

# **Ashburton River low flow regime – review and update**

**Report No. U04/20**

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**Report U04/20**

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## **Executive Summary**

The reason for this investigation and report was to address issues raised by Richard de Joux and John Young in regard to their report (de Joux, Young, 2002), and to answer questions raised at various public meetings in Ashburton regarding North Ashburton River flows.

The report details modifications made to data sets used to calculate natural Ashburton River flows. This resulted in minor changes to natural flow estimates.

It concludes that the:

- North Branch would flow continuously over its full reach if water abstractions ceased.
- Proposed minimum flows in the draft Natural Resources Regional Plan do not balance with the residual flow required at State Highway One.



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## 1 Introduction

The main impetus for carrying out this work is a review of 'Ashburton river low flow regime' (Horrell, 2001) carried out by Richard de Joux and John Young of 6th May 2002, and questions raised at various public meetings in Ashburton regarding North Ashburton River flows. This report updates and extends this earlier report.

Specific responses to the de Joux/Young review are included, additional analysis of natural flow regimes for spring fed tributaries of the North Branch of the Ashburton River is presented, while other abstractions from the groundwater resource adjacent to the Ashburton River are also discussed. Estimates of natural flows are provided for comparison with the 2001 results.

This report should be read in conjunction with the previous report (U01/26).

## 2 Natural river flow state

Changes have occurred to the natural flow regime, which are impossible to infer using simple spot gaugings (flow measurements) of river flows and abstractions. The overall flow regime of the tributaries and mainstem has changed forever. For example, with the draining of swamps (mainly in the 19<sup>th</sup> Century) flood peaks will be higher nowadays with lower flows in summer, as previously swamps acted as buffers storing water and releasing it later. The analysis makes no attempt to model these effects. Furthermore, modelling of natural flows also makes no allowance for willow planting or the straightening of channels. Rather, it is simply an attempt to infer what flows we would see in the tributaries and mainstem today if no abstractions occurred.

## 3 Review of natural flow regime

Two assumptions were made about how to account for irrigation takes when considering irrigation abstraction usage. **Firstly it was assumed that the irrigation season ran from 1 September to 30 April and that outside those dates no irrigation water was abstracted. Secondly that during the irrigation season 55% of the consented abstraction volume was being taken.** These assumptions cut out the enormous task of measuring all takes, but add uncertainty to the analysis. There is some basis for selecting 55% as follows. Sanders (1998) looked at the 1997/98 summer for Ashburton District (between the Rakaia and Rangitata Rivers) and compared the estimated groundwater pumpage for irrigation using power consumption figures to the consented allocation, for a 120-day, or half irrigation, season. Results showed that on a regional scale (Ashburton District) the estimated total abstraction for the whole season was equal to 55% of the volume that would be pumped in 120 days if all the consented takes were using their average allocation.

This review alters previous data sets used to construct natural flows by:

- considering that ungauged abstractions occurred at average rates, rather than maximum consented rates (55% of abstraction still applied)
- allowing for reduced abstraction on occasions of restrictions (only consents with minimum flows)
- revising consent abstraction information
- reviewing consent locations
- removing abstractions which do not permanently take water (Salmon farm)
- including omitted abstractions

