

# Water Resources of the Obelisk and Old Man Ranges

An overview of the 2014/15 irrigation season

March 2016

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

© Copyright for this publication is held by the Otago Regional Council. This publication may be reproduced in whole or in part, provided the source is fully and clearly acknowledged.

ISBN 978-0-908324-28-6

Report writer:           Xiaofeng Lu, Hydrologist  
Reviewed by:            Dean Olsen, Manager Resource Science

Published March 2016

## Executive summary

In many of the Region's catchments, the river flows are modified by abstraction, diversion, dams and urbanisation. To gain a picture of the true nature of a river's water resource it is necessary to estimate what the river flow would have been like without any water abstractions, i.e., the naturalised flow. Understanding naturalised river flows is a critical step in the management of the water resource.

This hydrological investigation includes the analysis of the actual water abstractions and the development of naturalised flows at key locations in the main catchments between the Old Man-Obelisk Range and the Clutha River during the 2014/15 irrigation season (Oct 2014 – Apr 2015, inclusive). These key locations are listed below:

- Omeo Creek at Fraser Dam Road
- Butchers Creek at Lye Bow Road
- Gorge Creek at SH8
- Shingle Creek at SH8
- Coal Creek at SH8
- Outlets of the main catchments (Figure 2.1) in the study area

Analyses of actual flow data, metered abstraction data, and consented allocations have been included in the river flow naturalisation process. The process depends on the availability of good quality data for both actual flows and all abstractions. Table E-1 summarises on a monthly basis, the ratio of actual water use to the consented amount of water use as a percentage for each catchment in the study area during the 2014/15 irrigation season.

**Table E-1 Ratio (%) of actual water use to the consented amount as a percentage by catchment and month during the 2014/15 irrigation season**

Catchment	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average
Omeo	49	50	51	36	35	32	31	40
Conroys	91	97	89	80	68	67	50	77
Butchers	69	82	99	94	74	79	57	79
Obelisk	1	24	50	54	47	46	22	35
Shingle	9	42	59	54	46	46	22	40
Elbow	0	0	27	26	33	9	1	14
Coal	62	81	70	22	21	16	20	42
Average	38	50	58	48	43	38	24	

The naturalised flow during the 2014/15 irrigation season has been generated by adding the respective upstream water takes back to the observed flows for each key flow site mentioned above. Also, the seven-day mean annual low flows (7dMALFs) for the key locations have been estimated from the flow records taken from the Pomahaka River at Glenken flow site (Pomahaka at Glenken), whose flows can be easily naturalised (detailed in Section 3). The naturalised 7dMALF across the available records (from 1992 to present) at Pomahaka at Glenken is estimated as a range between 2041 and 2164 l/s. By applying the combined ratio

method (see Appendix) to the estimated naturalised flows at Pomahaka at Glenken, the calculated 7dMALF and catchment yield at 7dMALF for each key location can be determined, and these results are summarised in Table E-2.

**Table E-2 Estimated long-term naturalised 7dMALF for the key locations in this study**

Catchment	Location	Area (km <sup>2</sup> )	Estimated naturalised 7dMALF (l/s)	Estimated catchment yield at 7dMALF (l/s·km <sup>2</sup> )
Omeo	Omeo at Fraser Dam	46	89 ~ 94	1.91 ~ 2.03
	Omeo catchment outlet	56	102 ~ 108	1.82 ~ 1.93
Conroys	Upstream of Conroys Dam	23	45 ~ 47	1.97 ~ 2.09
Butchers	Butchers Creek at Lye Bow Road	25	46 ~ 49	1.82 ~ 1.93
Obelisk	Gorge Creek at SH8	22	49 ~ 52	2.25 ~ 2.39
	Obelisk catchment outlet	48	97 ~ 103	2.01 ~ 2.13
Shingle	Shingle Creek at SH8	25	58 ~ 62	2.35 ~ 2.5
	Shingle catchment outlet	35	78 ~ 82	2.22 ~ 2.35
Elbow	Elbow Creek outlet	11	21 ~ 22	1.92 ~ 2.03
Coal	Coal Creek at SH8 (catchment outlet)	22	47 ~ 50	2.08 ~ 2.21
Pomahaka	Pomahaka at Glenken	713	2041 ~ 2164	2.86 ~ 3.03

## Table of contents

Executive summary.....	iii
1. Introduction .....	1
2. Study area.....	2
2.1. Vegetation.....	2
2.2. Land use and water allocation .....	2
2.3. Topography and soils .....	6
2.4. Rainfall.....	6
3. Flow naturalisation process .....	9
3.1. Data .....	9
3.2. Methods .....	9
3.2.1. Naturalised flows for the 2014/15 irrigation season .....	9
3.2.2. Naturalised 7dMALFs .....	9
4. Results.....	12
4.1. Omeo Creek.....	12
4.1.1. Water use.....	12
4.1.2. Naturalised flows .....	13
4.2. Conroys Creek .....	15
4.2.1. Water use.....	15
4.2.2. Naturalised flows .....	16
4.3. Butchers Creek .....	17
4.3.1. Water use.....	17
4.3.2. Naturalised flows .....	19
4.4. Obelisk Creek .....	20
4.4.1. Water use.....	20
4.4.2. Naturalised flows .....	21
4.5. Shingle Creek .....	23
4.5.1. Water use.....	23
4.5.2. Naturalised flows .....	24
4.6. Elbow Creek.....	25
4.6.1. Water use.....	25
4.6.2. Naturalised flows .....	26
4.7. Coal Creek.....	27
4.7.1. Water use and naturalised flow.....	27
4.8. Summary of water use.....	30
5. Conclusions .....	31
6. Glossary.....	32
7. References.....	33
8. Appendix.....	34

## List of figures

Figure 2.1 The study area .....	2
Figure 2.2 Land cover for the study area .....	3
Figure 2.3 Land use for the study area.....	3

Figure 2.4	Water takes within the study area .....	4
Figure 2.5	Soil types within the study area .....	6
Figure 2.6	Median annual rainfall patterns over the study area (Sourced from growOTAGO) .....	7
Figure 2.7	Mean monthly rainfall at the five rain gauges around the study area .....	8
Figure 3.1	The three nearby permanent flow recorders around the study area.....	10
Figure 4.1	Instantaneous rates of takes within the Omeo catchment.....	12
Figure 4.2	Percentage of the consented water use within the Omeo catchment that is actually used for the 2014/15 irrigation season .....	13
Figure 4.3	Hydrographs of actual and estimated naturalised flows in the Omeo catchment during the 2014/15 irrigation season .....	14
Figure 4.4	Instantaneous rates of takes within the Conroys catchment.....	15
Figure 4.5	Percentage of the consented water use within the Conroys catchment that is actually used for the 2014/15 irrigation season .....	16
Figure 4.6	Instantaneous rates of takes within the Butchers catchment .....	17
Figure 4.7	The actual water use as a percentage of the consented maximum for each take within the Butchers catchment for the 2014/15 irrigation season.....	18
Figure 4.8	Hydrographs of actual and estimated naturalised daily average flows at Butchers Creek at Lye Bow Road for the 2014/15 irrigation season .....	19
Figure 4.9	Instantaneous rates of takes within the Obelisk catchment.....	21
Figure 4.10	Hydrographs of actual and estimated naturalised flows in the Obelisk catchment during the 2014/15 irrigation season.....	22
Figure 4.11	Instantaneous rates of take within the Shingle catchment .....	23
Figure 4.12	Percentage of the consented monthly volume in the Shingle catchment that is actually used during the 2014/15 irrigation season .....	24
Figure 4.13	Hydrographs of the daily average actual and estimated naturalised flows in the Shingle catchment during the 2014/15 irrigation season.....	25
Figure 4.14	Instantaneous rates of takes within the Elbow catchment.....	26
Figure 4.15	Instantaneous rates of takes in the Coal catchment for the 2014/15 irrigation season ....	28
Figure 4.16	Daily actual and estimated naturalised flows at the Coal catchment outlet.....	29
Figure 4.17	Percentage of the consented monthly volume in the Coal catchment that is actually used for the 2014/15 irrigation season .....	30
Figure 4.18	Percentage of the consented water take that is actually used during the 2014/15 irrigation months by catchment .....	30

### List of tables

Table 2.1	The surface water takes monitored for this study .....	5
Table 2.2	Long-term annual rainfall statistics from the five rain gauges around the study area.....	7
Table 2.3	MAP for the key catchments in the study area .....	8
Table 3.1	Flow data availability and comparison among the upstream catchments from the three recorders around the study area.....	11

Table 3.2	Estimated naturalised 7dMALF at Pomahaka at Glenken.....	11
Table 4.1	Consented rates of take and statistics of the daily average actual water use for the 2014/15 irrigation season in the Omeo catchment .....	12
Table 4.2	Monthly actual water use within the Omeo catchment.....	13
Table 4.3	Flow statistics (on a daily basis) for the Omeo catchment .....	14
Table 4.4	Consented rates of take and statistics of the daily average actual water use for the 2014/15 irrigation season in the Conroys catchment.....	15
Table 4.5	Monthly actual water use within the Conroys catchment .....	16
Table 4.6	Daily average flow statistics within the Conroys catchment .....	17
Table 4.7	Consented rates of take and statistics of the daily average actual water use for the 2014/15 irrigation season within the Butchers catchment.....	18
Table 4.8	Monthly actual water use within the Butchers catchment.....	18
Table 4.9	Daily average flow statistics at Butchers Creek at Lye Bow Road.....	20
Table 4.10	Consented rates of take and statistics of the daily average actual water use within the Obelisk catchment.....	20
Table 4.11	Monthly actual water use within the Obelisk catchment.....	20
Table 4.12	Daily average flow statistics within the Obelisk catchment .....	22
Table 4.13	Consented rates of take and statistics of the daily average actual water use within the Shingle catchment.....	23
Table 4.14	Monthly actual water use within the Shingle catchment.....	24
Table 4.15	Daily average flow statistics within the Shingle catchment .....	25
Table 4.16	Consented rate of take and statistics of the actual water use within the Elbow catchment during the 2014/15 irrigation season.....	26
Table 4.17	Monthly actual water use within the Elbow catchment.....	26
Table 4.18	Daily average flow statistics within the Elbow catchment.....	27
Table 4.19	Daily average flow statistics at Coal Creek at SH8 (catchment outlet) .....	28
Table 4.20	Statistics of actual and estimated (WR1577R and WR1578R) water use during the 2014/15 irrigation season in the Coal catchment.....	28
Table 4.21	Monthly actual water use within the Coal catchment .....	29
Table 5.1	Estimated naturalised 7dMALFs at the key locations for this study.....	31





# 1. Introduction

The Regional Plan: Water for Otago 2004 (Water Plan) sets out as one of its objectives ‘to retain flows in rivers sufficient to maintain their life-supporting capacity for aquatic ecosystems and their natural characters’. As a means of achieving this objective, the Water Plan provides for the setting of minimum and residual flows in Otago’s rivers. The determination of long-term flow statistics is important to inform such flow-setting processes.

This study presents an assessment of the existing consented water takes and flow naturalisation (including seven-day mean annual low flow, i.e., 7dMALF) for a number of small streams that flow from the Old Man Range to the Clutha River during 2014/15 irrigation season (Oct 2014 – Apr 2015 inclusive).

## 2. Study area

The study area (249 km<sup>2</sup>) covered seven river catchments that drain east from the Obelisk and Old Man Ranges on the western bank of the Clutha River (Figure 2.1), located about four kilometres southwest of Alexandra along State Highway 8.

