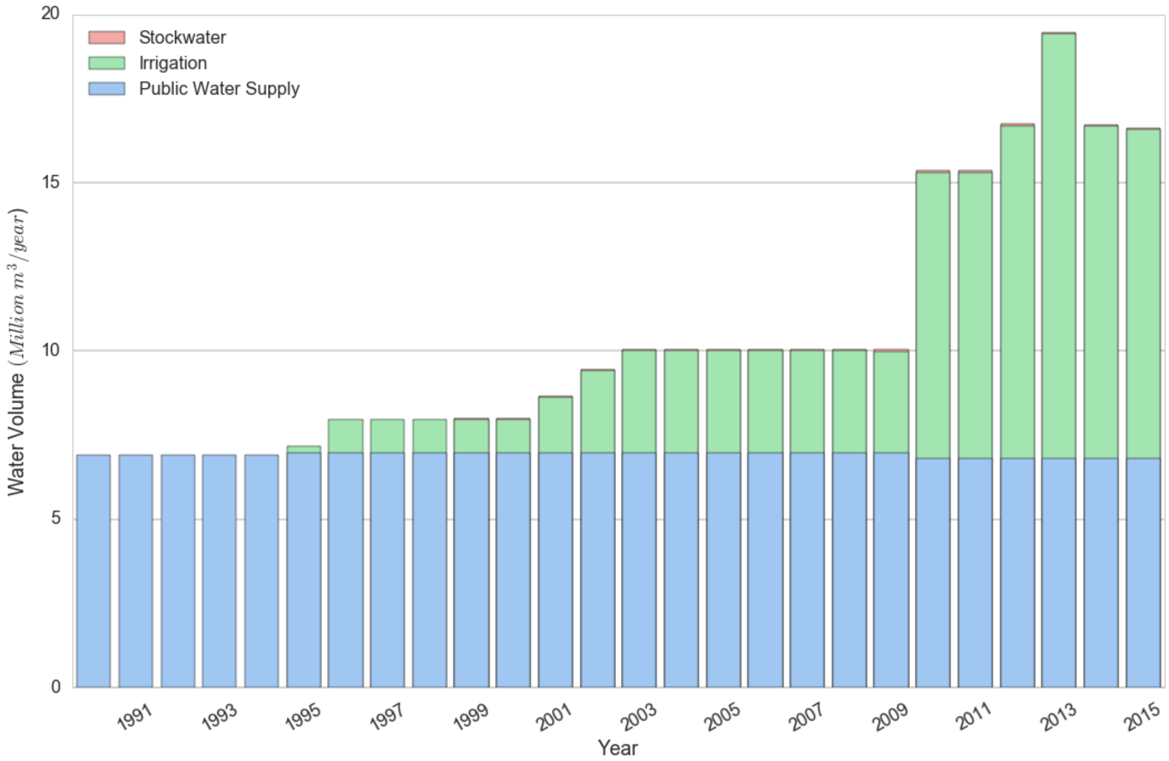

Figure 4-3: Total allocated surface water in the Pareora SWAZ stacked by water use type from 1990 to 2015. The years shown on the x-axis are the end of the water year. For example, 2015 is the 2014/2015 water year

4.3 Other south OTOP SWAZs

Although there is less surface allocated water in the adjacent SWAZs compared to the Pareora SWAZ, they do have a significant allocation volume of about 2.5 million m^3 in the 2014/2015 water year. Most of the allocated surface water (~90%) is abstracted in the Levels and Seadown Plains SWAZ. The allocated surface water shown as the "Other" water use type category is from one consent in the Levels and Seadown Plains SWAZ for cleaning stormwater and wastewater pipes.

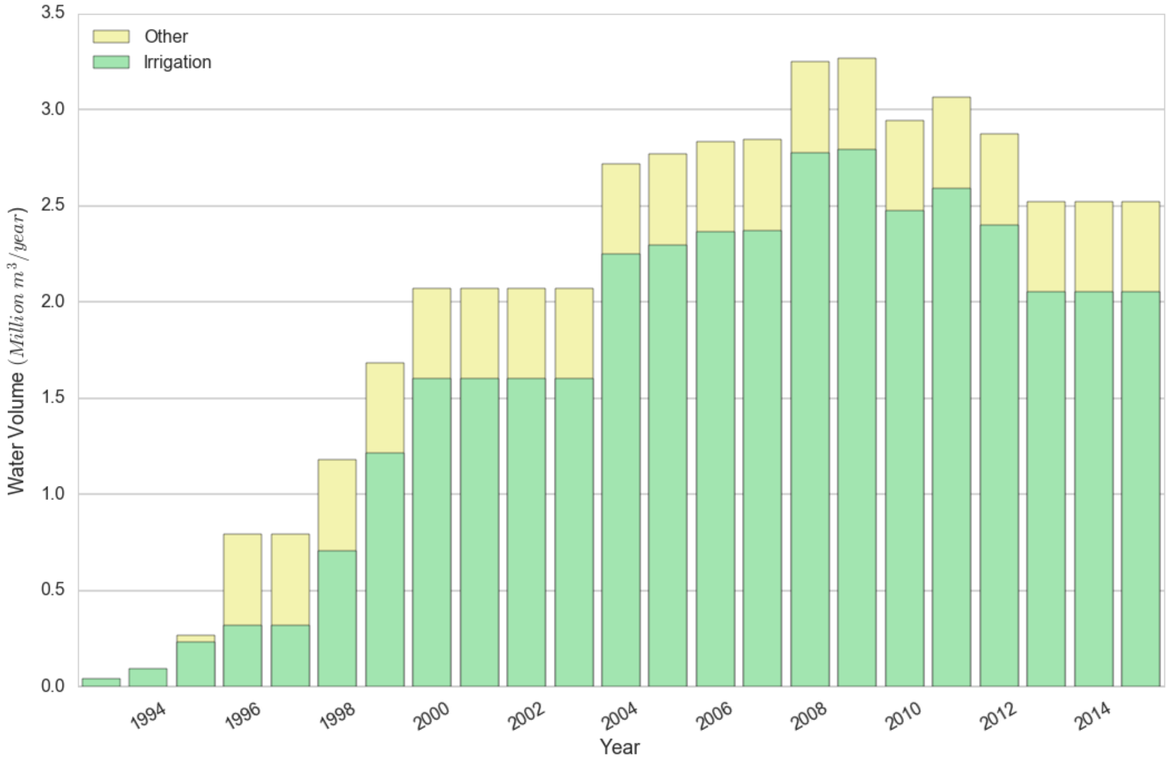

Figure 4-4: Total allocated surface water in the Saltwater Creek, Washdyke Creek, and Levels and Seadown Plains SWAZs by water use type. The years shown on the x-axis are the end of the water year. For example, 2015 is the 2014/2015 water year

5 Minimum flows

5.1 Background and methodology

To promote the sustainable management of water in the Pareora catchment, water allocation blocks based on minimum flow limits of the Pareora River at the Huts recorder (70103) were established (Pareora Catchment Regional Plan 2012). The allocation blocks apply to all surface water consents and any groundwater consents deemed to be hydraulically connected to the surface waters. The available allocation of a river is splits into allocation blocks with associated minimum flows. Allocation blocks can be broken into sub-blocks termed allocation bands which have specific minimum flow limits. The flow sites that have been assigned allocation blocks and bands are termed minimum flow sites.