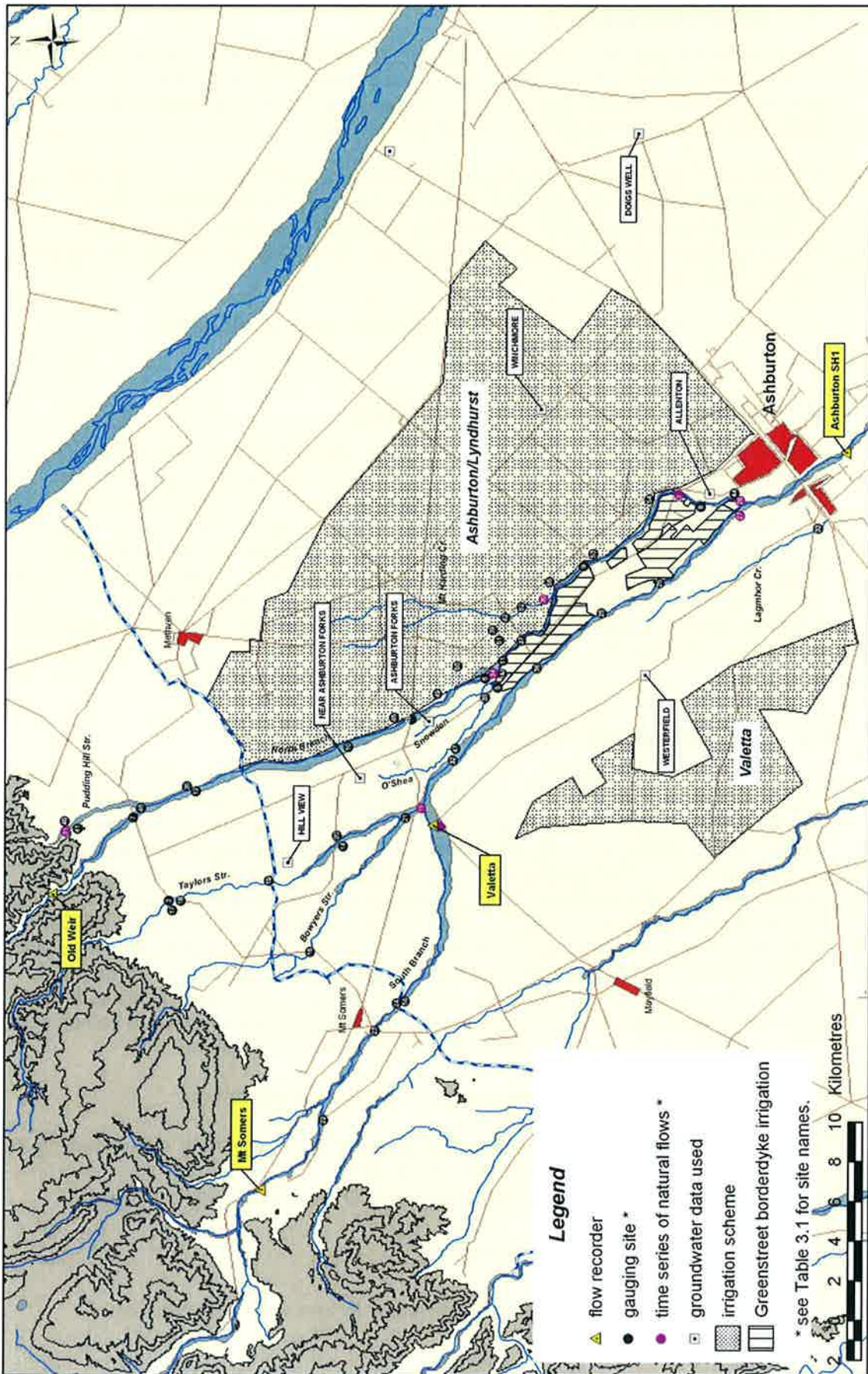


Figure 3.1 Location of hydrological sites

**Table 3.1 List of gauging sites (refer Figure 3.1)**

Gauging Site Reference No.	Gauging Site	Map Reference	Gauging Site Reference No.	Gauging Site	Map Reference
1	Greenstreet Irr Scheme @ Main Race	K36:988140	29	Ashburton River @ Above Lagoon (2km u/s)	L37:138856
2	Main Race @ Staffgauge (m)	K36:988140	30	Mt Harding Creek @ Aitkens Road	K36:026118
3	Taylor's Stream @ No. 72 SH	K36:873307	31	Pudding Hill Stream @ Above ADC Race	K36:908358
4	Ashburton River @ No.1 SHB	K37:087990	32	Greenstreet Irr Scheme @ Below Sth Ashburton Intake	K36:944165
5	O'Shea Creek @ Above Greenstreet Pond	K36:983143	33	Laghmor Creek @ Frasers Road	K37:062982
6	Snowdens Creek @ Above Greenstreet Pond	K36:984143	34	O'Shea Creek @ Bywash to Nth Ashburton	K36:985143
7	Nth Ashburton @ SH72	K36:915325	35	Methven Auxiliary @ Nth Ashburton	K36:932296
8	Spring Stream @ Rawles Crossing Rd	K37:073040	36	Sth Ashburton River @ Shearers Road	K36:991122
9	Nth Ashburton @ Ollivers Road	K37:045097	37	Nth Ashburton @ Shearers Road	K36:005130
10	Nth Ashburton @ Flemings Road	K36:951217	38	O'Shea Creek @ Ashburton/Staveley Road	K36:976148
11	Nth Ashburton @ Above Osheas Confl	K36:994140	39	Winchmore Main Race Take @ Mt Harding Creek	K36:009143
12	North Ashburton @ Below Methven Auxiliary	K36:930298	40	ADC W/Race @ Pudding Hill Stream	K36:908359
13	Ashburton @ Smalls Rd	L37:123890	41	Pudding Hill Stream @ Below ADC Race	K36:908358
14	Taylor's Stream @ Roxburgh Bridge	K36:902222	42	Mt Harding Creek @ Rakaia Gorge Rd	K36:016136
15	Taylor's Stream @ Above Sth Ashburton Confluence	K36:920179	43	Nth Ashburton @ Digbys Bridge	K37:079051
16	Bowyers Stream @ No. 72 SH	K36:847236	44	RDR Coniston Race @ Nth Ashburton	K37:077022
17	ADC @ Durrans Tce Stock W/Race	K36:873307	45	RDR Waste Race @ Lateral 1A	K36:966194
18	ADC @ Bushside Stock W/Race	K36:873301	46	Pudding Hill Stream @ Nth Ashburton Confluence	K36:920321
19	ADC @ Goughs Crossing Stock W/Race	K36:883257	47	Greenstreet Irr Scheme @ Below Shutoff Gate	K36:947165
20	Alford Station @ Irrigation Intake	K36:904222	48	North Ashburton @ Thompsons Track	K36:965185
21	Frank MacAtamney @ Irrigation Intake	K36:917189	49	RDR Waste Race @ Lateral 1B	K36:978172
22	Lincoln W/Race @ Intake	K36:754232	50	RDR Waste Race @ Lateral 2	K36:992162
23	Sth Ashburton River @ No.72 SH	K36:807203	51	RDR Waste Race @ Lateral 3	K36:005141
24	RDR Intake @ Sth Ashburton Siphon	K36:820193	52	RDR Waste Race @ Lateral 5	K36:022130
25	Sth Ashburton River @ Ollivers Road	K37:019090	53	RDR Waste Race @ Lateral 8	K37:046095
26	Sth Ashburton River @ Blacks Road	K37:033063	54	RDR Waste Race @ Lateral 9	K37:077066
27	Sth Ashburton River @ Above Confluence	K37:074017	55	RDR Waste Race @ Lateral 7	K36:035116
28	Nth Ashburton River @ Above Confluence	K37:076020	56	Sth Ashburton River @ Below RDR intake	K36:821192

Flow Recorder Site (also gauging site)	Map Reference
North Ashburton River @ Old Weir	K36:876366
South Ashburton River @ Mt Somers	K36:726261
South Ashburton River @ Valetta Bridge	K36:915174
Ashburton River @ No.1 SHB (Recorder)	K37:099967

Well number	Groundwater site	Map Reference
L36/0948	Winchmore	L36:123115
K36/0044	Ashburton Forks	K36:959173
K36/0051	Hill View	K36:913221
K37/0215	Westerfield	K37:978057
K37/0396	Allenton	K37:079037
K36/0045	Near Ashburton Forks	K36:937210
L37/0024	Doigs Well	L37:261071

3176001  
3175001

- including all groundwater abstractions calculated to be hydraulically connected to a surface water resource.
- allowing for stockwater bywash from Ashburton District Council, Water Ranger estimates

Further explanation of the methodology used for reconstructing natural flows from (Horrell, 2001) is included in Appendix 3.