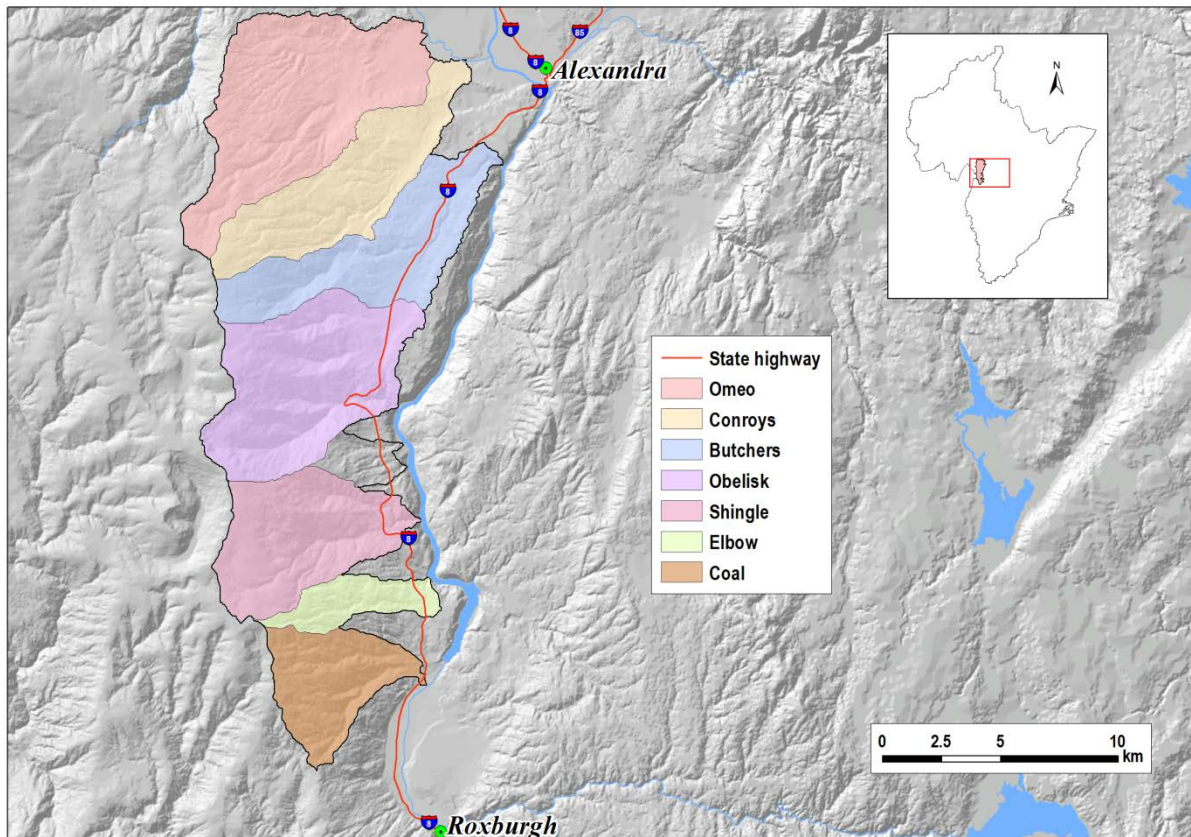


Figure 2.1 The study area

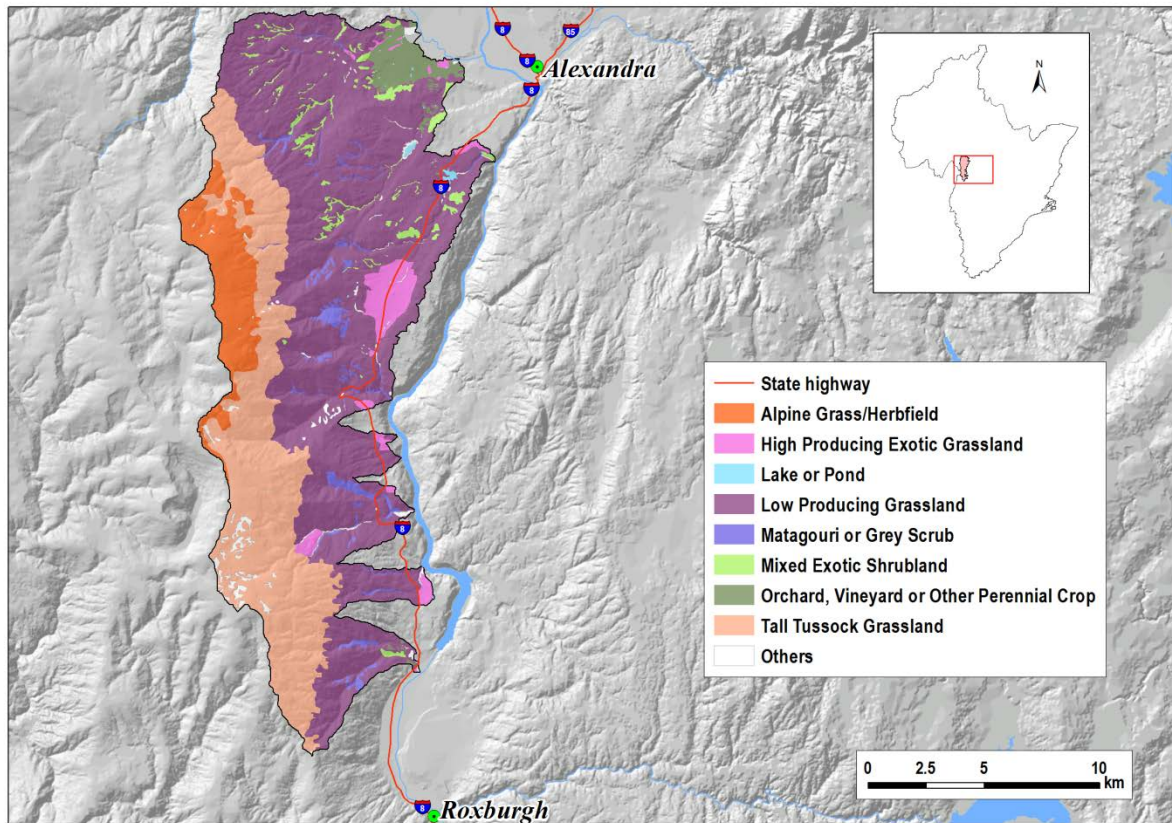
### 2.1. Vegetation

Low producing grasslands are the most common vegetation type in the study area (56%) and are mostly found in the eastern part of the study area, at elevations below 1000 m. Tall tussock grasslands predominate at high elevations in the west of the study area and cover almost 25% of the study area (Figure 2.2).

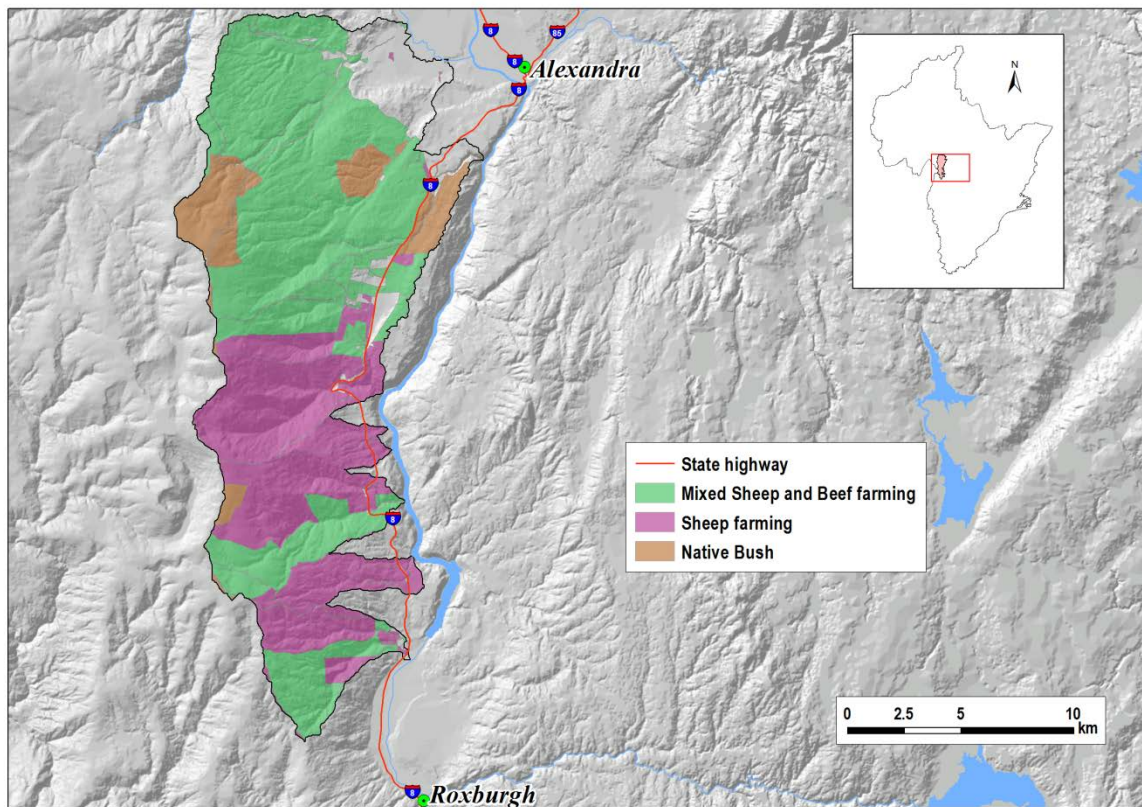
### 2.2. Land use and water allocation

Approximately half of the study area is currently used for mixed sheep and beef farming, most of them located in the north of the study area, with sheep farming accounting for a further third of the total area, mainly in the middle and south of the study area (Figure 2.3).

There are currently 28 consumptive primary surface water takes within the study area. Flow metering data from 25 of the takes were used to estimate the naturalised flows during the 2014/15 irrigation season in this study (Figure 2.4). The details of these takes are listed in Table 2.1.



**Figure 2.2** Land cover for the study area



**Figure 2.3** Land use for the study area

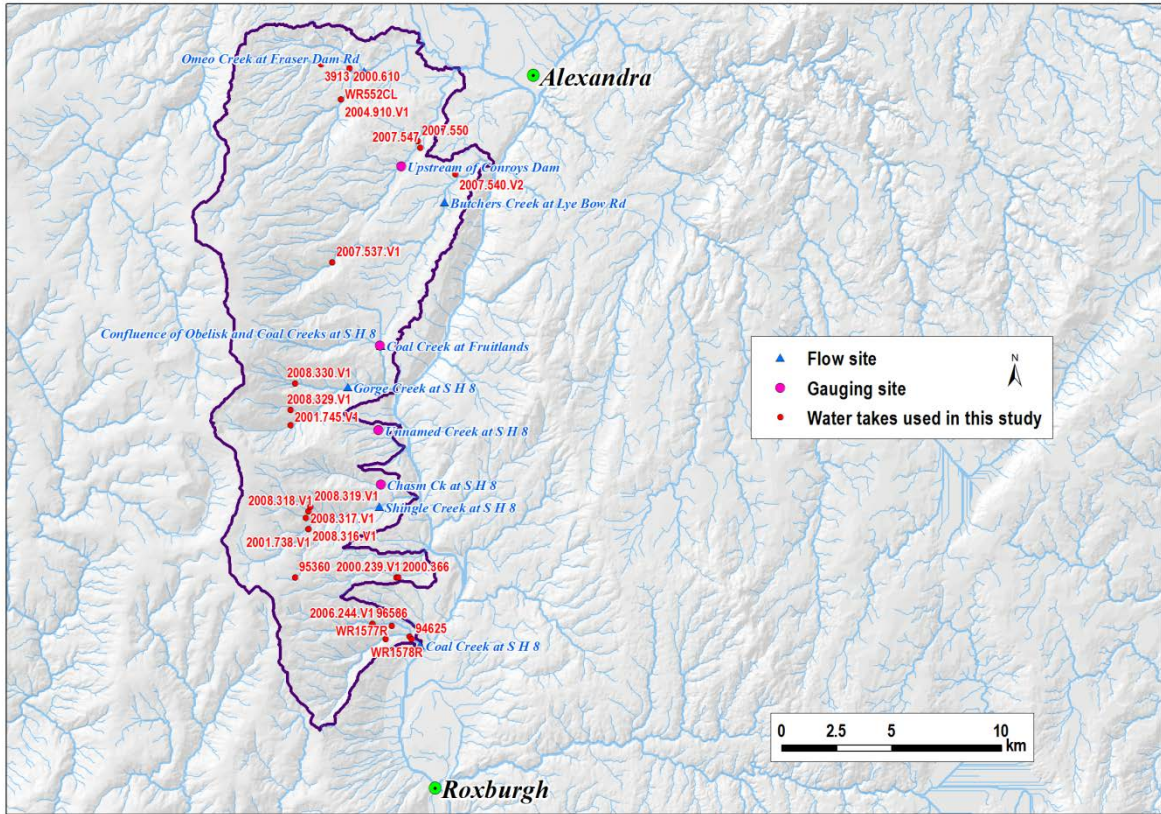


Figure 2.4 Water takes within the study area

**Table 2.1 The surface water takes monitored for this study**

Consent No.	MaxRate (l/s)	MaxMonthly (m <sup>3</sup> )	Catchment	Permit type	Residual Flow
2000.610	4	3600	Omeo	RMA	4 l/s at intake on coal creek.
2004.910.V1	87	233021	Omeo	RMA	None
3913	13.88	35977	Omeo	Deemed	None
WR552CL	111.1	287971	Omeo	Deemed	None
2007.547	84.9	223117	Conroys	Deemed	None
2007.550	84.9	220061	Conroys	Deemed	None
2007.537.V1	141.5	372658	Butchers	Deemed	None
2007.540.V2	226.4	594655	Butchers	Deemed	None
2001.745.V1	141.5	366768	Obelisk	Deemed	None
2008.329.V1	84.9	222995	Obelisk	Deemed	None
2008.330.V1	113.3	297327	Obelisk	Deemed	None
2001.738.V1	56.6	146707	Shingle	Deemed	None
2008.316.V1	28.3	74332	Shingle	Deemed	None
2008.317.V1	56.6	148663	Shingle	Deemed	None
2008.318.V1	28.3	74332	Shingle	Deemed	None
2008.319.V1	28.3	74332	Shingle	Deemed	None
95360	69.44	145000	Shingle	Deemed	None
2000.239.V1	83	223200	Elbow	RMA	8.5 l/s immediately d/s of abstraction point, no abstraction when Q<8.5 l/s
2000.366	3.3	8554	Elbow	RMA	None
2006.244.V1	28	39200	Coal	RMA	28 l/s in the Washpool Creek, below the intake
94325.V1	83.33	215991	Coal	Deemed	None
94625	263.8	683770	Coal	Deemed	None
96586	27.7	4800	Coal	Deemed	None
WR1577R	111.11	287997	Coal	Deemed	None
WR1578R	111.11	287997	Coal	Deemed	None

## 2.3. Topography and soils

The elevation of the study area ranges from below 300 m in the east to above 1000 m in the west. The soil distributions over the study area have a similar pattern to its topography and fall into three main categories (NZ Soils, 2015):

- Brown soils
- Semiarid soils
- Pallic Soils

Brown soils are the most common soil type in the study area (42%), and were mostly found at higher elevations in the west of the study area. Almost 30% of the soils within the study area are semiarid soils, most of them located in the northeast of the study area. Pallic soils predominate in most of the rest in the study area (Figure 2.5).