5.2 Results

In the Pareora catchment, there are two allocation blocks (A and B) with six allocation bands contained within. The A allocation block has lower minimum flow limits as compared to the B block, and most consents are in Band 11 of Block A. There are no minimum flow sites in the other south OTOP zone catchments.

The flow restrictions in the Pareora have two tiers of minimum flows. The first tier (the higher flow of the two) places a partial restriction on the water abstraction for consents in a particular block and band, while the lower tier fully restricts all water abstraction. In the A block, the partial restriction is a flat percentage of water abstraction with a single step of 50% reduction, while the B block is a linear decrease from 100% starting at the first tier to completely restricted at the second tier.

Table 5-1: Minimum flow allocation blocks and bands for the Pareora River

Site	Site Number	Allocation Block	Allocation Band	Number of Consents	Minimum Flow		Restrictions	
					Season	Flow m^3/s	Flow m^3/s	Restriction
Pareora River at Huts	70105	A	Band 7	1	1 Jan - 31 Dec	Conditions allow for max abstraction rate of 5.5 L/s		
			Band 11	19	1 Jan - 30 Sep	<0.3	<0.4	50%
					1 Oct - 30 Nov	<0.37	<0.47	50%
					1 Dec - 31 Dec	<0.3	<0.4	50%
			Band 13	1	1 Jan - 31 Dec	<1.6	<1.8	10%
			Band 14	1	1 Jan - 31 Dec	<0.4	<0.47	50%
		B	Band 9	1	1 Jan - 31 Dec	<5	<6	Pro Rata
			Band 12	3	1 Jan - 31 Dec	<6.5	<6.8	Pro Rata

6 Reliability of supply

6.1 Background and methodology

The allocation blocks and bands put restrictions on water abstraction during periods when flows at a specified site fall below the minimum flow limits. As described in Section 5.2, the restrictions can be either partial or full depending on the flow conditions. Due to these restrictions, the total water abstraction volume for a consent may be lower than the originally allocated volumes as presented in Section 4).

For each band within each minimum flow site, there are a number of associated consents. Combining the water allocation from Section 4 with the minimum flow band restrictions, the amount and frequency of the restrictions can be estimated for all consents for all bands with restrictions. Records of the minimum flow restrictions have been stored digitally at Environment Canterbury archives starting in the 2006/2007 water year.

6.2 Pareora SWAZ results

The number of days that each allocation block and band was on restriction is shown in Table 6-1. In many of the other OTOP catchments, the 2014/2015 water year had significant restrictions. This was not as much the case in the Pareora. The 2015/2016 water year on the other hand had a significant increase in restrictions with most bands having substantial restrictions. In Band 9, there were a significant number of days on restriction in the 2012/2013 water year (also seen in Table 6-1) and that amount of restricted allocated volume is shown in Figure 7-1. This allocation restriction was due to a single consent (Figure 7-1).

6.3 Other south OTOP SWAZs

The other south OTOP SWAZs do not have minimum flow sites, but some consents have abstraction restrictions based on the Huts site or minimum flow sites in the Opihi.

Table 6-1: Number of days each band is on restriction

			2012/2013	2012/2013	2013/2014	2013/2014	2014/2015	2014/2015	2015/2016	2015/2016
Site Name	**Allocation Block**	**Allocation Band**	**Days On Full Restriction**	**Days On Partial Restriction**	**Days On Full Restriction**	**Days On Partial Restriction**	**Days On Full Restriction**	**Days On Partial Restriction**	**Days On Full Restriction**	**Days On Partial Restriction**
Pareora River at Huts	A	Band 7	0	0	0	0	0	0	0	0
		Band 11					37	0	93	6
		Band 13							236	3
		Band 14							0	0
	B	Band 9	250	13	8	1	0	0	204	2
		Band 12							281	1

7 Water use

7.1 Background and methodology

Data on the actual water usage by water consent holders has been collected over the past decade through the installation of flow meters at the WAPs. Under the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010, consent holders must install flow meters at their associated WAPs by 2012 if the allocations are larger than 20 l/s, by 2014 for allocations larger than 10 l/s, and 2016 for allocations larger than 5 l/s. The metered usage data is sent to Environment Canterbury and processed for use in analyses. Water usage data in the study area prior to 2012 is sparse, however, and generally describes usage for only a small proportion of the consented abstractions.

As the consents with available metering data only represent a portion of the total consents, not all of the water allocation will be covered by the metering data. In earlier years with few metered WAPs, the allocation associated with the metered consents represented only a small amount of the total allocation, while later years have a high proportion of the total allocation metered.

7.2 Pareora SWAZ results

About 82% of the allocated surface water volume for all consents were captured in the consents with flow meters in the 204/2015 water year (Figure 7-1). Of the metered consents, about 60% of the allocated water was actually used by volume, which is approximately the same as the overall Canterbury usage estimated from the same analysis. As a large part of the annual surface water allocation in the Pareora SWAZ is associated with the TDC water supply abstraction and water supply abstractions are not as restricted by minimum flow limits, the 2014/2015 water year was not restricted much in terms of total volume as compared to number of days on restriction by allocation band (Table 6-1).