### 3.1 Natural flow record for the South Branch at Valetta

This data set was revised and the details are shown in Appendix 1. Six modifications were applied;

- corrected location removed one consent (CRC921562),
- ungauged irrigation abstractions had an assumption of 55% use applied to their average consented rate.
- one small groundwater abstraction with a calculated depletion rate was included (CRC921499).
- two dates within the data set occurred when 50% restrictions applied (4/2/1998 and 5/3/1998)
- calculation of additional South Branch channel losses to the groundwater system if natural flows occurred was made downstream of the RDR intake, (explained in detail below).
- allowance for stock water bywash

An adjustment was made for a higher contribution by the South Branch to the groundwater system between the RDR intake and Valetta (Figure 3.1, Table 3.1) for natural flow calculation. This adjustment assumes that if the flows are higher through this reach then the losses to the groundwater system also increase. This adjustment was not proven against a range of groundwater situations, for example where the groundwater is high and the flows are low then these losses may reduce to the extent that there is an overall gain to the river. However, no measurements exist to support this but with the belief that this reach of river always loses water, an adjustment has been carried out. These adjustments are based upon an analysis completed by Richard de Joux (de Joux, 2003).

The 2001 analysis allowed for losses within this reach for residual modified flows only. The updates in this review allow for additional losses if the abstracted water was also flowing in the reach.

**Table 3.2 Results of changes to natural flow estimations at Valetta (m<sup>3</sup> s<sup>-1</sup>)**

Analysis	2001	2003
Mean flow	10.52	9.90
Median flow	8.59	8.08
7DMALF	4.48	4.21

#### 3.1.1 Comments from Richard de Joux/ John Young review (attached as Appendix 2)

Type in **red** is from the de Joux/Young review

“For the South Ashburton reach between Mt Somers recorder and Valetta Bridge the analysis attempts to account for abstractions either by direct measurement (eg RDR abstraction and ADC Sth Ashburton Main intake) or by assuming 55% of the authorised abstractions (this was applied even when irrigation restrictions were imposed, eg 07/04/98, 29/04/98, 01/02/99).”

De Joux and Young imply that no account of restrictions was taken. Consents monitoring staff records have been checked and there was no total restriction on 7/04/98. Further supporting evidence is the gauged abstraction of RDR at the intake of 4,102 l/s on the same day. On the morning of the 29/04/98 a restriction was lifted, so no restriction applied. This is also verified by RDR abstraction of 2,784 l/s. Furthermore, on the morning of 1/02/99 the restriction was lifted and RDR was measured at 3,884 l/s.

According to our consents monitoring staff no restrictions occurred on any of those days in the Ashburton Catchment.

However, on the 4/02/98 and 5/03/98 they were at 50 % restriction and the revised data set accounts for this.

“However, no attempt is made to account for the inflows from both Woolshed Creek and Stony Creek, which have a combined inflow in excess of all of the consented abstractions apart from RDR and ADC.”

These inflows are accounted for, as they are part of the residual flow measured at Valetta. If their inflow did not exist the residual at Valetta would reflect this.

“The analysis fails to make allowance for the considerable losses to groundwater between the RDR and the Valetta Bridge, and merely assumes that the total flow rate of all of the upstream abstractions would occur at Valetta under “natural” conditions.”

Previous analysis allowed for losses to groundwater for the residual flows measured, but not for the elevated natural flows.

De Joux provided information in his evidence for the February 2003 RDR consents hearing, which describes how the reach between the RDR intake and the Valetta Bridge loses water.

The South Ashburton River flow recharge to groundwater between RDR intake and Valetta Bridge was calculated using the de Joux equation below and then differencing the RDR intake flow from Valetta Bridge.

$$\text{Valetta} = \text{South Ashburton flow at RDR intake} \times .9359 - 800$$

*RDR intake = Valetta + 800 ÷ .9359*

Calculations of recharge to groundwater above Valetta, for given flows in the South Ashburton at the RDR intake are given in Table 3.3.

This has proved valuable in assessing what the losses between the RDR intake and Valetta Bridge would be with raised natural flows described in 3.1 above.

**Table 3.3 Recharge to groundwater above Valetta**

South Ashburton flow at RDR intake (l s <sup>-1</sup> )	Groundwater recharge to Valetta Bridge (l s <sup>-1</sup> )
1000	864
2000	929
3000	993
4000	1057
5000	1121
6000	1185
7000	1249
8000	1313
9000	1377
10000	1441
15000	1762

The above calculations allow estimation of how much water would be lost between these two locations if the abstractions had remained in the river. Table 3.3 compares initial natural flow estimates made by Horrell in 2001, with new natural estimates which include consent and averaging adjustments (3.1), and accounting for losses to groundwater that are estimated to occur at elevated natural flows.

**Table 33A Estimated natural South Branch flows at Valetta (l s-1)**

Date	Horrell (2001)	Horrell (2003) (de Joux adjustment)
4/02/98	5369	5037
26/02/98	6124	5722
5/03/98	4024	3778
17/03/98	7749	7279
26/03/98	5536	5144
7/04/98	6816	6373
29/04/98	7744	7386
15/05/98	4348	4097
24/06/98	4890	4642
5/10/98	9322	8779
9/12/98	9085	8521
1/02/99	7544	7113

The majority of the difference between the two estimates is the additional losses to groundwater when accounting for elevated natural flows. Approximately 86 l s<sup>-1</sup> comes from the consent and averaging adjustments mentioned in 3.1.