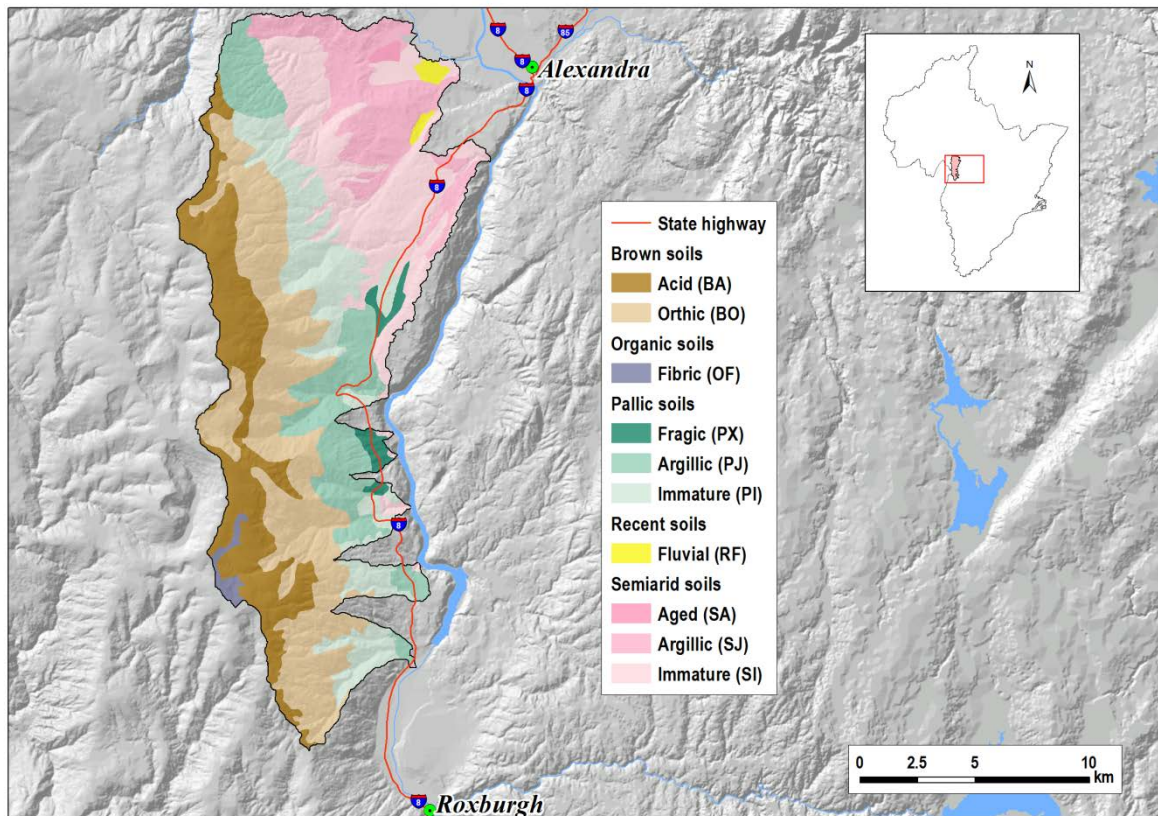
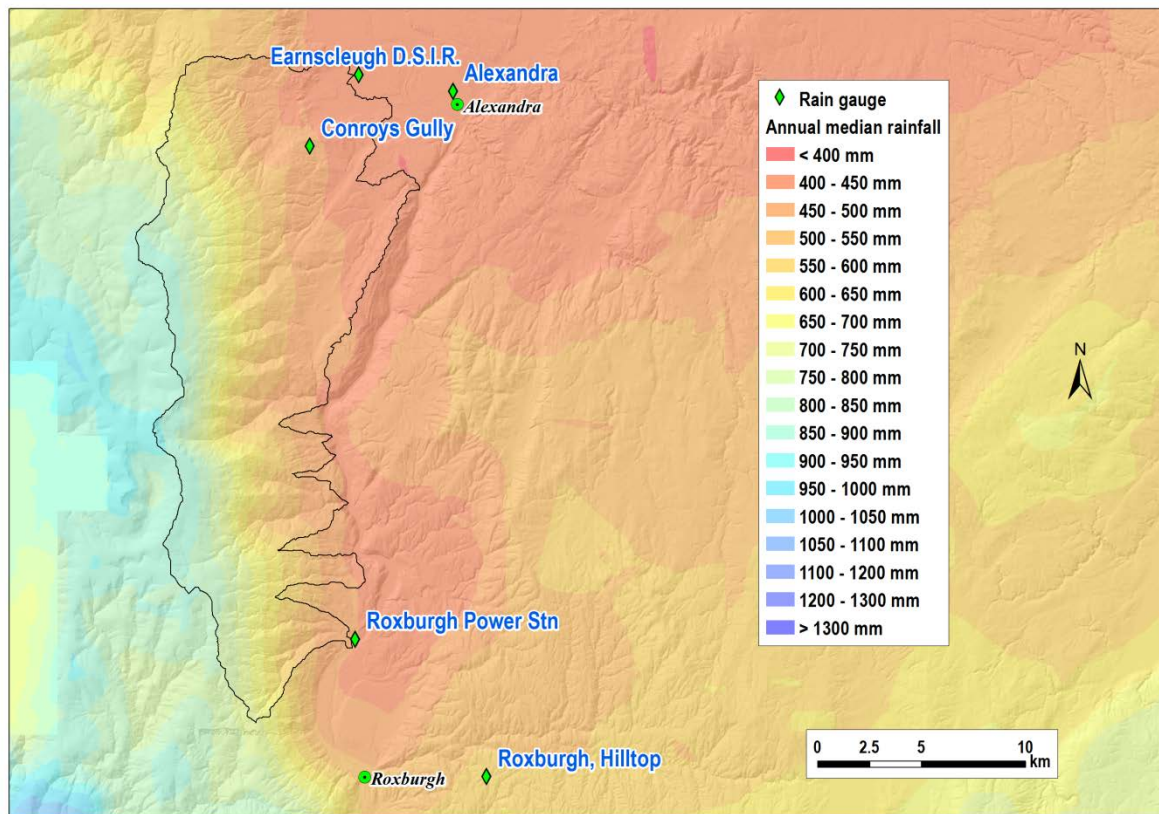


Figure 2.5 Soil types within the study area

## 2.4. Rainfall

As shown in Figure 2.6, the median annual rainfall over the study area ranges from below 400 mm in the northeast to over 900 mm along the Obelisk and Old Man Ranges in the west.

Figure 2.7 shows the monthly rainfall variations based on the long-term records from the five rain gauges (Figure 2.6) around the study area. Table 2.2 details these long-term rainfall statistics.

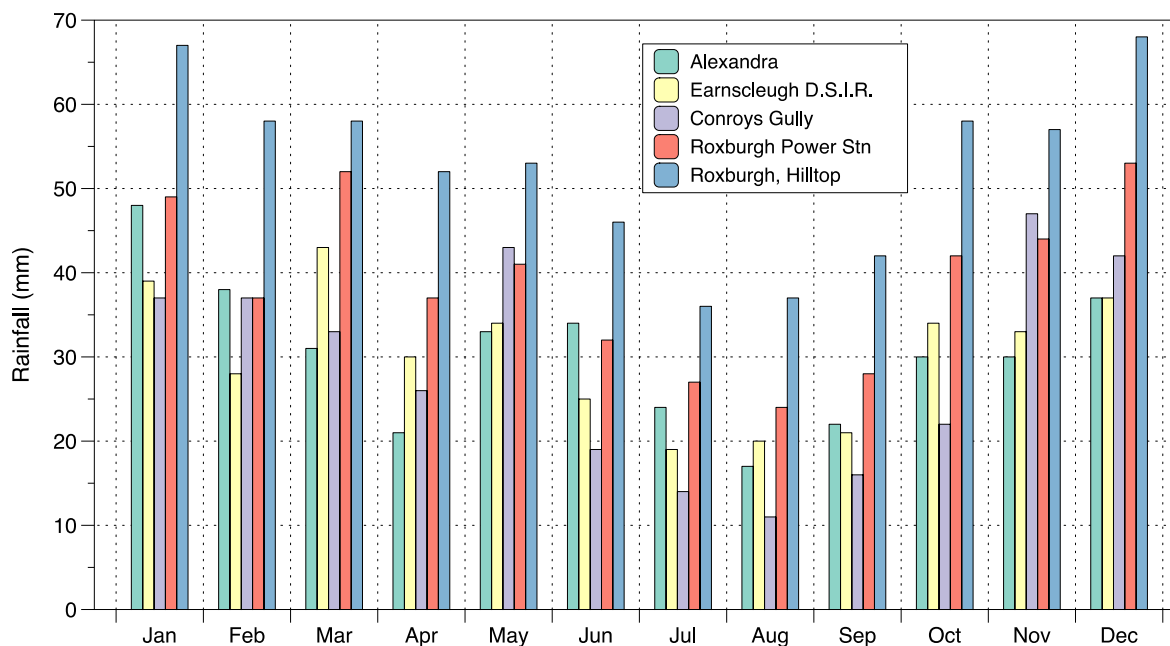


**Figure 2.6** Median annual rainfall patterns over the study area (Sourced from growOTAGO)

Table 2.3 shows the Median Aerial Precipitation (MAP) for the upstream catchment area from each key location in the study area. These MAP values are estimated from growOTAGO.

**Table 2.2** Long-term annual rainfall statistics from the five rain gauges around the study area

Rain gauge	Start	End	Record length (y)	Min (mm)	Mean (mm)	Max (mm)
Alexandra	May-90	Jul-15	25	264	352	492
Earnsclough D.S.I.R.	May-47	Mar-83	36	219	363	465
Conroys Gully	Apr-51	Feb-61	10	287	362	423
Roxburgh Power Stn	Jan-48	Oct-87	39	322	462	602
Roxburgh, Hilltop	Jan-33	Aug-15	82	420	627	819



**Figure 2.7** Mean monthly rainfall at the five rain gauges around the study area

**Table 2.3** MAP for the key catchments in the study area

Catchment	Location	Area (km <sup>2</sup> )	MAP (mm/y)
Omeo	Omeo at Fraser Dam	46	590
	Omeo catchment outlet	56	564
Conroys	Upstream of Conroys Dam	23	608
Butchers	Butchers Creek at Lye Bow Road	25	562
Obelisk	Gorge Creek at SH8	22	696
	Obelisk catchment outlet	48	620
Shingle	Shingle Creek at SH8	25	728
	Shingle catchment outlet	35	685
Elbow	Elbow Creek outlet	11	593
Coal	Coal Creek at SH8 (catchment outlet)	22	643
Pomahaka	Pomahaka at Glenken	713	885



## 3. Flow naturalisation process

### 3.1. Data

The instantaneous flows and water metering data used for the flow naturalisation process during the 2014/15 irrigation season provided to Otago Regional Council by consent holders. Locations of flow recorders are illustrated in Figure 2.4. Table 2.1 lists the water takes that were included in the flow naturalisation process. However, data on water abstractions under the consents WR1577R and WR1578R were not available due to a lack of metering devices. The estimation of actual water use for these two takes is detailed in Section 4.7.1.

### 3.2. Methods

The methodology applied for estimating naturalised flows during the 2014/15 irrigation season and 7dMALFs is described separately in the following sections.

#### 3.2.1. Naturalised flows for the 2014/15 irrigation season

Naturalised flow records were produced by the following procedure:

- Deriving a dataset of average daily water abstractions and converting recorded instantaneous flow records to daily mean flows.
- Comparing metered abstraction data to the consented allocation volume for the site and obtaining the monthly ratio of actual water use to the consented amount of use for each abstraction during the 2014/15 irrigation season.
- Adding the abstraction to the daily flow record to derive naturalised flows if both datasets are available. If either actual water abstraction or actual flow data is not available, a reference flow site with naturalised flow records needs to be used for estimating naturalised flows at points of interest (see Appendix).

#### 3.2.2. Naturalised 7dMALFs

To estimate naturalised 7dMALFs in the study catchments, the combined ratio method (see Appendix) is applied due to the short flow records for those sites shown in Figure 2.4. To employ the combined ratio method, a flow site with long-term naturalised flows<sup>1</sup> is needed as a reference. Three nearby flow recorders (Waipahi at Waipahi, Pomahaka at Glenken, and Waikaia at Piano Flat) with relatively long measured flows are available (Figure 3.1). The availability of the flow data and a comparison among the upstream catchments from these three recorders are listed in Table 3.1.

---

<sup>1</sup> either measured flows being natural or naturalised flows being reasonably estimated

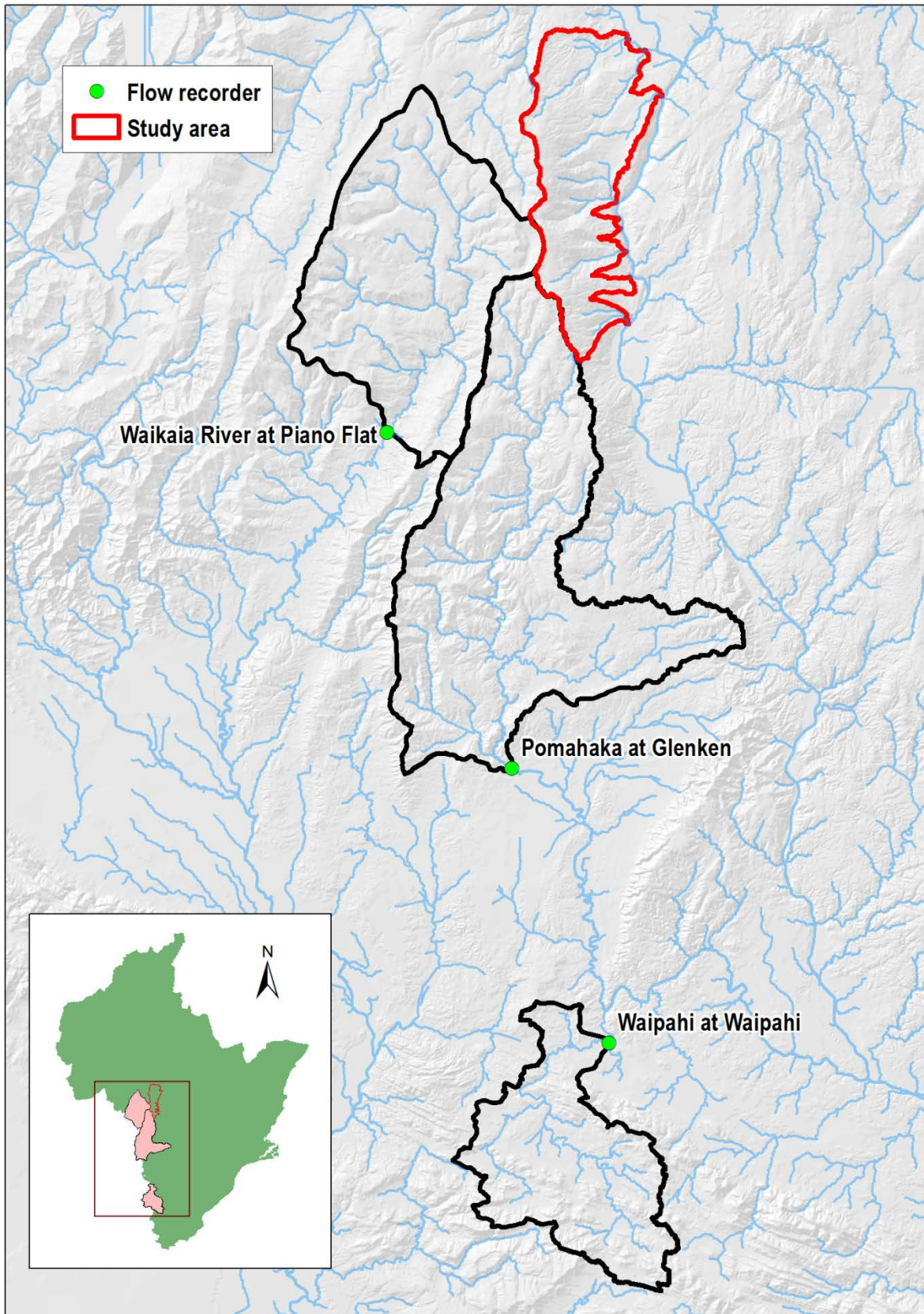


Figure 3.1 The three nearby permanent flow recorders around the study area

**Table 3.1** Flow data availability and comparison among the upstream catchments from the three recorders around the study area

Upstream area	Flow records	Area (km <sup>2</sup> )	Elevation (m)	MAP (mm)
Waipahi at Waipahi	July 1996 ~ present	300	Not available	1006
Pomahaka at Glenken	July 1992 ~ present	713	0 ~ 1483	885
Waikaia at Piano Flat	July 1979 ~ present	486	Not available	979
Study Area	----	243	92 ~ 1683	562 - 728

Both upstream catchment areas from recorders at Waipahi at Waipahi and Waikaia at Piano Flat currently have no upstream water abstractions. Recorded flows at these two sites would approximate 'natural' flows. However, these two catchment areas had much higher general annual rainfall (MAP) compared with the study catchments and do not meet the criteria of 'sharing catchment similarity' (Table 3.1). The flow site at Pomahaka at Glenken was the most similar to the study catchments and was used to estimate the 7dMALFs at the key locations in the study area, even if its recorded flows are not quite 'natural'. Fortunately, the naturalised flows at Pomahaka at Glenken were easily estimated.