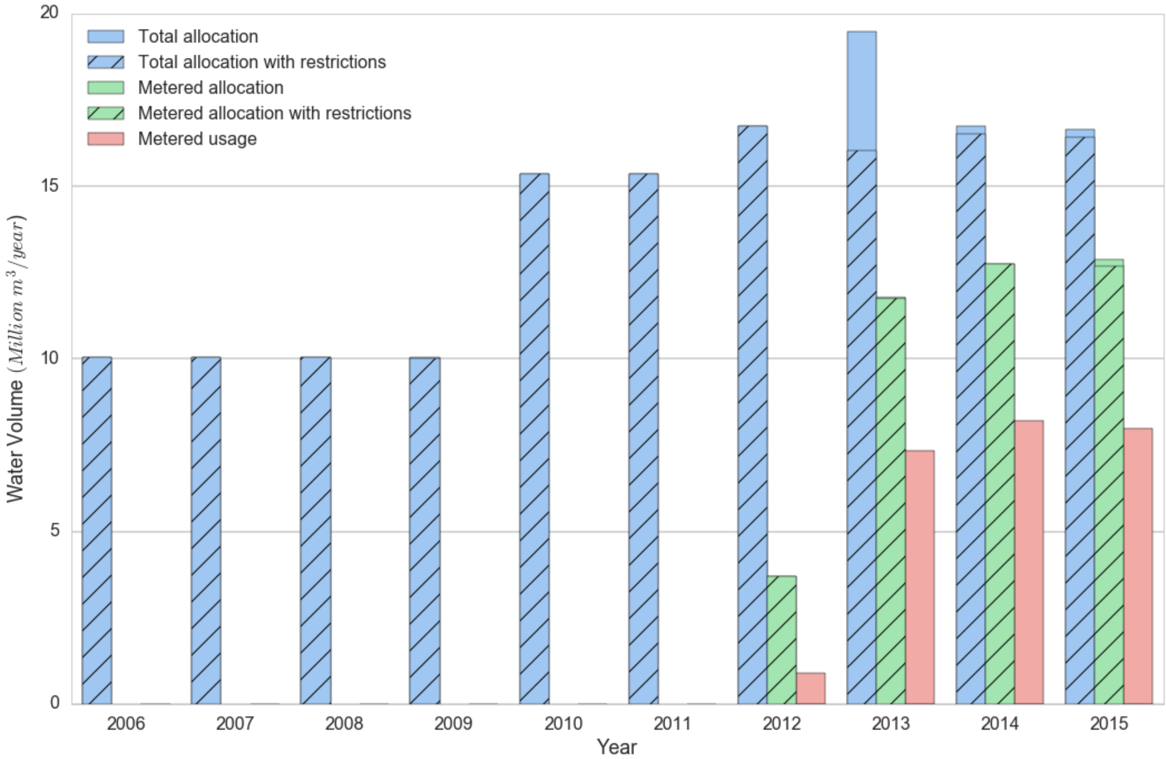

Figure 7-1: Water usage and allocation in the Pareora SWAZ in the last 10 years. 'Total allocation' includes all consented water abstraction volumes within the catchment, 'Metered allocation' includes the consented water abstraction volumes associated with the WAPs that have flow meters, and the 'Metered usage' is the volume of water abstraction from the metered WAPs. The 'Total allocation' and 'Metered allocation' with restrictions take in consideration the minimum flow restrictions for consents. The years shown on the x-axis are the end of the water year. For example, 2015 is the 2014/2015 water year

7.3 Other south OTOP SWAZs

Most of the allocated consent volumes during the study period did not have available metered usage data, so an accurate interpretation of overall actual usage to total allocation for the SWAZs was not currently feasible (Figure 7-2).

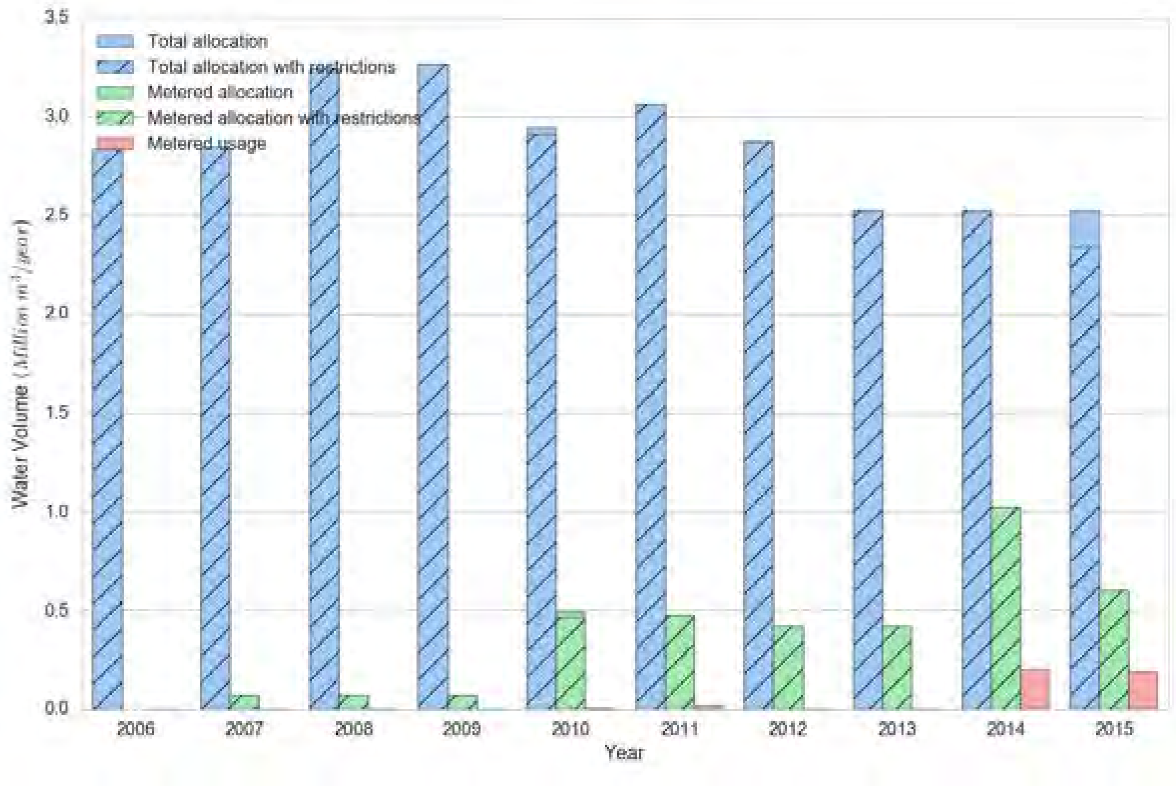

Figure 7-2: Water usage and allocation in the Saltwater Creek, Washdyke Creek, and Levels and Seadown Plains SWAZs. The years shown on the x-axis are the end of the water year. For example, 2015 is the 2014/2015 water year

8 Recorded and naturalised flows

8.1 Background and methodology

The long term record (LTR) for the Pareora at Huts recorder and the Pareora at SH1 recorder were used for all time series flow statistics in this section. All flow statistics were performed on daily mean flows for consistency within this report and previous reports. In addition to the normal time series statistics (min, max, mean, and median), other time series flow calculations were made to represent important attributes about the streams and rivers.