*“The comment is made in section 2.1.1 that “in winter the natural record matches closely to that actually recorded”. This comment raises concerns over the validity of the methodology and assumptions used, because the only difference between “winter” and “summer” demand is 124 l/s attributed to irrigation season abstractions (table 1, appendix 2) . Given the relatively small irrigation demand of 124 l/s, there is no reason why the “natural” flow relation should provide a better prediction of winter flows than summer ones.”*

De Joux and Young are correct. This comment was loosely referring to September, October 1995 and part of April and May 1996. Upon reflection the natural record matches closely to that actually recorded, during periods of RDR shutdown (for maintenance) (John Young per coms). It is interesting that the month of May 1996 in de Joux's evidence (RDR hearing)

showed no RDR abstraction at all. This is a period when estimated natural flows match closely to actual recorded flows at Valetta.

### 3.2 Natural flow record for Taylors Stream at the South Ashburton confluence

This data set was revised and the details are shown in Appendix 1. Three changes were applied to this data set;

- (i) corrected location of one abstraction added to the data set (SCY710047),
- (ii) four dates in the data set were when 50% restrictions was applied, 5/4/1995, 19/4/1995, 4/2/1998 and 5/3/1998
- (iii) allowance for stock water bywash

The ungauged irrigation abstractions sum to  $37 \text{ l s}^{-1}$  with the 55% reduction and 50 % restriction reducing the likely irrigation abstraction to a maximum of  $20 \text{ l s}^{-1}$  and minimum  $10 \text{ l s}^{-1}$ . Furthermore with the inclusion of an unaccounted stockwater abstraction of  $42 \text{ l s}^{-1}$  resulted in, little difference compared to the 2001 analysis.

**Table 3.4 Results of changes to natural flow estimations at Taylors Stream at South Ashburton confluence ( $\text{m}^3 \text{ s}^{-1}$ ).**

Analysis	2001	2003
Mean flow	4.05	4.07
Median flow	2.90	2.93
7DMALF	1.05	1.08

#### 3.2.1 Comments from Richard de Joux / John Young review (attached as Appendix 2)

“The analyses used for Taylors and Bowyers Streams introduce an additional source of data error and uncertainty by attempting to derive a relation between those tributaries, depths to groundwater at Hill View and the flow in the North Ashburton. While the report recognises that this approach introduces errors in the analysis, there is no attempt to modify the results obtained from the analysis.”

Ideally a seventeen-year record of flows below the confluence of Bowyers and Taylors Streams would have been a most useful record to base this analysis upon. However, there was no such record, nor was there a record of these individual streams measured at their gorges. Therefore the only method left was to compare spot gaugings at Taylors above the South Ashburton confluence (which includes Bowyers) with recorded flows from the only continually measured Ashburton tributaries; South Ashburton at Mt Somers and North Branch at Old Weir. The North Branch showed a better correlation with the Taylors site probably because of its similar aspect and vicinity. Like Taylors and Bowyers Streams, the North Ashburton catchment receives more frontal rainfall from the south than the South Ashburton catchment, whereas the South Ashburton catchment is more influenced by nor' west rain.

Including the groundwater records at Hill View (well number K36/0051) in the regression improved the relationship, although the resulting  $r^2$  of 0.84 is not high. No other useful data was available to improve this relationship.

It is not appropriate to use a relatively short period of recent groundwater data for the purposes of predicting a longer-term natural flow. The report refers to the significant amount of wetlands within Bowyers and Taylors Stream that have been drained since 1980. It is reasonable to expect that this drainage has also affected depths to groundwater within the

area, and to also have affected the previous relation between the depth to groundwater and surface water flow.

The length of record from Hill View is 55 years from 1947 to the present. It is appropriate to use this in this analysis for the development of a 17 year period of natural flows from 1982 to 1999.

The groundwater/ surface flow relationship will have changed with the draining of swamps since the 1980's. However the 1800's drainage was probably more significant. These relationships have changed, but from an initial state which is unknown so therefore no corrections can be made. However, Hill View is to the east of Taylors Stream and away from the effects of recent swamp drainage in Bowyers Stream. Further analysis of Hill View shows response to rainfall recharge and downslope groundwater movement, rather than river flows (R Sanders pers com) which perhaps makes it more suitable for use in the regression analysis.

### 3.3 Natural flow record for the South Ashburton at North Branch confluence

This data set was revised and the details are shown in Appendix 1. Five modifications were applied to this data set

- (i) one stockwater take added (CRC980746)
- (ii) ungauged irrigation abstractions had an assumption of 55% use applied to their average consented rate.
- (iii) two small groundwater abstractions with a calculated depletion rate were included (CRC921550D, CRC921550E)
- (iv) 50% restriction applied on two occasions, 4/12/1998 and 5/3/1998
- (v) allowance for stock water bywash

**Table 3.5 Results of changes to natural flow estimates at South Branch flow at North Ashburton confluence ( $m^3 s^{-1}$ ).**

Analysis	2001	2003
Mean flow	20.59	19.66
Median flow	16.76	15.96
7DMALF	9.72	9.17

### 3.4 Natural flow record for the North Ashburton at South Branch confluence

This data set was revised and the details are shown in Appendix 1. Six modifications were applied to this data set

- (i) four stockwater takes added (SCY690643, SCY710054 Sub Main, SCY690644 and SCY800153)
- (ii) one stockwater take removed (SCY710047)
- (iii) ungauged irrigation abstractions had an assumption of 55% use applied to their average consented rate.
- (iv) two surfacewater takes deleted as water is not actually removed from the river (CRC960065 and CRC990718)
- (v) restrictions applied on four occasions 4/2/1998, 5/3/1998, 20/1/1999 and 9/3/1999.
- (vi) allowance for stock water bywash.

### Analysis

When the natural flow data set was revised the simple linear relationship with Old Weir resulted in an adjusted  $r^2$  of only 0.69, this is a relatively poor result for modelling natural flows. Further analysis using groundwater level records by multi-linear regression improved this relationship to an  $r^2$  0.78.

The wells used included: Hill View K36/0051 and Near Ashburton Forks K36/0045. Hill View is between the North Branch and Taylors Stream. This well appears to represent the rainfall upon the plain and downslope movement of groundwater. It is independent of flows in the North Branch.