Specifically, there are five water takes within the upstream catchment area from Pomahaka at Glenken. Based on the available water take data for each irrigation season since April 2012, the actual amount of consumptive water is around 11% of the total maximum consented rate of 307.26 l/s. Considering the relatively dry and wet seasons since 1992, an assumption of 10 ~ 50% of the total maximum consented being taken above Pomahaka at Glenken was made. Therefore, the estimated naturalised 7dMALF for Pomahaka at Glenken were calculated by adding the assumed range of water abstractions (31 ~ 154 l/s) back to its 7dMALF (2010 l/s) derived from actual flow records. The estimated naturalised 7dMALF for Pomahaka at Glenken is listed in Table 3.2.

**Table 3.2** Estimated naturalised 7dMALF at Pomahaka at Glenken

	Lower limit	Upper limit
<b>Estimated percentage of the total consented (%)</b>	10	50
<b>Estimated actual water take (l/s)</b>	31	154
<b>Estimated naturalised 7dMALF (l/s)</b>	2,041	2,164

Therefore, the 7dMALFs for the key locations in the study area can further be estimated from the estimated naturalised 7dMALF of 2,041 ~ 2,164 l/s at Pomahaka at Glenken by applying the combined ratio method (see Appendix). The results are detailed in Section 4.

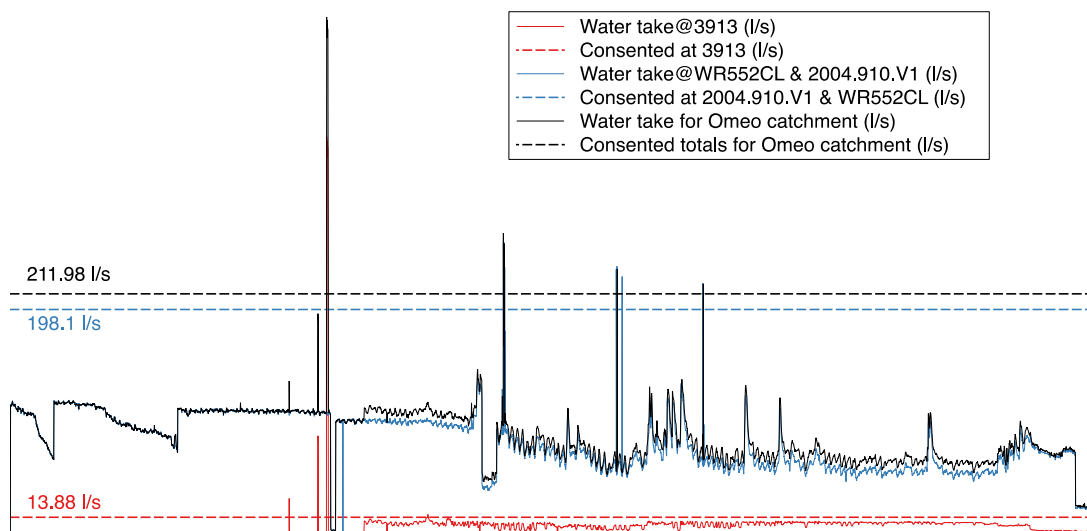
## 4. Results

### 4.1. Omeo Creek

Omeo Creek has a catchment area of 56 km<sup>2</sup> with an MAP of 564 mm/year. The total monthly consented allocation within the catchment is 556,969 m<sup>3</sup>.

#### 4.1.1. Water use

There are three water takes within the Omeo catchment, of which consents 2004.910.V1 and WR552CL were metered together. Figure 4.1 shows their instantaneous rates of abstraction, and Table 4.1 lists the statistics of the daily average actual water use for the 2014/15 irrigation season. The monthly actual water use within the catchment is summarised in Table 4.2.



**Figure 4.1** Instantaneous rates of takes within the Omeo catchment

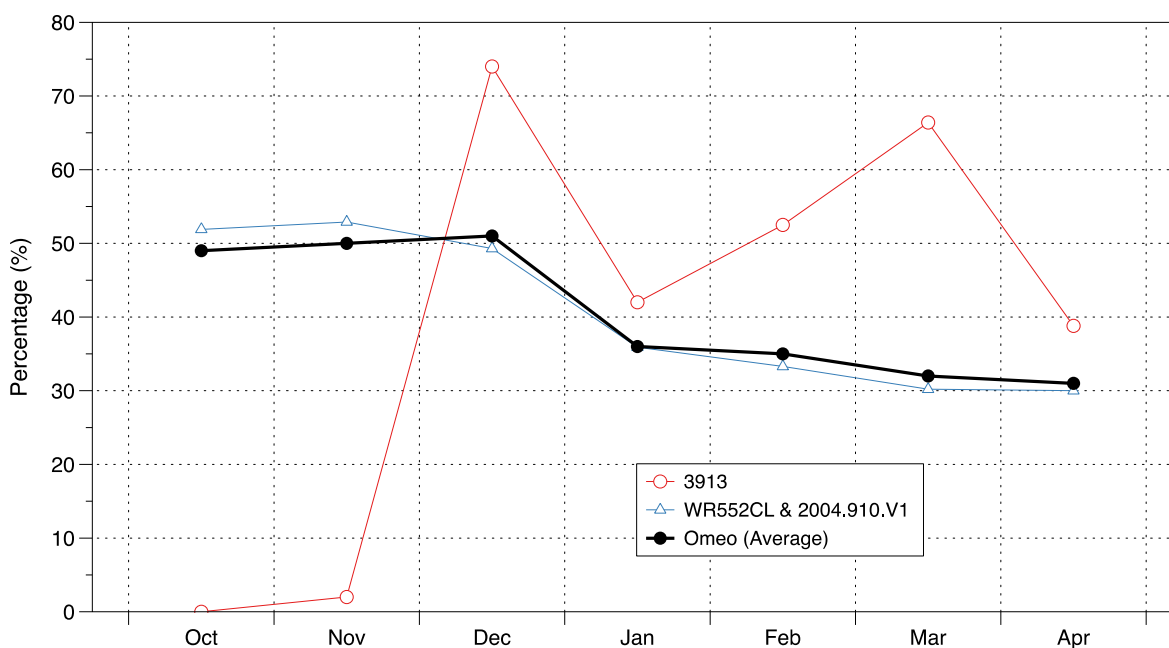
**Table 4.1** Consented rates of take and statistics of the daily average actual water use for the 2014/15 irrigation season in the Omeo catchment

Consent No.	Maximum consented instantaneous rate (l/s)	2014/15 actual use (daily average)			
		Min (l/s)	Max (l/s)	Mean (l/s)	Median (l/s)
3913	13.88	0	86	5	6
WR552CL 2004.910.V1	198.1	22	124	81	78
Total	211.98	24	165	86	84

**Table 4.2 Monthly actual water use within the Omeo catchment**

Consent No.	Monthly consented (m <sup>3</sup> )	Monthly actual use (m <sup>3</sup> ) for 2014/15 irrigation season						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
3913	35,977	0	718	26,615	15,125	18,894	23,885	13,965
WR552CL 2004.910.V1	520,992	270,508	275,844	257,086	186,921	173,629	157,105	156,426
Total	556,969	270,508	276,562	283,701	202,046	192,522	180,990	170,391

Figure 4.2 shows the percentage of the consented amount within the Omeo catchment that is actually used during the 2014/15 irrigation season.

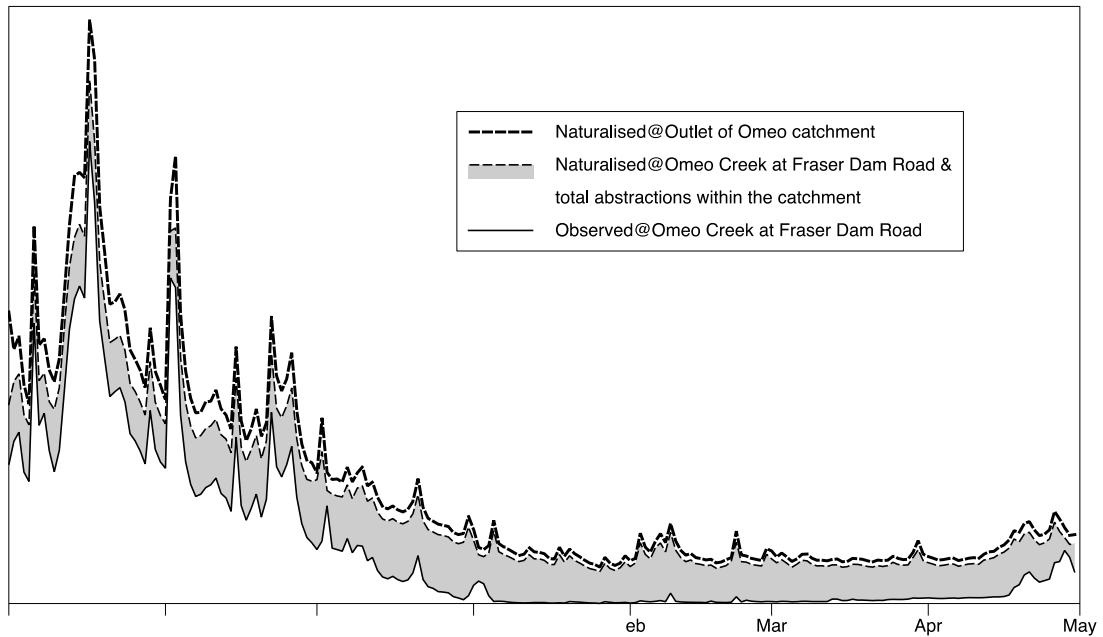


**Figure 4.2 Percentage of the consented water use within the Omeo catchment that is actually used for the 2014/15 irrigation season**

**4.1.2. Naturalised flows**

The naturalised flows at Omeo Creek at Fraser Dam Road were estimated by adding the existing water takes back to its observed flows, while the combined ratio method (see Appendix) was used to estimate the naturalised flows at the Omeo catchment outlet using the naturalised flows from the site at Fraser Dam Road. The hydrographs of the actual and estimated naturalised flows in the Omeo catchment during the 2014/15 irrigation season are shown in Figure 4.3.

By applying the combined ratio method (see Appendix), the 7dMALFs at the key locations within the Omeo catchment can be calculated from the estimated naturalised 7dMALF at Pomahaka at Glenken (2041 ~ 2164 l/s) based on the assumption of 10 ~ 50% of the total maximum consented being taken above Pomahaka at Glenken. These naturalised 7dMALFs and the daily flow statistics for the 2014/15 irrigation season are shown in Table 4.3.



**Figure 4.3** Hydrographs of actual and estimated naturalised flows in the Omeo catchment during the 2014/15 irrigation season

**Table 4.3** Flow statistics (on a daily basis) for the Omeo catchment

Location		Omeo at Fraser Dam Road		Omeo catchment outlet
Type		Actual	Naturalised	Naturalised
2014/15 irrigation season	Min (l/s)	0	59	68
	Max (l/s)	851	964	1107
	Mean (l/s)	107	193	222
	Median (l/s)	15	112	128
	7dLF <sup>2</sup> (l/s)	1	64	74
7dMALF (l/s)		----	89 ~ 94	102 ~ 108

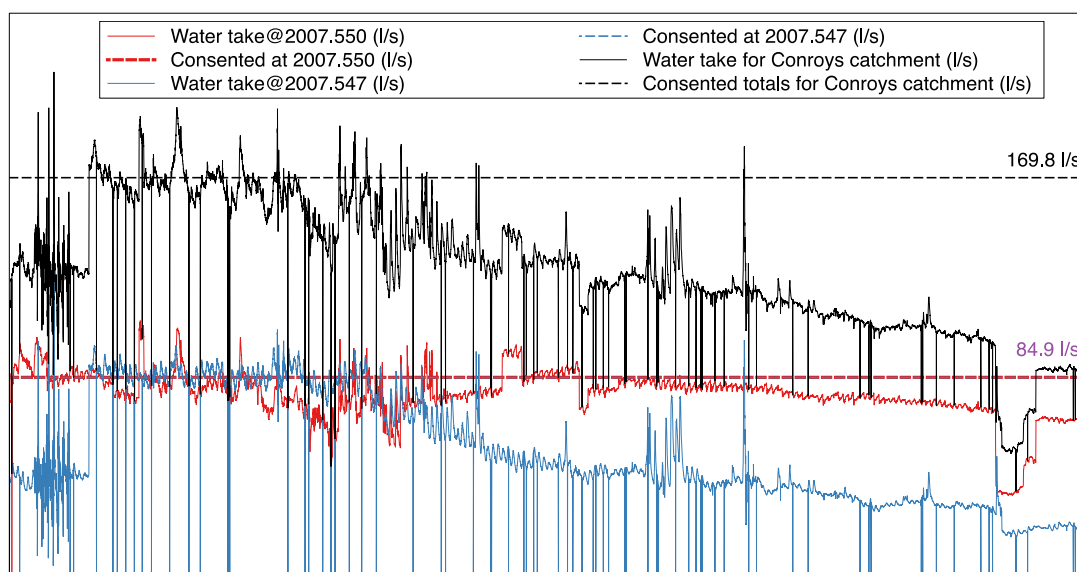
<sup>2</sup> 7-day low flow

## 4.2. Conroys Creek

Conroys Creek has a catchment area of 35 km<sup>2</sup> with an MAP of 551 mm/year. The total consented monthly allocation within the catchment is 443,178 m<sup>3</sup>.