The 7 day mean annual low flow (7DMALF) is often used to set limits for minimum flows due to cultural, recreational, and ecological values. The 7DMALF is a long term average of the lowest 7 consecutive days of flow. A minimum of at least 10 years of flow data was used for the final calculation of 7DMALF to ensure a representative aggregate mean. Additionally, at least 245 days of flow data during a particular water year must be available to be included in the final 7DMALF calculation. The missing days were also checked to ensure that the majority of missing record did not cover the low flow period. 245 days was used as a minimum number of necessary days when summarising all flow statistics by water year. All flow data were used in the analyses up until the end of the 2014/2015 water year (i.e. 2015-06-30).

The annual frequency of flows greater than three times the median (Fre3) has been shown to be an appropriate proxy for flow variability for periphyton accumulation (Clausen and Biggs (1997)). A higher Fre3 with more frequent floods was shown to have less periphyton accumulation. The Accrual period is the time between Fre3 events; the length of this period also affects the amount of periphyton accumulation in a river.

The naturalisation of river flows is the process of ‘adding back’ the surface water abstractions and hydraulically connected groundwater abstractions to a flow record. Naturalisation is a process to recreate the flow record if the upstream water abstractions did not take place. For the naturalisation process, water usage needs to be estimated for all of the years included in the flow record.

The procedure to estimate the water usage for all historic water abstraction points (WAPs) uses the actual water usage starting from the water year of 2012/2013 (2012-07-01) to the end of the water year 2014/2015 (2015-06-30). Monthly consented allocated volumes and actual usage were obtained for those three water years and usage ratios were calculated by dividing the monthly water usage by the monthly water allocation. Additionally, monthly totals of potential evapotranspiration (PET) were made from the VCSN data from within the catchment starting in 1970. As irrigation tends to follow the seasonal ET trend, a linear regression was made between the monthly ET and the monthly usage ratio for all WAPs for all years with water consents. Two sets of regressions were made: one with a combination of irrigation and stockwater as they should follow the seasonal ET trends, and another with all of the other usage types which would be less influenced by seasonal ET trends. The normalised root mean square error (NRMSE) of the regressions for the Pareora catchment is 0.72 for the irrigation/stockwater lumped categories and 0.21 for all other lumped categories.

The upstream surface water abstractions were directly added back to the river flow for downstream flow recorders, but the contribution of the hydraulically connected groundwater abstractions to the surface water flow would need to be estimated as not all of the water abstraction is connected to the nearby surface waters. Stream depletion estimates for each water abstraction well in the Pareora Catchment were undertaken using the methodology described in Smith, 2015. The naturalisation procedure assumes that all of the water abstracted from a particular river is consumptive, and does not re-enter through any pathways. This is unlikely to be completely accurate as water used for irrigation may have a certain proportion that would seep back into the groundwater and eventually return to the nearby streams (albeit potentially different streams from the abstraction streams). Due to the large variability in the irrigation types and rates, the infiltration rates due to variability in soil types, and application location to other streams compared to the source of the abstraction, no additional assumptions were made to account for the recharge uncertainty.

8.2 Flow statistics

8.2.1 Pareora results

The Huts recorder is a long term recorder (LTR) with a flow record of over 30 years (Table 8-1). The SH1 recorder has a comparatively short flow record with about 6.5 years of record. Due to the short record, neither the 7DMALF nor the monthly aggregation statistics were performed on SH1.

As water supply for the TDC is the main use type for the abstractions in the Upper Pareora, the seasonal abstraction dynamics are much more stable than that of irrigation which is focused much more during the growing season around summer. Consequently, the flow naturalisation for the Huts recorder is relatively consistent throughout the year (Figure 8-1) and between years (Figure 8-2 and Figure 8-3). The SH1 recorder on the other hand has a significant impact by the seasonality of irrigation abstractions in addition to the TDC as shown in the 7DALF (Figure 8-3).

There were 31 days and 75 days in the water years of 2009/2010 and 2014/2015 respectively where there was no flow at the SH recorder. Neither the Huts recorder nor the simulated naturalised SH1 recorder flow dropped to zero (Table 8-1).

Table 8-1: Flow statistics of the recorded and naturalised flows for the recorders on the Pareora River

	Pareora at SH1		Pareora at Huts	
	Recorded	**Naturalised**	**Recorded**	**Naturalised**
Minimum flow (m^3/s)	0	0.238	0.253	0.410
Median flow (m^3/s)	0.921	1.445	1.378	1.558
Mean flow (m^3/s)	4.223	4.878	3.687	3.866
Maximum flow (m^3/s)	521.150	521.331	500.786	500.960
Start of record	20/11/2008	20/11/2008	03/04/1982	03/04/1982
End of record	Current	Current	Current	Current
Number of missing days	53	53	700	700
Years of record	6.5	6.5	31.3	31.3
Average number of zero flow days per year	16.3	0	0	0
7DMALF (m^3/s)	NA	NA	0.481	0.664
Fre3 event flow (m^3/s)	2.913	4.336	4.133	4.43
Average number of Fre3 events per year	6.5	7.3	6.9	6.9
Average accrual period (days)	43	43	46.7	47.2