Near Ashburton Forks well represents the groundwater associated with the headwater springs of O'Shea and Snowden Creeks.

Once again a search for a long-term shallow groundwater well to the east of the North Branch proved fruitless. The long record (1974-1985 and 1998-2000) at Winchmore Research station was unsuitable due to artificial recharge by border dyke irrigation and the gap in recording from 1985 to 1998. A well near Chertsey on the Doig property was trialled as representative of the shallow groundwater to the east of the North Branch. This well has a long record. Its waterlevels are driven by rainfall recharge and despite a deep at approximately 60 metres and lack of influence from border dyke irrigation. However it is affected by pumping for spray irrigation. This well displays a sharp decline in water levels during November and December due to the onset of irrigation (refer to Figure 3.2). Waterlevels rise with rainfall recharge and downslope groundwater movement during the winter. Small rises within the irrigation season are displayed when it rains, a likely response to the short-term pause in groundwater pumping for irrigation.

It was of interest to use Doig's well within the North Branch data set for the calculation of a natural flow record. The multi-linear regression included wells to the west (described above) representing some parts of the groundwater system, while Doig's well to represent groundwater to the east, as well as the Old Weir flows. The regression gave an  $r^2$  of 0.87, the best model thus far to explain the flow variations in the North Branch.

However, testing for independence between all the variables revealed that the Old Weir flows and Doigs well were not independent, negating the result. Figure 3.3 shows mean monthly flows of the North Ashburton and levels at Doigs well to have a similar pattern. Upon close inspection they differ slightly, perhaps due to the decline in groundwater levels at the start of the irrigation season in the well. October flows are higher due to snowmelt in the North Branch. They both increase in winter due to the increase in runoff and recharge as rainfall exceeds evapotranspiration in the foothills and over the plains.

Due to this lack of independence, the Old Weir flows were removed from the data set and predictions made using the three groundwater wells resulted in an  $r^2$  is 0.85. This is an acceptable model. It supports earlier discussion that knowledge of the groundwater systems would enhance the model, even though only a small portion of the Ashburton groundwater systems are represented within this simplistic regression model.

Accordingly the early years of recordings at Doigs well have two gaps which when combined exceed four years. This analysis did not proceed, because an unbroken period of 17 years was required. M Ettema (ECan Groundwater Section) analysed the groundwater data at Doigs and constructed a data set for the missing period from a recording well nearby. The regression model was used for interest only and the results are shown in Table 3.6. For this analysis these values were not used, as it would be using synthetic data to produce a synthetic natural flow, which is not valid.