### 4.2.1. Water use

There are two water takes just downstream of the Conroys Dam. Figure 4.4 shows instantaneous rates of the two takes, and Table 4.4 lists the consented allocations and statistics of the daily average actual water use for the 2014/15 irrigation season. The monthly actual water use within the catchment is summarised in Table 4.5.



**Figure 4.4 Instantaneous rates of takes within the Conroys catchment**

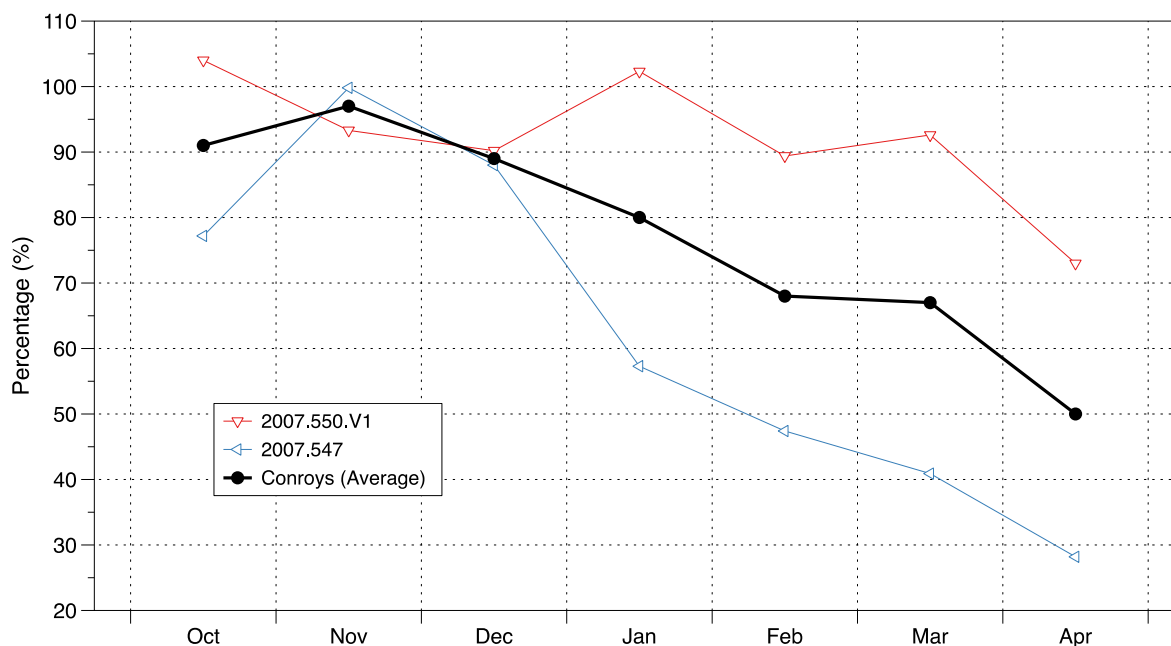
Figure 4.5 shows the percentage of the consented monthly volume within the Conroys catchment that is actually used during the 2014/15 irrigation season.

**Table 4.4 Consented rates of take and statistics of the daily average actual water use for the 2014/15 irrigation season in the Conroys catchment**

Consent No.	Maximum consented instantaneous rate (l/s)	2014/15 actual use (daily average)			
		Min (l/s)	Max (l/s)	Mean (l/s)	Median (l/s)
2007.550	84.9	35	99	77	78
2007.547	84.9	17	93	53	45
Total	169.8	54	186	131	130

**Table 4.5 Monthly actual water use within the Conroys catchment**

Consent No.	Monthly consented (m <sup>3</sup> )	Monthly actual use (m <sup>3</sup> ) for 2014/15 irrigation season						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
2007.550	220,061	228,887	205,219	198,416	225,126	196,652	203,761	160,641
2007.547	223,117	172,277	222,693	196,278	127,793	105,794	91,149	62,912
Total	443,178	401,164	427,912	394,694	352,919	302,447	294,911	223,553

**Figure 4.5 Percentage of the consented water use within the Conroys catchment that is actually used for the 2014/15 irrigation season**

Water take under the consent 2007.550.V1 was slightly above its consented monthly volume in October 2014 and January 2015, respectively.

#### 4.2.2. Naturalised flows

Naturalised flows were estimated for the gauging site upstream of the Conroys Dam, as the flows at downstream of the Conroys Dam would be affected by the amount of water stored in Conroys Dam. Table 4.6 lists the daily average flow statistics during the 2014/15 irrigation season at the upstream of Conroys Dam, and the naturalised 7dMALF calculated from the estimated naturalised 7dMALF at Pomahaka at Glenken.



**Table 4.6 Daily average flow statistics within the Conroys catchment**

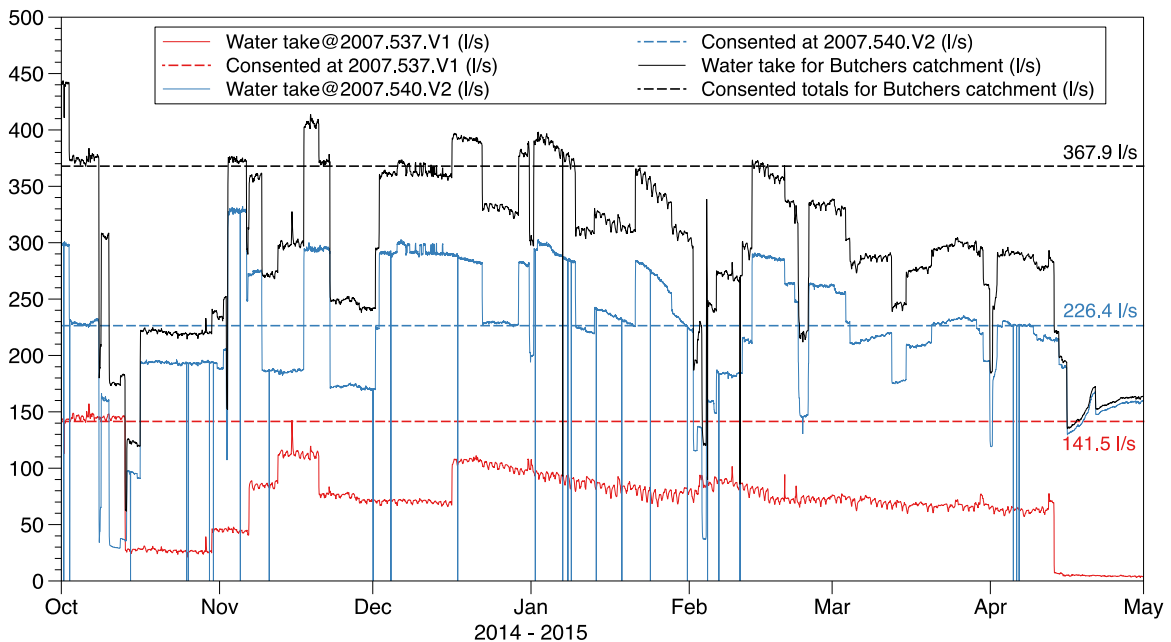
Location		Upstream of Conroys Dam
Type		Naturalised
2014/15 irrigation season	Min (l/s)	30
	Max (l/s)	484
	Mean (l/s)	97
	Median (l/s)	56
	7dLF (l/s)	32
7dMALF (l/s)		45 ~ 47

### 4.3. Butchers Creek

Butchers Creek has a catchment area of 36 km<sup>2</sup> with an MAP of 526 mm/year.

#### 4.3.1. Water use

There are two water abstractions in the Butchers catchment with a total monthly consented allocation of 967,313 m<sup>3</sup>. Figure 4.6 shows the instantaneous rates of abstraction in the catchment, and Table 4.7 lists the consented allocations and statistics of the daily average actual water use for the 2014/15 irrigation season. The monthly actual water use within the catchment is summarised in Table 4.8.



**Figure 4.6 Instantaneous rates of takes within the Butchers catchment**

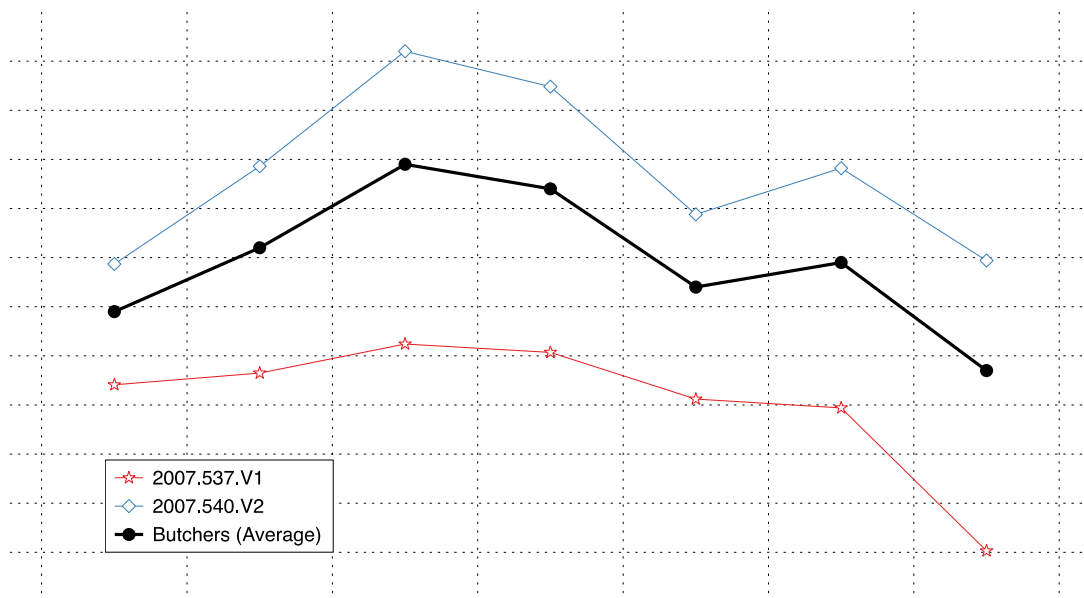
Figure 4.7 shows the actual water use as a percentage of the consented maximum for each take during the 2014/15 irrigation season in the Butchers catchment.

**Table 4.7** Consented rates of take and statistics of the daily average actual water use for the 2014/15 irrigation season within the Butchers catchment

Consent No.	Maximum consented instantaneous rate (l/s)	2014/15 actual use (daily average)			
		Min (l/s)	Max (l/s)	Mean (l/s)	Median (l/s)
2007.537.V1	141.5	4	148	72	73
2007.540.V2	226.4	30	329	221	225
Total	367.9	122	436	293	296

**Table 4.8** Monthly actual water use within the Butchers catchment

Consent No.	Monthly consented (m <sup>3</sup> )	Monthly actual use (m <sup>3</sup> ) for 2014/15 irrigation season						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
2007.537.V1	372,658	201,477	210,465	232,379	226,039	190,635	184,270	75,536
2007.540.V2	594,655	467,840	586,303	725,509	682,839	527,935	584,058	472,118
Total	967,313	669,317	796,768	957,888	908,878	718,570	768,328	547,654

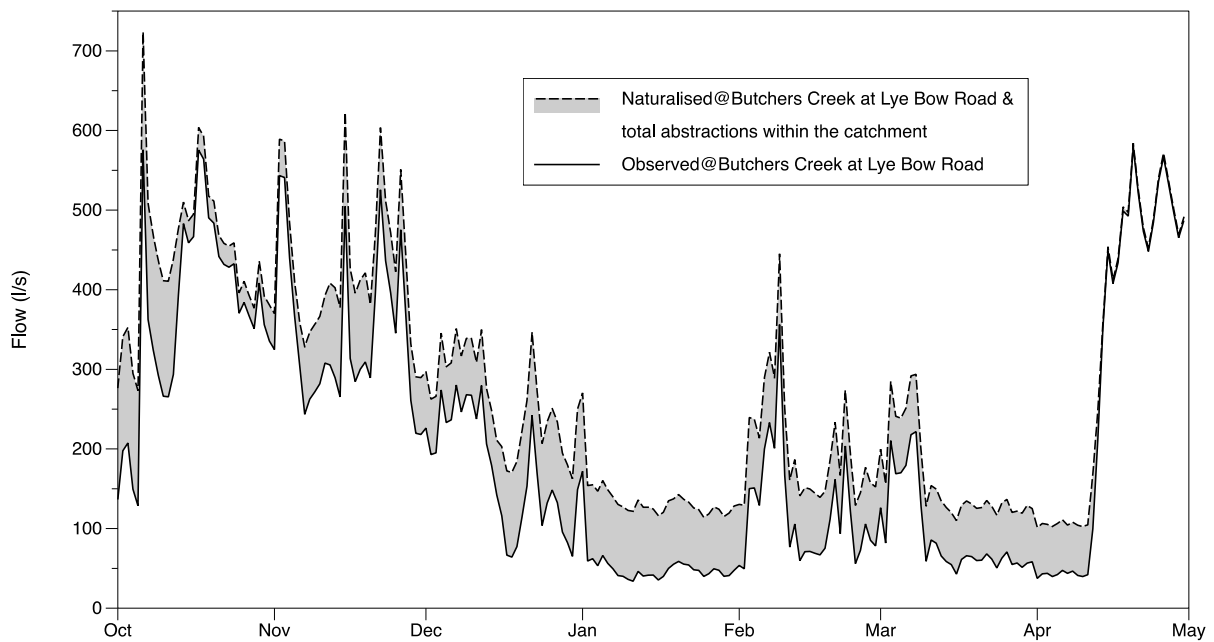


**Figure 4.7** The actual water use as a percentage of the consented maximum for each take within the Butchers catchment for the 2014/15 irrigation season

Holder of the consent 2007.540.V2 took around 15% and 20% above the consented monthly volume for December 2014 and January 2015, respectively.