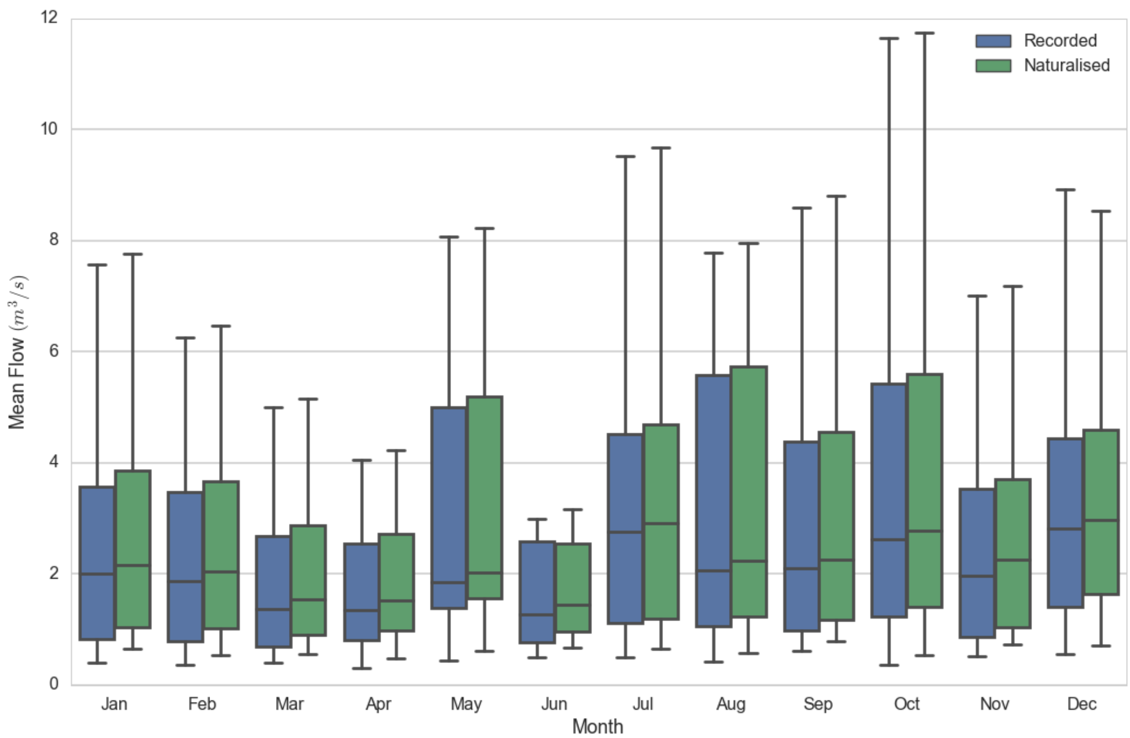

Figure 8-1: Boxplots of aggregated monthly mean flow for the entire flow record of the Huts recorder (70105)

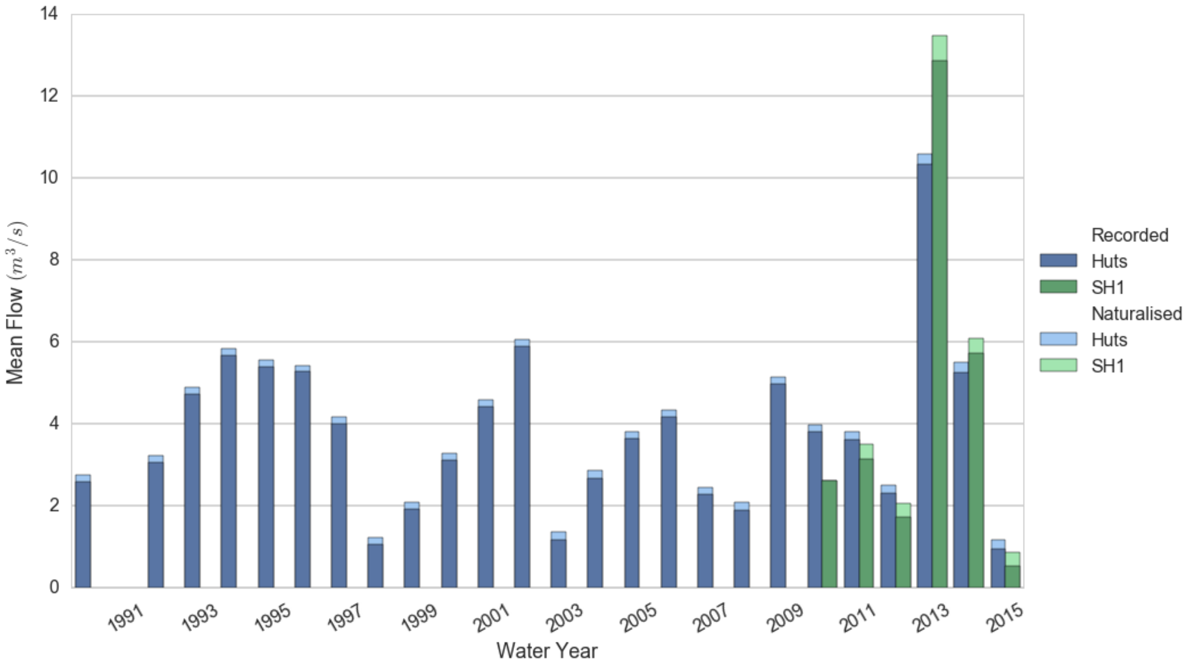

Figure 8-2: Annual mean flow of the two recorders on the Pareora River. The years shown on the x-axis are the end of the water year. For example, 2015 is the 2014/2015 water year

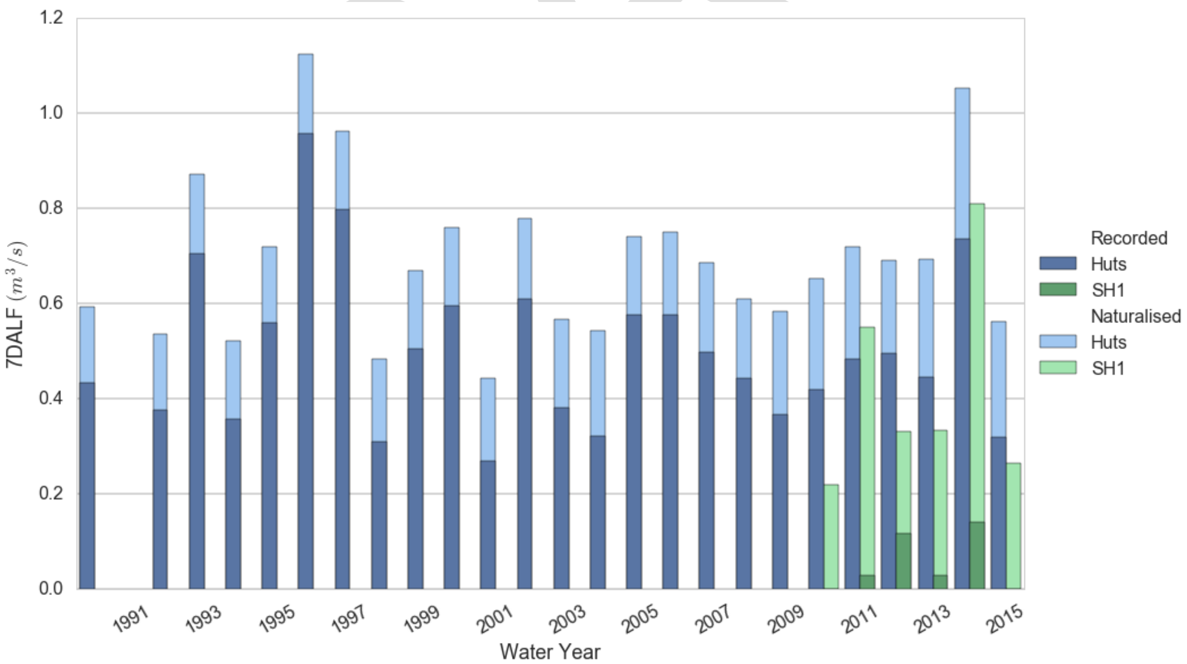

Figure 8-3: The 7DALF of the flow record of the two recorders on the Pareora River. The years shown on the x-axis are the end of the water year. For example, 2015 is the 2014/2015 water year