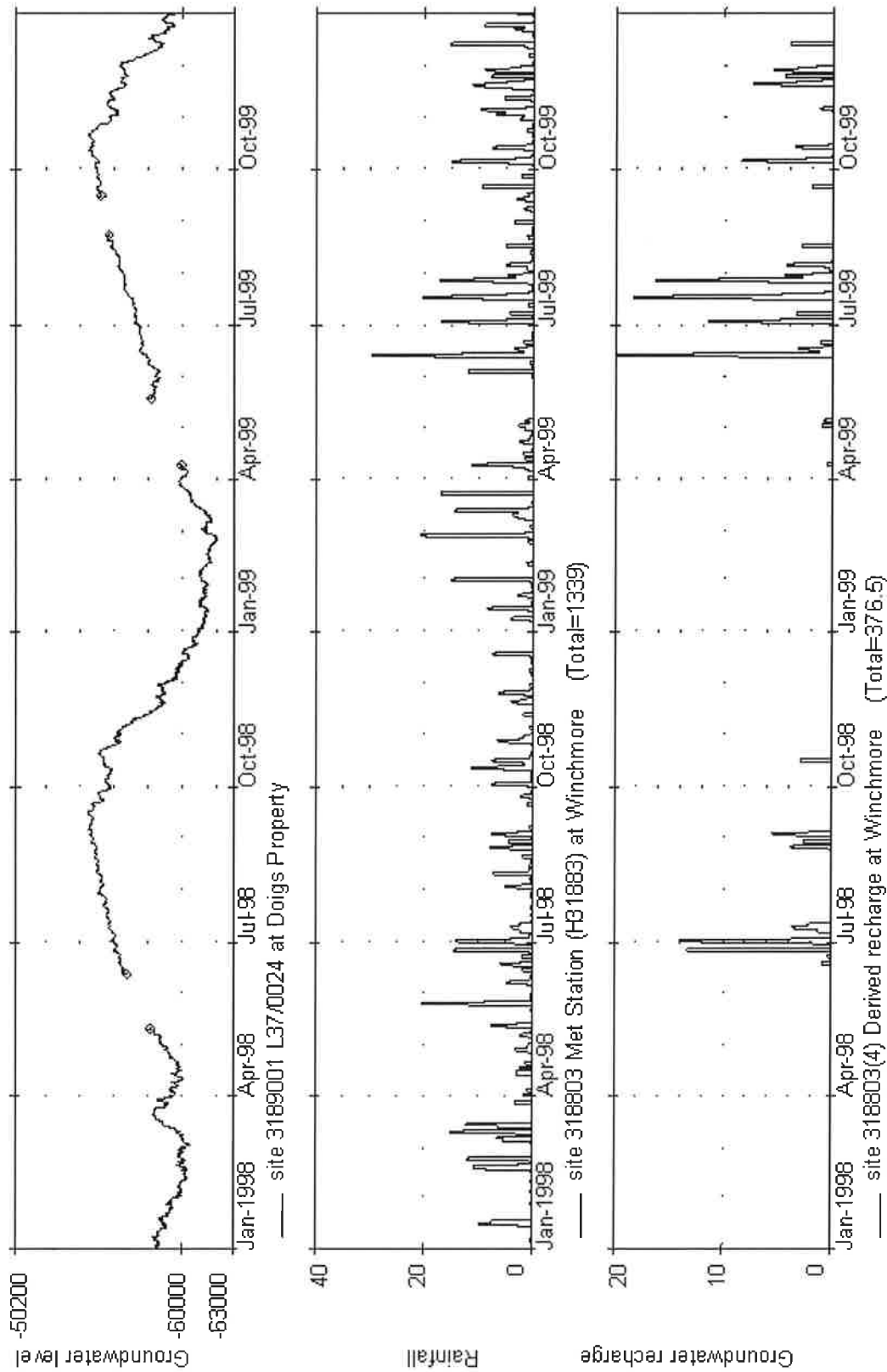


Figure 3.2 Comparison of groundwater level to rainfall and recharge

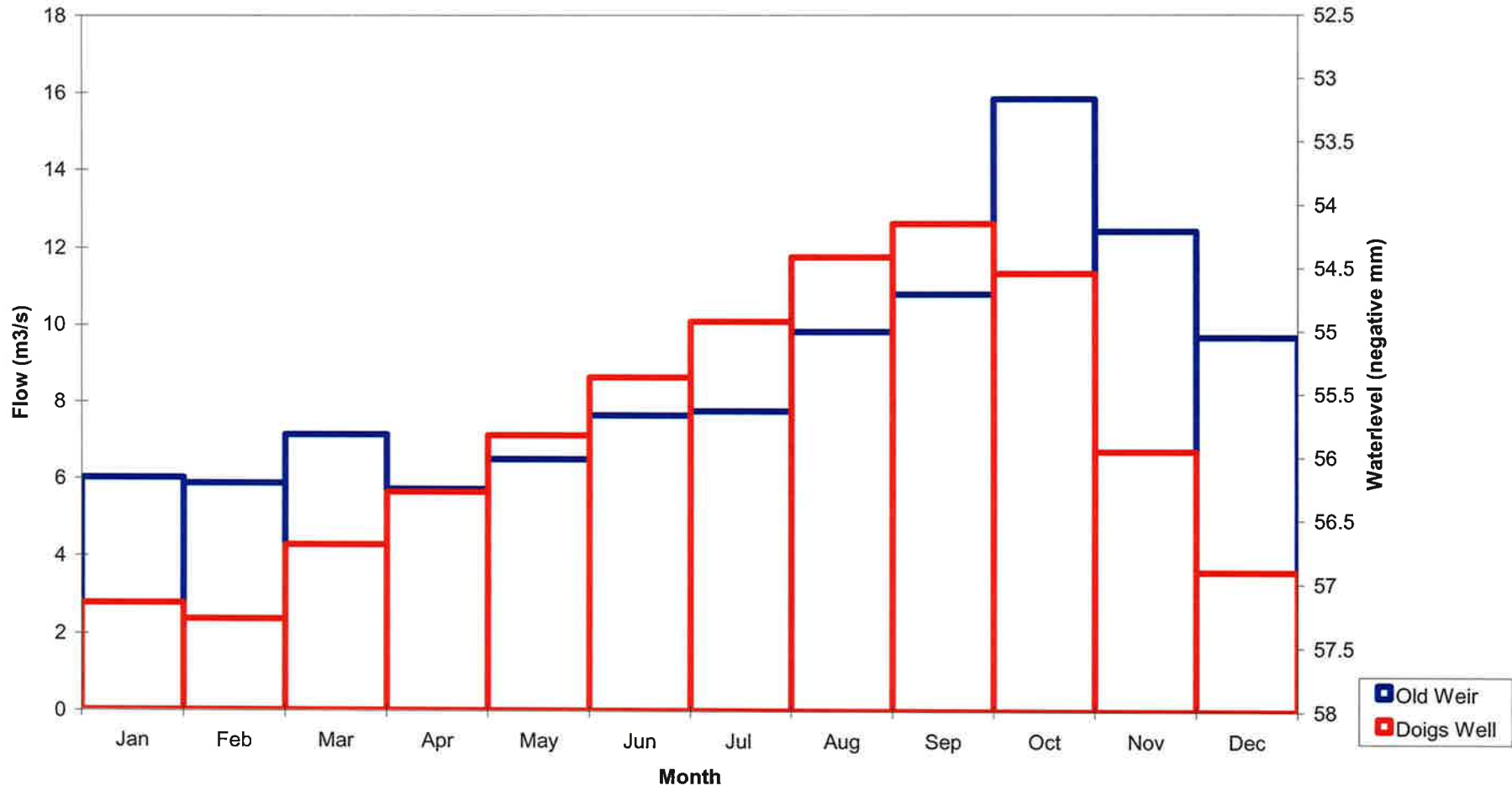


Figure 3.3 Comparison of mean monthly North Ashburton flow and groundwater levels in Doigs well

**Table 3.6 Results of changes to natural flow estimations at North Branch at South Ashburton confluence ( $\text{m}^3 \text{s}^{-1}$ )**

Analysis	2001 Old Weir	2003 Old Weir	2003 Old Weir and two wells *	2003 three wells (interest only)
R <sup>2</sup>	0.74	0.69	0.78	0.85
Mean flow	7.98	7.74	8.02	8.65
Median flow	5.57	5.24	5.62	6.58
7DMALF	3.69	3.30	3.87	4.51

\* Final model adopted

The final model adopted had Old Weir daily mean flows, and groundwater levels measured at Hill View and near Ashburton Forks as independent variables.

### 3.4.1 Comments from Richard de Joux / John Young review (attached as Appendix 2)

The North Ashburton River has a very complex hydrology, and this is adequately described and acknowledged in section 2.1.4.1 of the report. The acknowledgement in that section that the uncertainties over the hydrology detracts from the accuracy of the natural flow model are unfortunately not reinforced later in the report. No account has been taken of the fact that a significant portion of the flow in Mt Harding Creek is sourced from water outside the North Ashburton River (i.e. the water did not flow past the North Ashburton flow recorder site).