### 4.3.2. Naturalised flows

Butchers Dam might largely affect the hydrology of the downstream Butchers Creek. Therefore, naturalised flow time series were estimated for the flow recorder at Lye Bow Road only. The water abstraction under 2007.537.V1 was added back to the actual flows at the recorder to derive the naturalised flow time series. The hydrographs of the actual and estimated naturalised daily average flows during the 2014/15 irrigation season are shown in Figure 4.8.



**Figure 4.8 Hydrographs of actual and estimated naturalised daily average flows at Butchers Creek at Lye Bow Road for the 2014/15 irrigation season**

Table 4.9 lists the daily average flow statistics at Butchers Creek at Lye Bow Road during the 2014/15 irrigation season, and the naturalised 7dMALF calculated from the estimated naturalised 7dMALF at Pomahaka at Glenken.

**Table 4.9 Daily average flow statistics at Butchers Creek at Lye Bow Road**

Location		Butchers Creek at Lye Bow Road	
Type		Actual	Naturalised
2014/15 irrigation season	Min (l/s)	34	101
	Max (l/s)	579	724
	Mean (l/s)	208	280
	Median (l/s)	162	251
	7dLF (l/s)	39	105
7dMALF (l/s)		----	46 ~ 49

#### 4.4. Obelisk Creek

The Obelisk catchment has an area of 48 km<sup>2</sup> with an MAP of 620 mm/year. The total consented monthly allocation within the catchment is 887,090 m<sup>3</sup>.

##### 4.4.1. Water use

All three water abstractions within the Obelisk catchment were metered together. Table 4.10 lists the consented limits and statistics of the daily average actual water use during the 2014/15 irrigation season. The monthly actual water use within the catchment is summarised in Table 4.11.

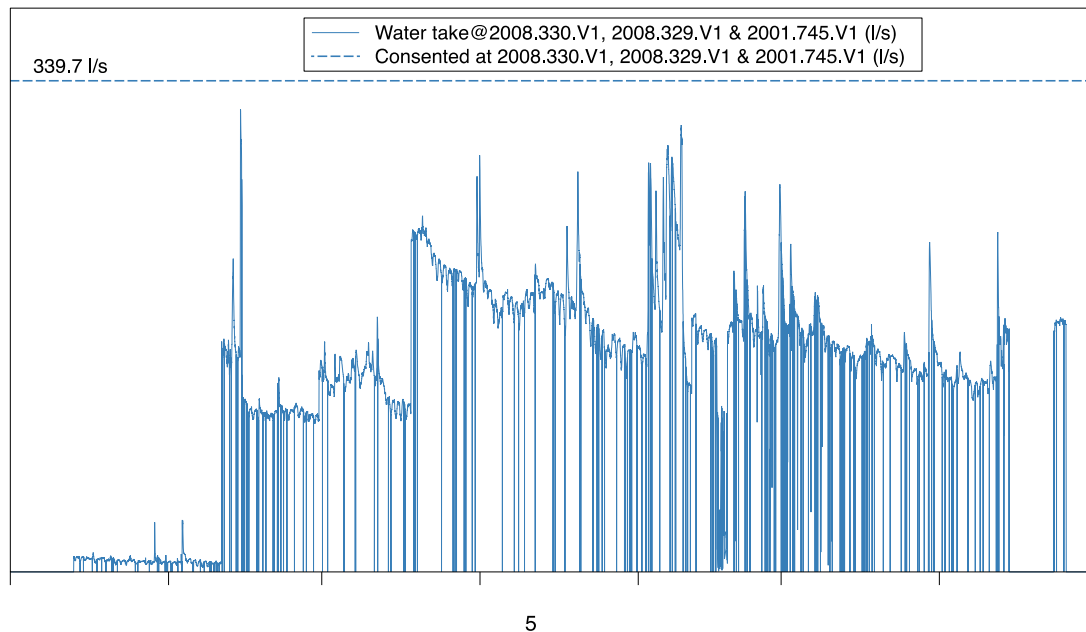
**Table 4.10 Consent rates of take and statistics of the daily average actual water use within the Obelisk catchment**

Consent No.	Maximum consented instantaneous rate (l/s)	2014/15 actual use (daily average)			
		Min (l/s)	Max (l/s)	Mean (l/s)	Median (l/s)
2008.330.V1, 2008.329.V1, and 2001.745.V1	339.7	0	261	119	140

**Table 4.11 Monthly actual water use within the Obelisk catchment**

Consent No.	Monthly consented (m <sup>3</sup> )	Monthly actual use (m <sup>3</sup> ) for 2014/15 irrigation season						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
2008.330.V1, 2008.329.V1, and 2001.745.V1	887,090	12,811	211,357	444,281	479,651	417,614	408,723	197,280

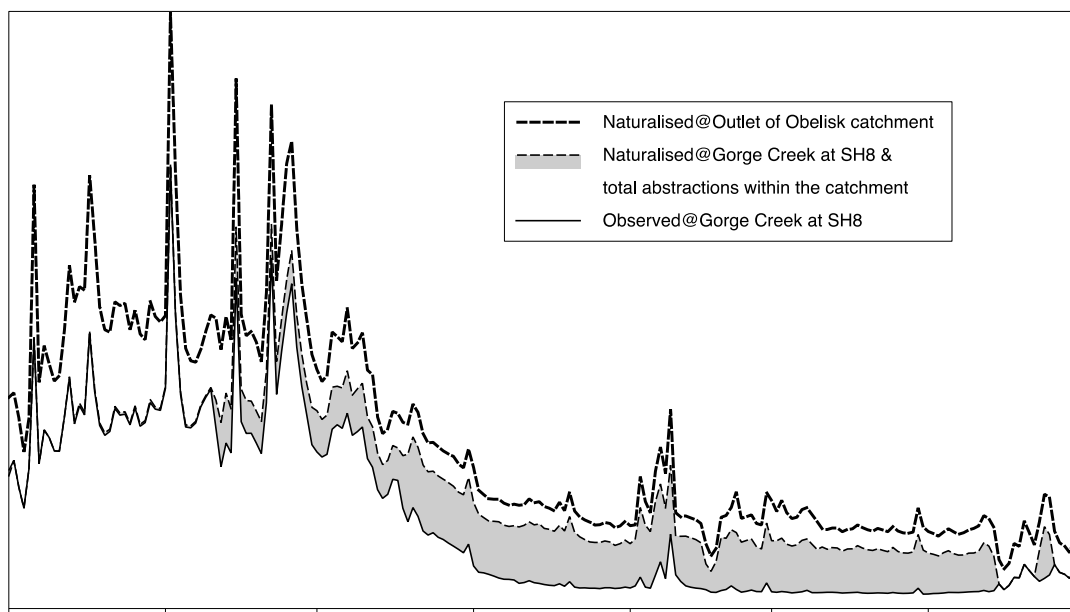
The instantaneous rate of abstractions within the Obelisk catchment is illustrated in Figure 4.9.



**Figure 4.9** Instantaneous rates of takes within the Obelisk catchment

#### 4.4.2. Naturalised flows

The flow site at the confluence of Obelisk and Coal Creeks at SH8 recorded 'natural' flows at this location, as there were no upstream water abstractions during the 2014/15 irrigation season. The naturalised flows at Gorge Creek at SH8 were estimated by adding all the upstream water takes to its actual flows, while the naturalised flows at the Obelisk catchment outlet were calculated from the estimated naturalised flows at Gorge Creek at SH8 by the combined ratio method for the irrigation season. The naturalised 7dMALFs within the Obelisk catchment were calculated from the estimated naturalised 7dMALF at Pomahaka at Glenken (listed in Table 4.12). Figure 4.10 shows the hydrographs of both actual and estimated naturalised flows in the catchment for the 2014/15 irrigation season.



**Figure 4.10** Hydrographs of actual and estimated naturalised flows in the Obelisk catchment during the 2014/15 irrigation season

**Table 4.12** Daily average flow statistics within the Obelisk catchment

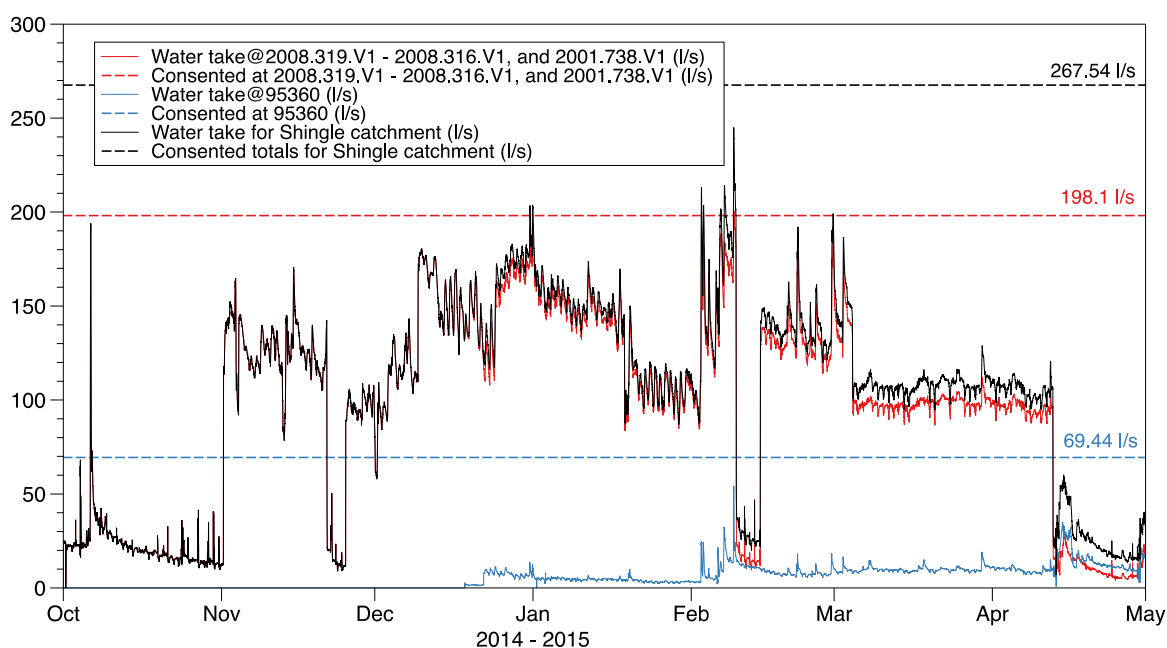
Location		Confluence of Obelisk and Coal Creek at SH8	Gorge Creek at SH8		Obelisk catchment outlet
Type		Actual	Actual	Naturalised	Naturalised
2014/15 irrigation season	Min (l/s)	28	48	63	133
	Max (l/s)	397	1480	1487	2041
	Mean (l/s)	87	297	415	566
	Median (l/s)	52	112	286	366
	7dLF (l/s)	28	51	99	200
7dMALF (l/s)		----	----	49 ~ 52	97 ~ 103

## 4.5. Shingle Creek

Shingle Creek has a catchment area of 35 km<sup>2</sup> with an MAP of 685 mm/year. The total consented monthly allocation within the catchment is 663,365 m<sup>3</sup>.

### 4.5.1. Water use

Six water abstractions are located within the Shingle catchment, of which the water abstractions under consents 2008.316.V1 – 2008.319.V1 were measured together. Figure 4.11 shows all the instantaneous water abstractions within the catchment, and Table 4.13 lists the consented allocations and the statistics of these daily average water abstractions during the 2014/15 irrigation season. The monthly actual water use within the catchment is summarised in Table 4.14.



**Figure 4.11** Instantaneous rates of take within the Shingle catchment

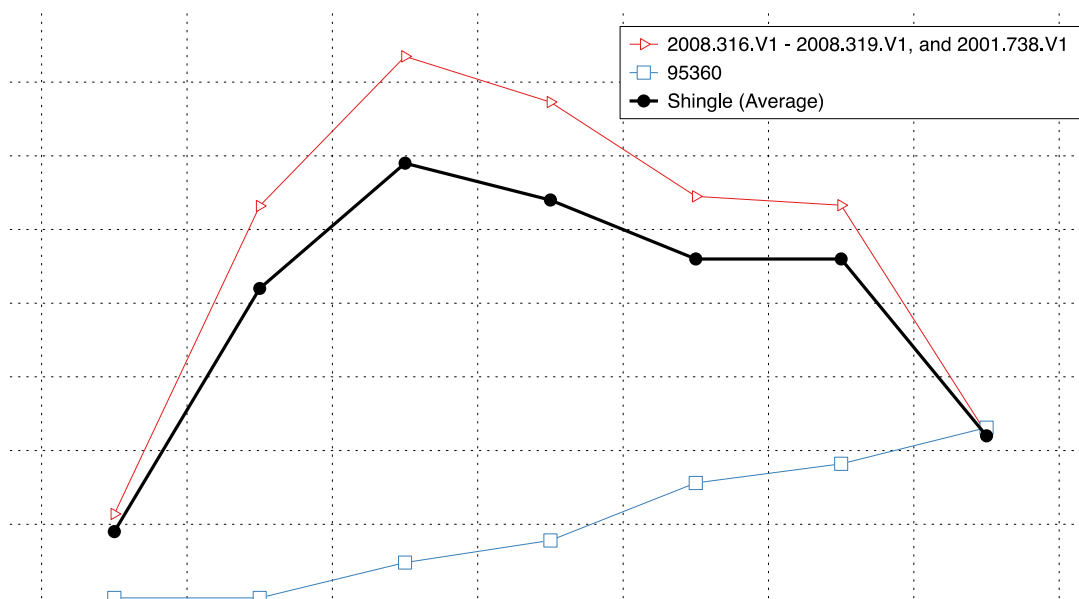
**Table 4.13** Consented rates of take and statistics of the daily average actual water use within the Shingle catchment

Consent No.	Maximum consented instantaneous rate (l/s)	2014/15 actual use (daily average)			
		Min (l/s)	Max (l/s)	Mean (l/s)	Median (l/s)
2008.316.V1 - 2008.319.V1, and 2001.738.V1	198.1	5	178	95	101
95360	69.44	0	34	6	5
Total	267.54	12	189	100	109

**Table 4.14 Monthly actual water use within the Shingle catchment**

Consent No.	Monthly consented (m <sup>3</sup> )	Monthly actual use (m <sup>3</sup> ) for 2014/15 irrigation season						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
2008.316.V1 - 2008.319.V1, and 2001.738.V1	518,365	59,066	275,542	381,224	348,930	282,690	276,030	115,446
95360	145,000	0	0	6,922	11,348	22,676	26,374	33,526
Total	663,365	59,066	275,542	388,147	360,278	305,366	302,403	148,972

Figure 4.12 shows the percentage of the consented monthly volume in the Shingle catchment that was actually used for the 2014/15 irrigation season.