8.2.2 Other south OTOP catchments

In the Saltwater Creek and Washdyke Creek SWAZs there are two recorders (South End (69901) and SH1 (69801) respectively). These recorders only record water level and have no water level to discharge relationship. Consequently, no flow statistics can be made for these recorders and only basic statistics can be presented (Table 8-2).

Table 8-2: Summary of the water level statistics from the Saltwater Creek and Washdyke Creek recorders

	Saltwater Creek at South End	Washdyke Creek at SH1
Minimum level (masl)	0.710	0.722
Median level (masl)	0.866	1.556
Mean (masl)	0.927	1.573
Maximum (masl)	2.177	2.684
Start of record	06/10/2011	05/06/1993
End of record	30/6/2015	30/6/2015
Missing number of days	191	231
Years of record	3.2	21.4

9 Losses and gains

9.1 Background and methodology

Many streams in Canterbury are regularly gauged to maintain continuous recorders and/or to independently estimate flows for various reasons. One particular reason for gauging sites not associated with recorders is to estimate the net stream to groundwater gains and losses along river networks. To do this, several teams would gauge many sites in a river network over a one to two day period to capture flows during a stable period. To ensure a representative sample for a season, these large gauging runs would be performed every one or two months in the same river network. In the Pareora, this was performed during the summer months (November to May) of the water years 2000/2001, 2002/2003, and 2008/2009. Only the last stream gaugings in the 2008/2009 water year have gaugings in the Upper Pareora, while all three have gaugings in the Lower Pareora (Figure 9-1).

Estimating the net stream gains and losses involved taking the difference in the flow estimate from adjacent upstream and downstream gaugings. Uncertainty analysis was performed on the gains and losses estimate by estimating the uncertainty of the flow gaugings and propagating the uncertainty through the difference in the upstream and downstream flows.

9.2 Results

Since consistent and extensive stream gaugings did not occur in the Upper Pareora prior to 2008, only the latest and most extensive gaugings in 2008/2009 can be used to estimate the gains and losses in the Upper Pareora, in addition to using the known geology as an indicator. As expected from the geology, the Pareora River gains water through the gorge associated the shallow bedrock at the Pareora Gorge that funnels both the surface water and groundwater from the Upper Pareora through the gorge. Nevertheless, both the upper Pareora River and the Motukaika River appear to have been losing to groundwater shortly before the gorge.

The lower Pareora below the gorge has shown an increasing trend towards stream losses over the three gauging periods (Figure 9-1). There could be two contributing explanations to the increasing losses in the Lower Pareora. The first is differences in the quantity of precipitation during those three water years. Less precipitation would increase the stream losses due to a depleted aquifer. The second is that an increase in the water abstraction surrounding the Pareora would increase the losses along the river. In the 2000/2001 water year, little surface water abstraction occurred in the Pareora River. The surface water abstraction almost tripled from the 2000/2001 to the 2002/2003 water years than doubled from the 2002/2003 to the 2008/2009 water years (Figure 4-3). As seen in the 7DMALF calculation using naturalised flows for the SH1 recorder (70103), the water abstractions can have a significant impact on the summer low flows when these gaugings occurred (Figure 8-3).