It is acknowledged that a portion of Mt Harding Stream did not flow past the Old Weir site. It is correct that some of this flow was not sourced as the dependent variable of this regression. The Taylors /Bowyers residual was also compared to the Old Weir flow but none of those flows went past the Old Weir recorder either. However the primary site Old Weir, gave the best model to represent the variation found at Taylors/ Bowyers confluence with the South Branch.

The same argument applies to the North Branch.

“The analysis of the North Ashburton River concentrates on the available flow at the bottom end of specific reaches without having regard to the pattern of flow losses or gains within those reaches. There is reference to this in section 2.2.2 of the report, which describes the reach between Shearers Road and Ollivers Road. The report refers to an overall gain of flow in this section, and refers to it in Figure 2.5 as having a gain of 870 l/s. On every occasion when there were sufficient flow gaugings carried out, the reach between Shearers Road (which is downstream of O’Sheas Creek confluence) and Ollivers Road loses water. This loss is despite the inflow of Mt Harding Creek (which obtains at least ½ of its flow from water outside the Nth Ashburton river).”

The difference here is whether we are looking at the river channel as a modified river or in its natural state. Mt Harding abstractions were not added back to the stream, where as on average  $555 \text{ l s}^{-1}$  is removed. In the 2001 report these flows were added back to the river. (See also 3.4.2 and 5.2)

### 3.4.2 Specific measurements completed by de Joux

Richard de Joux provided concurrent flow measurements taken over two days (21<sup>st</sup> and 25<sup>th</sup> of March 2002) on the North Branch reach from Thompsons Track Bridge to the confluence with the South Branch, Figure 3.4 (sites 1 to 14). Observations or stream measurements were conducted at 14 locations while Greenstreet irrigation turned off at 8pm on the 22<sup>nd</sup> March and restarted at 2pm on the 25<sup>th</sup>.

The results (Table 3.7) are interesting and provide some comparisons with the earlier work of Horrell (2001), and additional knowledge within some river reaches. Adjustment for abstractions from the main channel or the tributaries were not made, so the patterns of losses or gains observed are made upon residual flows alone.

The first run on the 21<sup>st</sup> is when Greenstreet irrigation was abstracting, while the second run on the 25<sup>th</sup> is when Greenstreet irrigation released 919 l s<sup>-1</sup> to the North Branch.

The loss rate from Horrell (2001) between Thompsons Track Bridge and Shearers Crossing was 99 l s<sup>-1</sup> per km, however abstractions were accounted for. The de Joux measurements gave two answers for this reach; the first run had a loss rate of 223 l s<sup>-1</sup> per km while the second was 125 l s<sup>-1</sup> per km. The second loss rate is considerably less than the first because of one abstraction, Greenstreet, had ceased irrigating. This result is similar to (Horrell 2001), and clearly demonstrates the importance of adding back abstraction to obtain the correct natural loss rates.

The measurements from Shearers Crossing to below Mt Harding Creek (for comparison to Ollivers Road (Horrell 2001)) resulted in two quite different answers. The first was a gain of 115 l s<sup>-1</sup> per km while the second was a loss of 0.4 l s<sup>-1</sup> per km. Horrell (2001) shows a gain of 145 l s<sup>-1</sup> per km. This is generally a losing reach with one large inflow (gain) - Mt Harding Creek. These two results would have displayed an even larger gain if the full natural flow of Mt Harding Creek could have entered the North Branch.

What is important here is that de Joux carried out further measurements firstly by observing where the North Branch was dry on the 21<sup>st</sup> and also on the 25<sup>th</sup> and measured the flow in the North Branch at the Mt Harding confluence and also the Mt Harding Creek input. Results are shown in Table 3.7. De Joux shows, that within the reach the loss rate was 244 and 230 l s<sup>-1</sup> per km and the gain is totally due to one input, Mt Harding Creek.

“On every occasion when there were sufficient flow gaugings carried out, the reach between Shearers Road (which is downstream of O’Sheas Creek confluence) and Ollivers Road loses water. This loss is despite the inflow of Mt Harding Creek (which obtains at least ½ of its flow from water outside the Nth Ashburton river).”

De Joux’s statement that on every occasion there is always a loss despite the inflow from Mt Harding is problematic as his own data shows an overall gain.

If one is describing what the water resource is doing in general over this river reach then this part of the river is gaining. However the reach is losing until the one inflow from Mt Harding Creek.

From below Mt Harding confluence to Digby’s Bridge is also of interest, but on both occasions the river was not flowing at Digby’s Bridge. The loss rate was calculated to where the river ceased flowing, giving two values 182 and 231 l s<sup>-1</sup> per km. This is similar to previous calculations of 194 l s<sup>-1</sup> per km.

Note also that de Joux’s distance measurements will be more precise (used GPS), as Horrell (2001) were positioned using a 1 to 50,000 scale map.

De Joux’s measurements showed the reach between Digby’s Bridge and the confluence with the South Branch to gain 1040 and 693 l s<sup>-1</sup>, while previous analysis (Horrell, 2001) gave a gain of 727 l s<sup>-1</sup>.