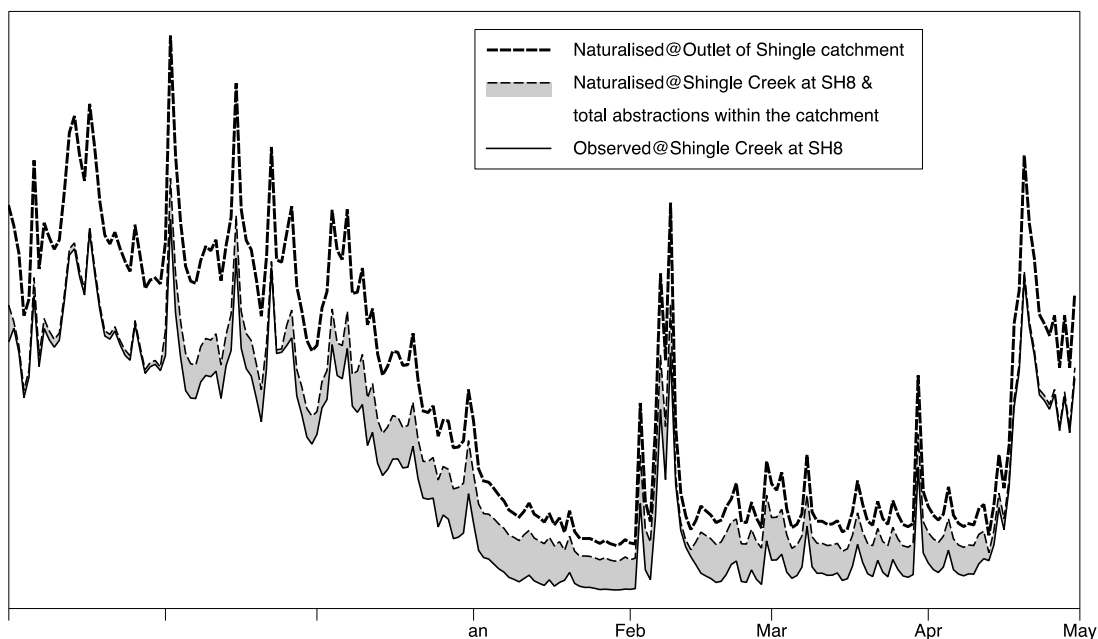


**Figure 4.12 Percentage of the consented monthly volume in the Shingle catchment that is actually used during the 2014/15 irrigation season**

#### 4.5.2. Naturalised flows

The naturalised flows at Shingle Creek at SH8 were estimated by adding all the water abstractions back to its actual recorded flows. The estimated naturalised flows for Shingle Creek at SH8 were then used as a reference for determining the naturalised flow time series at the catchment outlet by applying the combined ratio method (see Appendix). Figure 4.13 shows these hydrographs. Table 4.15 summarises the daily flow statistics during the 2014/15 irrigation season and the estimated naturalised 7dMALFs calculated from the estimated naturalised 7dMALF at Pomahaka at Glenken within the Shingle catchment.





**Figure 4.13** Hydrographs of the daily average actual and estimated naturalised flows in the Shingle catchment during the 2014/15 irrigation season

**Table 4.15** Daily average flow statistics within the Shingle catchment

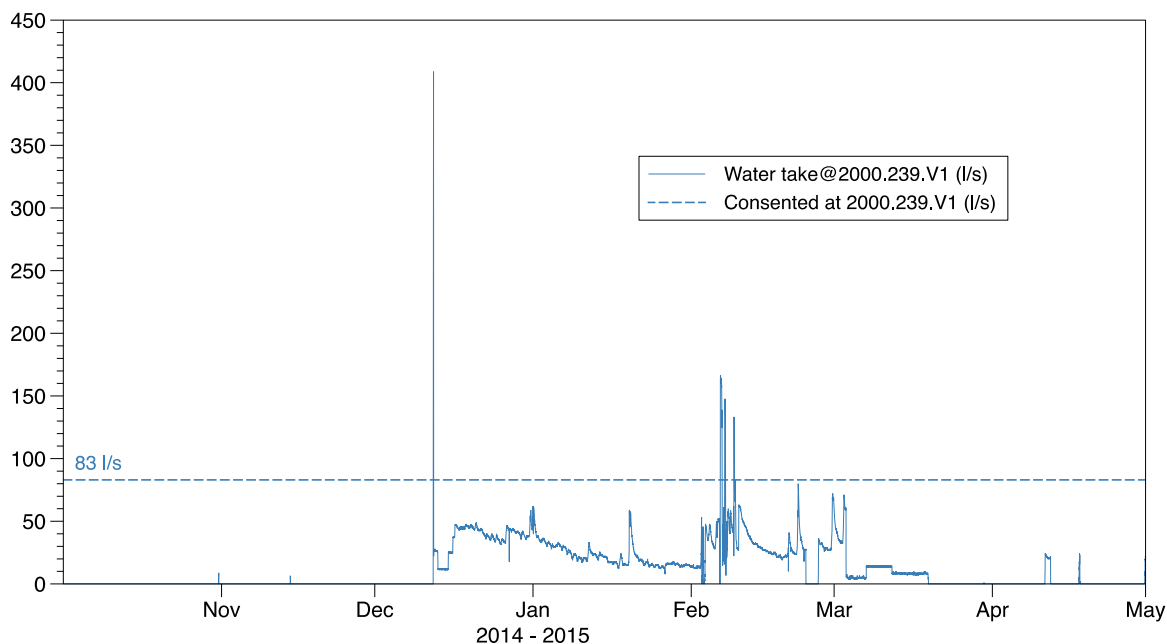
Location		Shingle Creek at SH8		Shingle catchment outlet
Type		Actual	Naturalised	Naturalised
2014/15 irrigation season	Min (l/s)	66	167	223
	Max (l/s)	1,369	1,515	2,025
	Mean (l/s)	474	575	768
	Median (l/s)	369	489	654
	7dLF (l/s)	67	172	230
7dMALF (l/s)		----	58 ~ 62	78 ~ 82

## 4.6. Elbow Creek

Elbow Creek has a catchment area of 11 km<sup>2</sup> with an MAP of 593 mm/year. The total consented monthly allocation within the catchment is 223200 m<sup>3</sup>.

### 4.6.1. Water use

There are two water abstractions from Elbow Creek. However, no metering data was available for consent 2000.366 (3.3 l/s), as the water metering regulations do not yet apply to takes below 5 l/s. Table 4.16 shows the statistics of daily average actual water use during the 2014/15 irrigation season for the only remaining consent in the Elbow catchment. The instantaneous rate of take within the Elbow catchment is shown in Figure 4.14.



**Figure 4.14** Instantaneous rates of takes within the Elbow catchment

**Table 4.16** Consented rate of take and statistics of the actual water use within the Elbow catchment during the 2014/15 irrigation season

Consent No.	Maximum consented instantaneous rate (l/s)	2014/15 actual use (daily average)			
		Min (l/s)	Max (l/s)	Mean (l/s)	Median (l/s)
2000.239.V1	83	0	78	12	0

Table 4.17 summarises the monthly actual water use within the catchment.

**Table 4.17** Monthly actual water use within the Elbow catchment

Consent No.	Monthly consented (m <sup>3</sup> )	Monthly actual use (m <sup>3</sup> ) for 2014/15 irrigation season						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
2000.239.V1	223,200	12	6	62,638	59,863	77,541	21,770	2,379

#### 4.6.2. Naturalised flows

Flows in Elbow Creek were not monitored. Therefore, the naturalised flows at the outlet of the Elbow catchment during the 2014/15 irrigation season can be determined by those that have been estimated from Shingle Creek at SH8 as the two catchments are geographically close. The 7dMALF at the outlet of the Elbow catchment can be determined from the naturalised flows from Pomahaka at Glenken by applying the combined ratio method (see Appendix). Table 4.18 summarises the daily statistics of the estimated naturalised flows during the 2014/15 irrigation season and the estimated naturalised 7dMALF at the outlet of the Elbow catchment.

**Table 4.18** Daily average flow statistics within the Elbow catchment

Location		Elbow Creek outlet
Type		Naturalised
2014/15 irrigation season	Min (l/s)	60
	Max (l/s)	543
	Mean (l/s)	206
	Median (l/s)	175
	7dLF (l/s)	62
7dMALF (l/s)		21 ~ 22

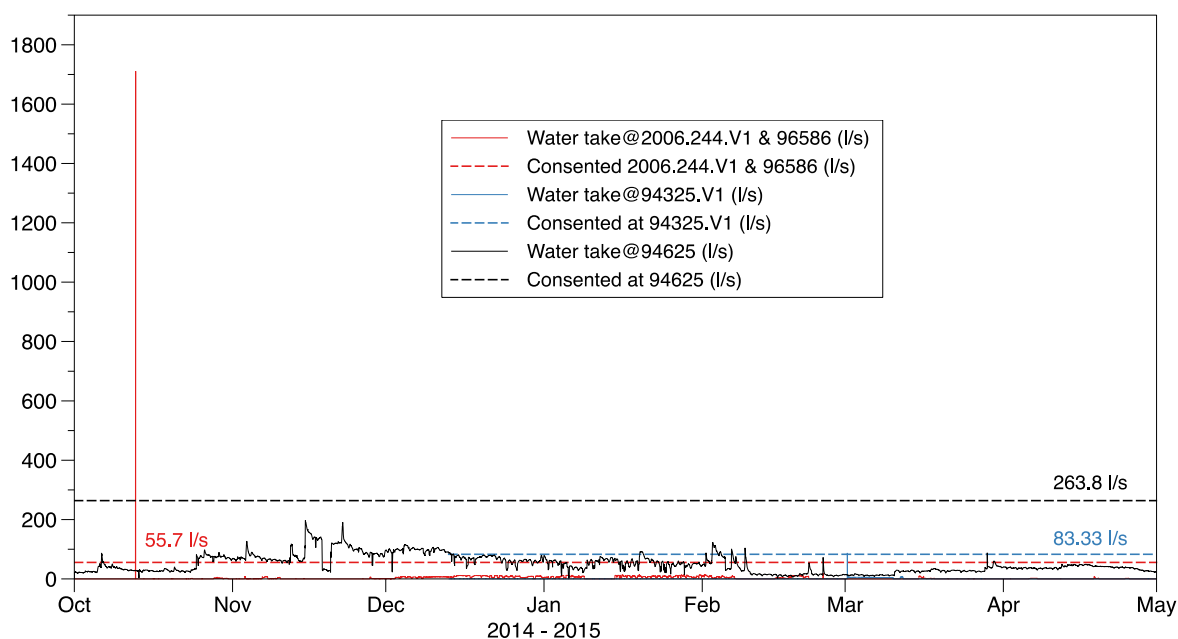
## 4.7. Coal Creek

The Coal Creek catchment has an area of 22 km<sup>2</sup> with an MAP of 643 mm/year. The total consented monthly allocation within the catchment is 1,519,755 m<sup>3</sup>.

### 4.7.1. Water use and naturalised flow

There are six water takes in the Coal Creek catchment. Water use data are not currently available for the consents WR1577R and WR1578R. Therefore, the combined ratio method (see Appendix) has to be used to estimate the naturalised flows at the catchment outlet based on the estimated naturalised flows at the Shingle Creek at SH8 (Section 4.5.2). Comparison of estimated naturalised and the actual flows provides an approximate estimate of the total water abstractions within the Coal catchment. The unknown water abstractions WR1577R and WR1578R can be further calculated by subtracting the known metered water use data from the estimated naturalised flows at the catchment outlet.

Figure 4.15 shows the available instantaneous water takes within the Coal catchment during the 2014/15 irrigation season. Table 4.19 shows the statistics of the daily average actual and naturalised flows during the 2014/15 irrigation season, and the estimated naturalised 7dMALF at the catchment outlet. Table 4.20 lists the statistics of the actual and estimated (WR1577R and WR1578R) water use during the 2014/15 irrigation season for the Coal catchment. The monthly actual water use within the catchment is summarised in Table 4.21.