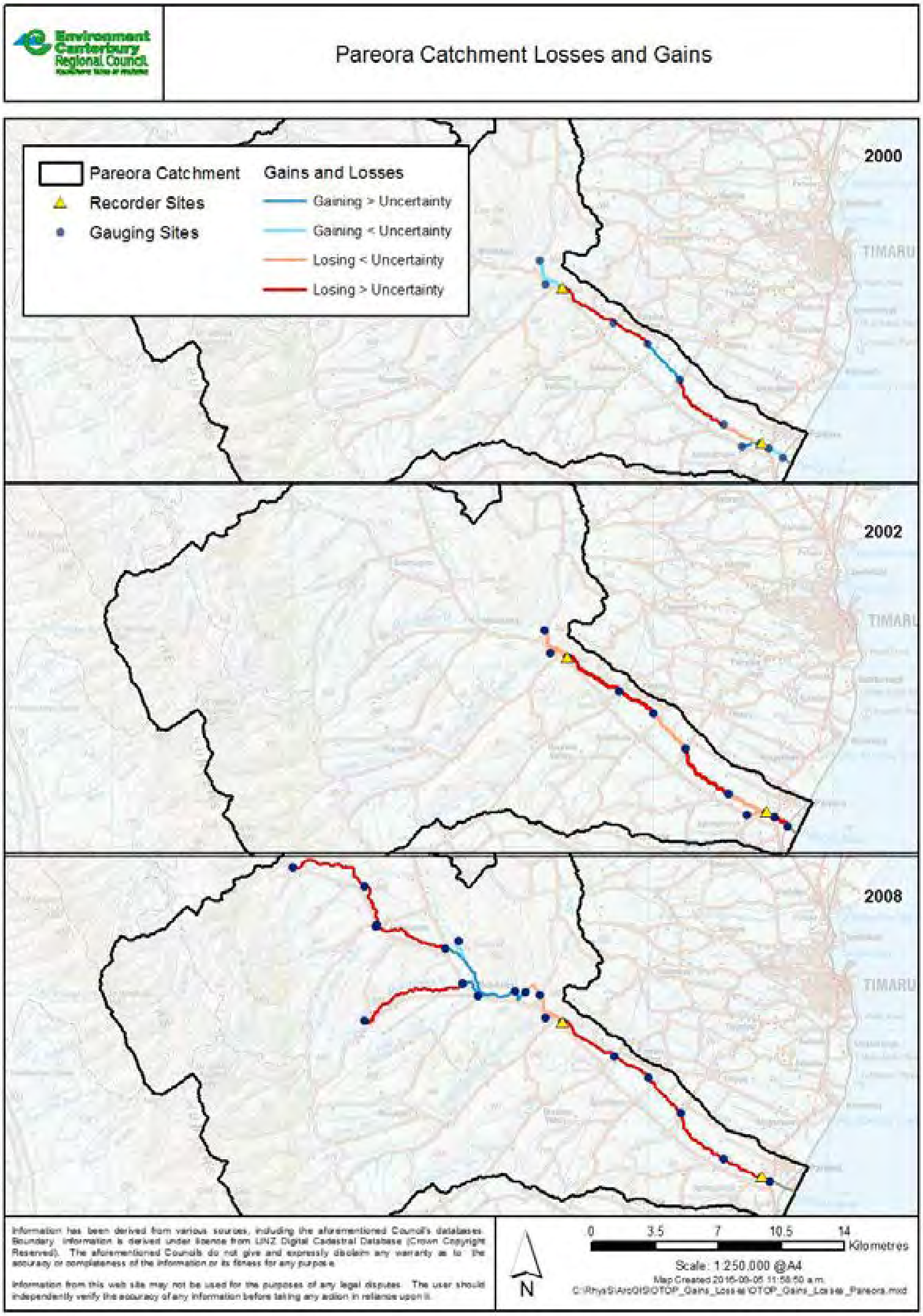

Figure 9-1: Net stream reach gains and losses in the Pareora catchment for the three sets of gauging periods

10 Conclusions

In the South OTOP, the combined water allocation is 18.5 million m^3 for the 2014/2015 water year with 16 million m^3 from the Pareora SWAZ and 2.5 million m^3 from the other SWAZs. In the Pareora SWAZ, half of the allocation is water supply for the TDC, while the remainder in the Pareora SWAZ and most of the allocation in the other south OTOP SWAZs is for irrigation. The total allocation has been relatively constant since the 2009/2010 water year. The 2015/2016 water year had significant minimum flow restrictions for the Pareora River as compared to previous years. Approximately 60% of the total allocated water in the 2014/2015 water year is actually being used according to the available metering data.

Flow data from the Pareora River indicates that at Huts the flow has never gone dry, but the MALF is affected by upstream abstractions according to the naturalisation. Even with a short record, the SH1 recorder has gone dry in multiple years, and when the flow is naturalised the SH1 recorder would not go dry. The effect of abstractions is mainly felt during the summer dry periods when flow is naturally low and there is high demand on water for irrigation. The gains and losses results illustrate these conclusions. In the 2000/2001 water year prior to major irrigation consents in the Lower Pareora, there were gaining reaches in addition to losing reaches in the Lower Pareora. In the later years when allocations have increased, the Lower Pareora no longer has any gaining reaches.

11 References

Aitchison-Earl, P; Ettema, M; Horrell, G; McKerchar, A; Smith, E; 2006: Pareora – Waihao River: Water Resource Summary. Environment Canterbury Report R06/20. ISBN 1-86937-602-1.

Burrell, G. (2008): Pareora River aquatic ecology and minimum flow requirements. Report by Golder Associates to Canterbury Regional Council.

de Joux R.T. (2000): The North Branch Pareora River hydrology and water quality. Report prepared by Environmental Consultancy Services Ltd for Timaru District Council.

de Joux, R., and Scarf, F., 2010. Review of the Hydrology, Water Allocation and Management of the Pareora Catchment water resources. Report prepared for the Canterbury Regional Council.

Environment Canterbury 2012. Pareora Catchment Environmental Flow and Water Allocation Regional Plan. ISBN 978-1-927210-65-9.

Landcare Research New Zealand Ltd. 2015. New Zealand Land Cover Database. https://lris.scinfo.org.nz/layer/423-lcdb-v41-land-cover-database-version-41-mainland-new-zealand/.

Sanson RL, Scott DJ. 2003. Proceedings of the Food Safety, Animal Welfare & Biosecurity, Epidemiology & Animal Health Management, and Industry branches of the NZVA, Proceedings of the 3rd Pan Commonwealth Veterinary Conference: Plenary Sessions and Proceedings of the Industry and Food Safety & Biosecurity Branches of the NZVA. FCE Publication No. 231, 69-74.

Tait, A. and Woods, R. 2006. Spatial Interpolation of Daily Potential Evapotranspiration for New Zealand Using a Spline Model. Journal of Hydrometeorology, vol 8, 430-438.

Waugh, J R (Ed); 1987: Pareora Catchment Water and Soil Resource Report 1987. South Canterbury Catchment Board and Regional Water Board publication No. 54, December 1987. ISSN 0111-7335.

Appendix 1: Normalisation of flow records

As the SH1 recorder has a short record, comparing the SH1 flow record to the Huts LTR will determine the representativeness of the recent short record of SH1 to the long term record of Huts and how they compare to each other. The overlapping mean monthly flows correlate well between the two recorders (Table A1-1 and Figure A1-1), and are very well correlated with mean monthly flows under 10 m^3/s (Table A1-1 and Figure A1-2).

As expected from the nearly 1:1 slope from the linear regression (Table A1-1), the mean annual flows for both recorders during the period of record of SH1 is nearly identical (Table A1-2). Nevertheless, the long term mean annual flow from the Huts period of record is considerably lower indicating that flows in the recent years have been well above the historic average (Figure 8-2).

Table A1-1: Linear regression statistics relating the Huts long record (70105) to the SH1 short record (70103) in mean monthly flows. "All flow" includes all overlapping months between the two recorders, and "< 10 m^3/s" includes only the mean monthly flows of less than 10 m^3/s

	Slope	Intercept	R^2	NRMSE	p	n-obs
All flows	1.22	-1.028	0.95	0.706	0	88
< 10 m^3/s	1.028	-0.497	0.972	0.247	0	80

Table A1-2: Mean annual flows for the period of record for both recorders in the Pareora

	Pareora at SH1		Pareora at Huts	
	Recorded	**Naturalised**	**Recorded**	**Naturalised**
Huts record period	NA	NA	3.68	3.77
SH1 record period	4.43	4.83	4.37	4.6
Number of years	6	6	32	32

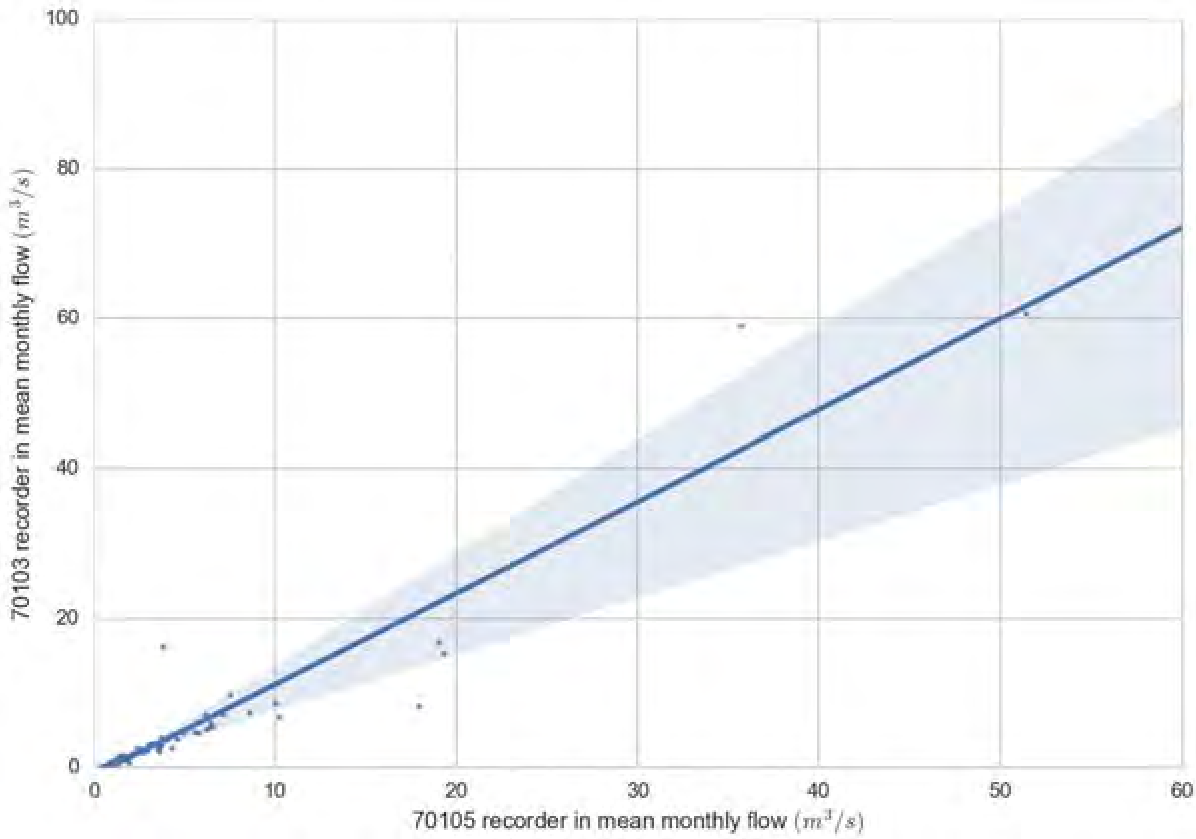

Figure A1-1: Linear regression of the mean monthly flows between the two recorders on the Pareora River. The semi-transparent blue area is the 95% confidence area of the slope of the regression line. This figure includes all overlapping months

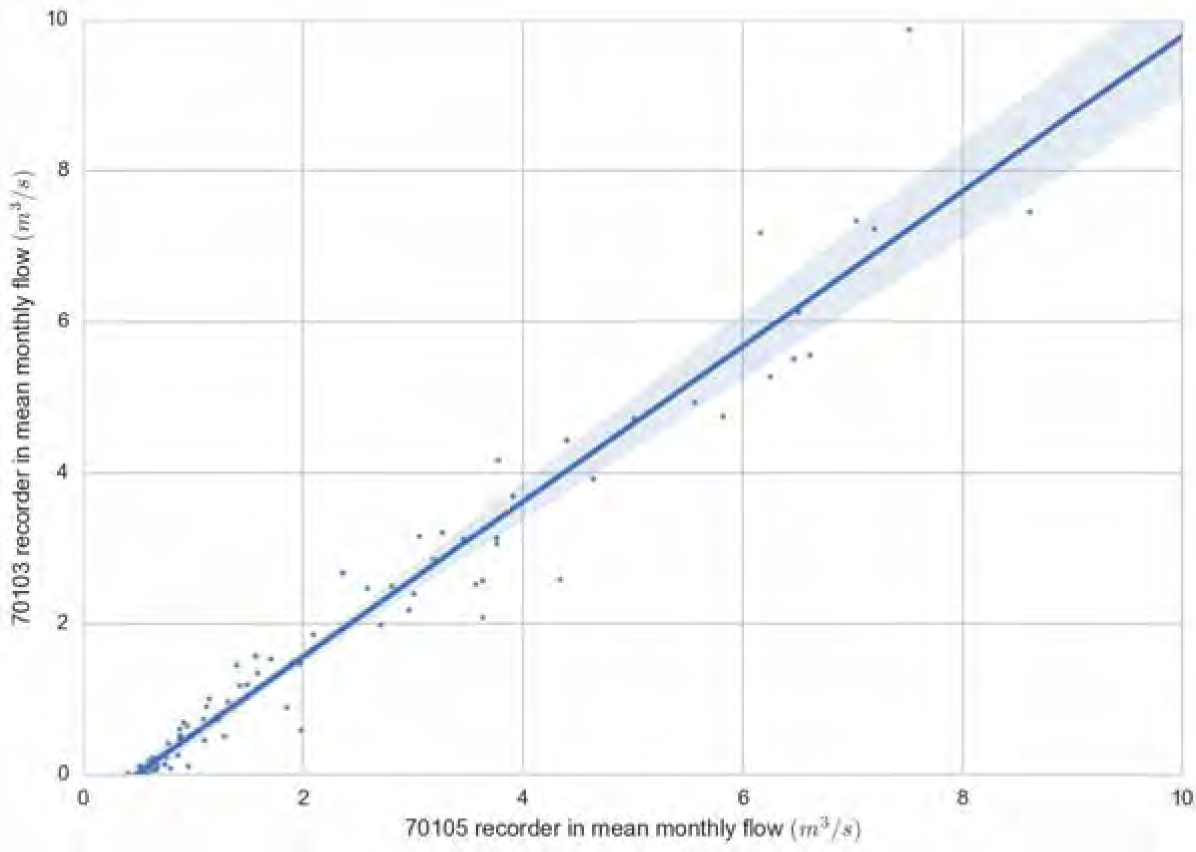

Figure A1-2: Linear regression of the mean monthly flows between the two recorders on the Pareora River. The semi-transparent blue area is the 95% confidence area of the slope of the regression line. This figure only includes months with mean monthly flows of less than 10 m^3/s for both recorders

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Facilitating sustainable development in the Canterbury region

ecan.govt.nz