**Figure 4.15** Instantaneous rates of takes in the Coal catchment for the 2014/15 irrigation season

**Table 4.19** Daily average flow statistics at Coal Creek at SH8 (catchment outlet)

Location		Coal Creek at SH8 (catchment outlet)	
Type		Actual	Naturalised
2014/15 irrigation season	Min (l/s)	48	134
	Max (l/s)	1303	1322
	Mean (l/s)	227	469
	Median (l/s)	143	403
	7dLF (l/s)	52	139
7dMALF (l/s)		----	47 ~ 50

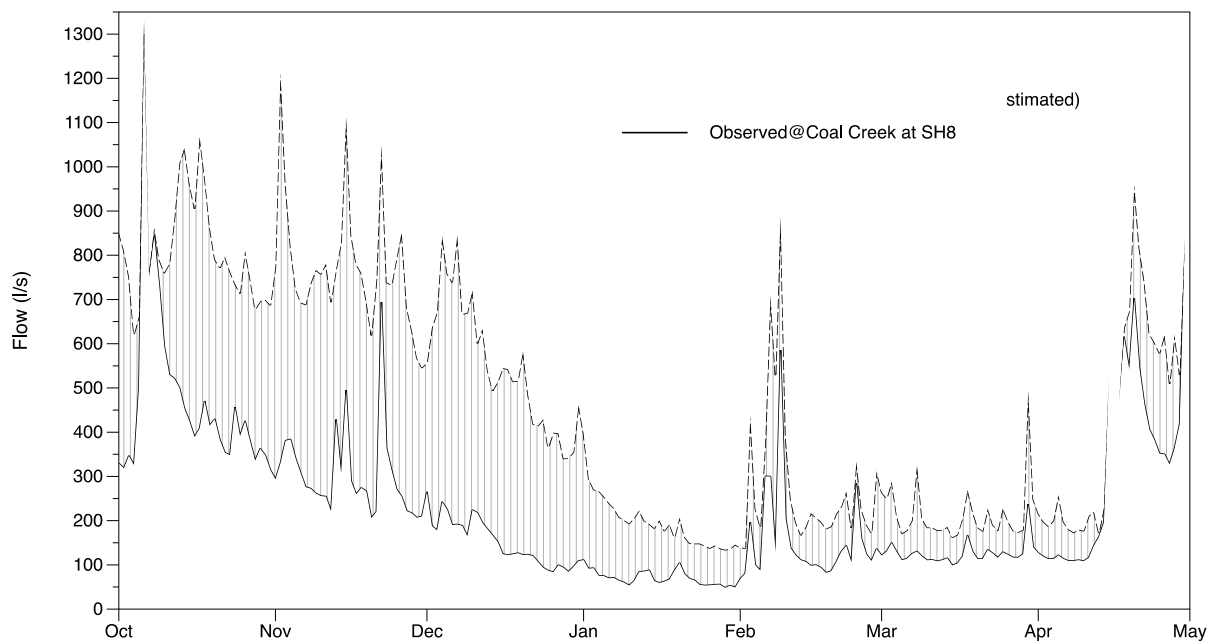
**Table 4.20** Statistics of actual and estimated (WR1577R and WR1578R) water use during the 2014/15 irrigation season in the Coal catchment

Consent No.	Maximum consented instantaneous rate (l/s)	2014/15 actual use (daily average)			
		Min (l/s)	Max (l/s)	Mean (l/s)	Median (l/s)
2006.244.V1 96586	55.7	0	18	3	0
94325.V1	83.33	0	6	0	0
94625	263.8	10	153	50	44
WR1577R WR1578R	222.22	0	883*	240*	174*
Total water use (estimated*)	625.05	0	883*	242*	179*

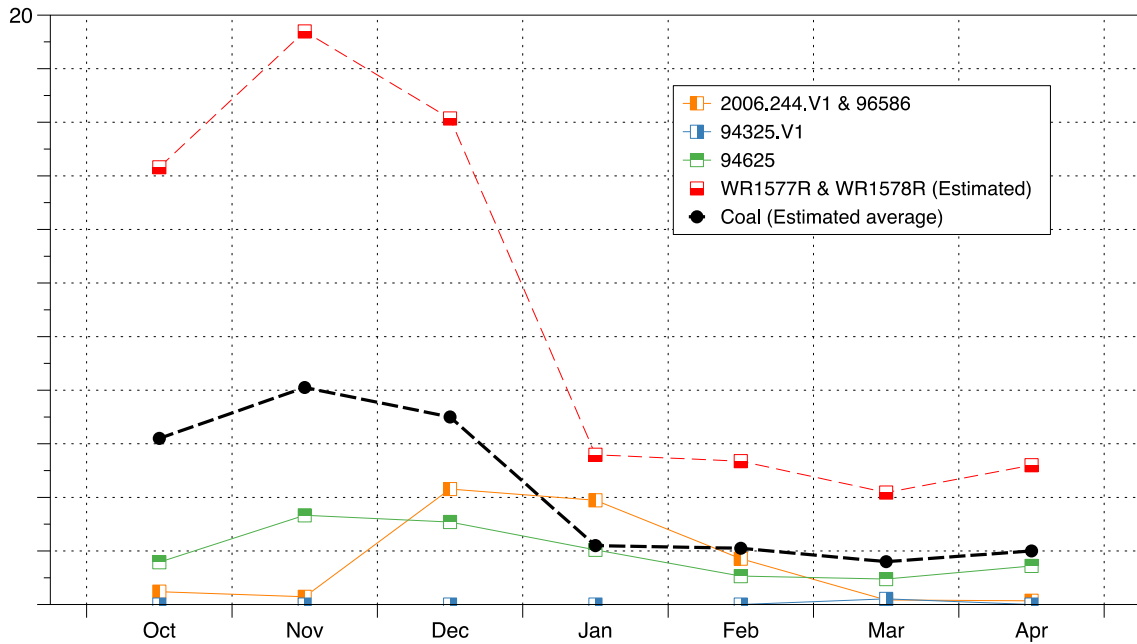
**Table 4.21 Monthly actual water use within the Coal catchment**

Consent No.	Monthly consented (m <sup>3</sup> )	Monthly actual use (m <sup>3</sup> ) for 2014/15 irrigation season						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr
2006.244.V1 96586	44,000	2,104	1,270	18,947	17,098	7512	753	612
94325.V1	215,991	0	0	15	25	8	4,451	4
94625	683,770	107,750	227,737	210,286	139,812	72,203	65,278	98,725
WR1577R WR1578R	575,994	939,891*	1,232,176*	1,045,022*	321,753*	308,339*	240,971*	299,669*
Total water use (estimated*)	1,519,755	1,049,745*	1,461,183*	1,274,269*	478,688*	388,061*	311,454*	399,010*

Figure 4.16 shows the hydrographs of the actual and the estimated naturalised flows at the catchment outlet during the 2014/15 irrigation season, and Figure 4.17 illustrates the percentage of the consented monthly volume in the Coal catchment that is actually used for the 2014/15 irrigation season.



**Figure 4.16 Daily actual and estimated naturalised flows at the Coal catchment outlet**

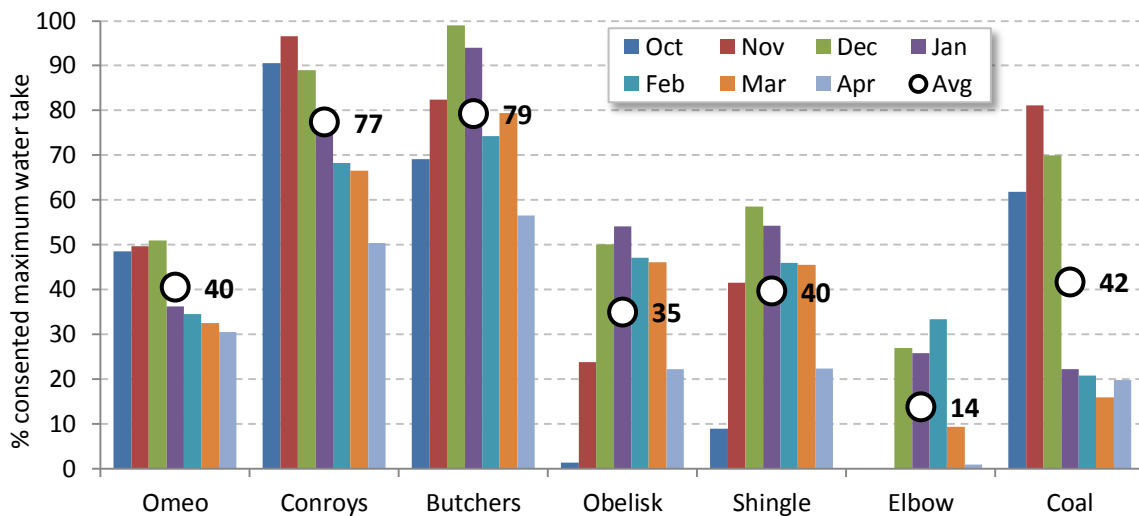


**Figure 4.17 Percentage of the consented monthly volume in the Coal catchment that is actually used for the 2014/15 irrigation season**

This estimation of total water abstractions of WR1577R and WR1578R might not be accurate, but the analysis does imply significant temporal variation of the abstractions during the 2014/15 irrigation season, with much greater water use between October and December 2014 compared with the rest of the irrigation season.

### 4.8. Summary of water use

Figure 4.18 illustrates how much water has been actually taken compared to the total consented allocations for each irrigation month.



**Figure 4.18 Percentage of the consented water take that is actually used during the 2014/15 irrigation months by catchment**

## 5. Conclusions

Where available, water take data and measurement of actual flows were used to estimate naturalised flows for seven catchments draining the Old Man and Obelisk Ranges. However, if either of these datasets were not available, the combined ratio method was used (see Appendix). The estimated naturalised 7dMALF at Pomahaka at Glenken was estimated based on a range of possible water use (10 ~ 50% total maximum consented rate of take), and this estimated naturalised 7dMALF used as a reference for the estimations of the naturalised 7dMALFs for key locations in the study area. The estimated 7dMALF for key locations in this study are summarised in Table 5.1.

**Table 5.1 Estimated naturalised 7dMALFs at the key locations for this study**

Catchment	Location	MAP (mm/y)	Estimated naturalised 7dMALF (l/s)
Omeo	Omeo at Fraser Dam	590	89 ~ 94
	Omeo catchment outlet	564	102 ~ 108
Conroys	Upstream of Conroys Dam	608	45 ~ 47
Butchers	Butchers Creek at Lye Bow Road	562	46 ~ 49
Obelisk	Gorge Creek at SH8	696	49 ~ 52
	Obelisk catchment outlet	620	97 ~ 103
Shingle	Shingle Creek at SH8	728	58 ~ 62
	Shingle catchment outlet	685	78 ~ 82
Elbow	Elbow Creek outlet	593	21 ~ 22
Coal	Coal Creek at SH8 (catchment outlet)	643	47 ~ 50
Pomahaka	Pomahaka at Glenken	885	2041 ~ 2164

Naturalised 7dMALFs in the study area were calculated from the estimated naturalised 7dMALF at Pomahaka at Glenken. The upstream catchment from Pomahaka at Glenken was the best reference catchment among the upstream catchments from all the available three mentioned flow recorders in Table 3.1, as it was most similar to those in the study area: it covers a similar elevation range, has similar vegetation and rainfall and is geographically close.

The flow recorder at Glenken does not measure the 'natural' flows. Metering data quantifying water abstractions across the period of available flows at Glenken were only available since April 2012. The short period of metering data may exclude very dry seasons and may bring uncertainties to the estimation in the naturalised 7dMALF at Glenken. Although the 2014/15 summer included in the analysis was a very dry year. Potential errors in the estimation of naturalised flows in the Pomahaka at Glenken will affect those calculated at key locations in the study area.

The hydrological information arising from this work will inform future water allocation work for these and nearby catchments as well as setting residual flows.

## 6. Glossary

**Catchment** – The area drained by a river or body of water

**7dLF (seven-day Low Flow)** – The lowest seven-day moving average flow over a specific period for a given location

**7dMALF (seven-day mean annual low flow)** – In any hydrological year, the 7-day low flow is the lowest average flow over 7 consecutive days for every 7 consecutive day period in the year. In this study, the irrigation season is applied instead of a hydrological year.

**Mean flow** – The average flow of a watercourse (i.e., the total volume of water measured divided by the number of sampling intervals)

**Median flow** – The ‘middle’ value of the whole flow records when they have been arranged in the order from the lowest to the highest

**Minimum flow** – The flow below which the holder of any resource consent to take water must cease taking water from that river

**Primary allocation** – The volume of water established under Policy 6.4.2 of the RPW that is able to be taken, subject to a primary allocation minimum flow

**Vegetation** – Plant cover, including trees, shrubs, plants or grasses

**Water abstraction** – The extraction of water from a water body (including aquifers). In this study, this refers to the consumptive surface water use only.



## 7. References

NZ Soils. 2015. Soils Of NZ: By New Zealand Classification. [online] Available at:

<http://www.nzsoils.org.nz/PageFiles/233/SoilsOfNZ%20By%20NZ%20Classification.pdf>

[Accessed: 21 Sep 2015].

## 8. Appendix

### Combined ratio method for flow naturalisation

To apply the combined ratio method, there are assumptions for the catchments in comparison:

- Catchments in comparison are reasonably hydrological comparable or similar, i.e., similar general annual rainfall.
- The total long-term annual rainfall (in volume) is proportional to its naturalised river flows at the catchment outlet.

Therefore, the naturalised flows at a point of interest can be estimated by using the naturalised flows at the outlet of another catchment which is hydrological similar.

Specifically, the steps described below can be followed:

- Use GIS application to identify the estimated long-term annual **median aerial precipitation (MAP)** between the successive isohyets (R), by multiplying its respective area (A), and the long-term rainfall in volume for the catchment can be found as  $[\sum_{i=1}^m (R_i A_i)]_I$
- Repeat the last step for a chosen catchment with naturalised flows available, to derive the long-term MAP in volume, which is  $[\sum_{j=1}^n (R_j A_j)]_{II}$
- Apply the mentioned assumption:

$$\frac{[\sum_{i=1}^m (R_i A_i)]_I}{(Flows@Outlet)_I} = \frac{[\sum_{j=1}^n (R_j A_j)]_{II}}{(Flows@Outlet)_{II}}$$

Therefore, the estimated long-term naturalised flow at Outlet of catchment<sub>II</sub> can be calculated as:

$$(Flows@Outlet)_{II} = (Flows@Outlet)_I \times \frac{[\sum_{j=1}^n (R_j A_j)]_{II}}{[\sum_{i=1}^m (R_i A_i)]_I}$$