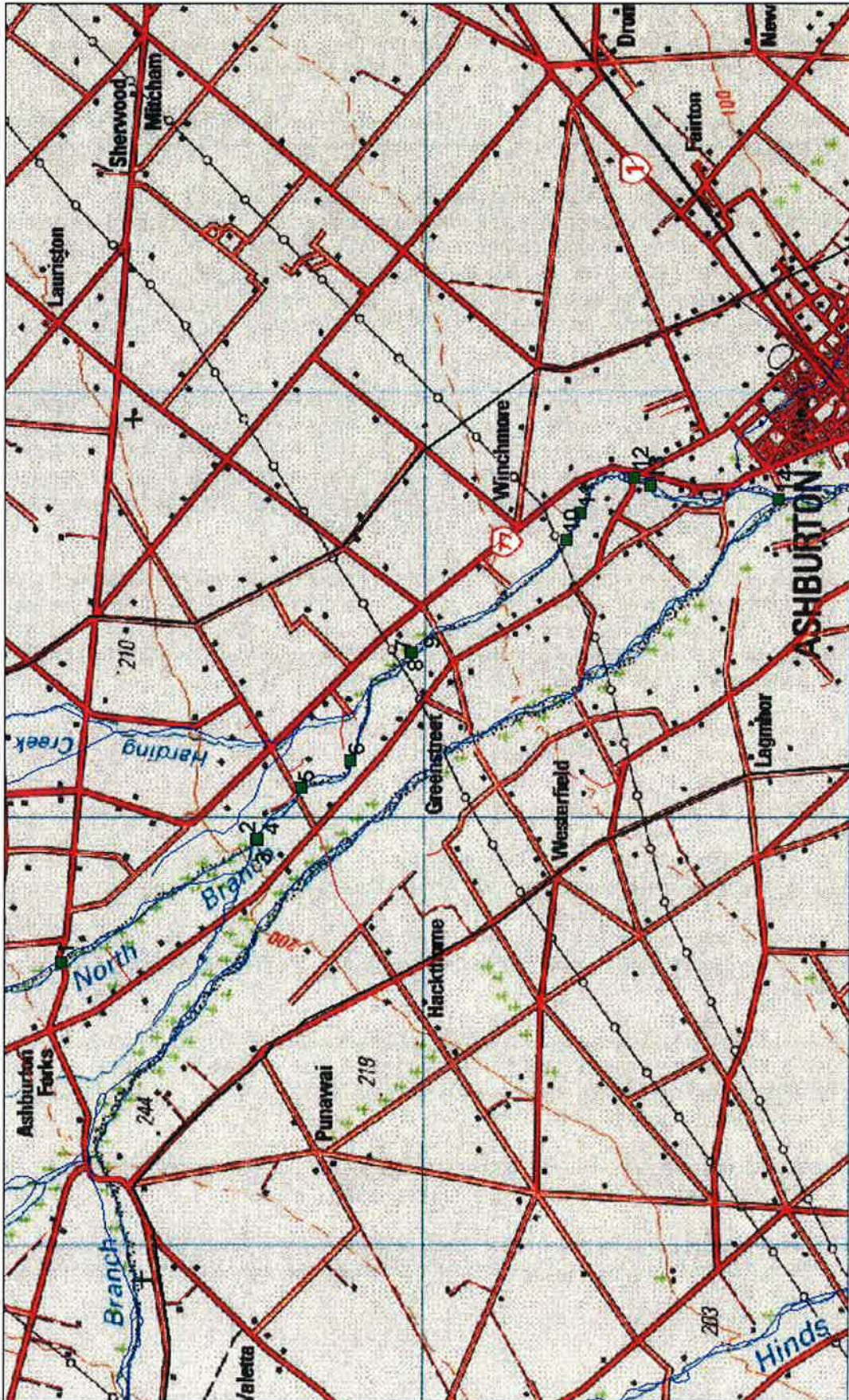


Figure 3.4 Location of de Joux's North Branch flow measurements – 21 and 25 March 2002

**Table 3.7 de Joux's North Branch flow measurements  
Including comparison with Horrell (2001)**

Location - Refer Figure 3.4	Easting	Northing	Distance	Flow (l s <sup>-1</sup> )		Loss/Gain rate per Km (l s <sup>-1</sup> )				
						De Joux original Calcs		Comparing totals for selected reaches from two studies		
				21/03/2002	25/03/2002	21/03/2002	25/03/2002	21/03/2002	25/03/2002	Horrell (2001)
1 Thompsons Track	2396571	5718470		1890	2087					
2 Nth Ash above O'Sheas	2399454	5713930	5378	514	669	-256	-264			
3 O'Sheas at Nth Ash confluence	2399411	5713884	63	102	919					
4 Flow below O'Sheas	2399454	5713897	5441	616	1588					
5 Nth Ash at Shearers Rd	2400649	5712886	1590	325	1210	-183	-238	-223	-125	-99
6 Dry above Mt Harding on 21/3/02	2401295	5711721	1332	0		-244				
7 Mt Harding Creek	2403832	5710338	2889	814	959					
8 Nth Ash above Mt Harding Creek	2403841	5710309	30	0	241		-230			
9 Nth Ash below Mt Harding Creek	2403841	5710309	0	814	1200			115	-0.4	145
10 Dry above Digbys on 21/3/02	2406489	5706693	4482	0		-182				
11 Dry above Digbys on 25/3/03	2407110	5706350	709		0		-231			
12 Nth Ash at Digbys	2407953	5705117	1494	0	0			-182	-231	-194
13 Flow starts below Digbys on both days	2407743	5704739	432	0	0					
14 Nth Ash above Sth Confluence	2407433	5701743	3012	1040	693	345	230	301	201	182

Two observations from this analysis are worth noting:

- (i) For the river conditions observed in the de Joux gauging exercise, to maintain a flow in the North Branch above Mt Harding stream confluence, the Greenstreet Scheme must not abstract.
- (ii) To calculate natural flow, abstractions must be added back to the residual flow.

**“Any attempt to predict downstream river flows must take account of the actual rates of gain or loss within each river reach. The analysis carried out in the report fails to do so”**

Fundamental to modelling the loss / gain rates within each reach of the river is knowledge of the neighbouring groundwater system and its influence over stream flows. This was not available. However, this does not detract from the North Branch analysis significantly as the overall sum of losses and gains is measured as a residual at the downstream site of interest. Therefore it is not necessary to regard losses or gains within a specific reach because in the analysis to estimate natural flows, comparisons between upstream flows and downstream residuals were used thereby considering the overall loss or gain. It is acknowledged that losses and gains do vary within a reach.

Section 2.2 of the Horrell (2001) report does describe the general flow losses and gains measured at specified reaches either from historic measurements or at specific interest sites to ECan on the South and North Branches and Bowyers and Taylors. Consequently measurements specifically within these reaches were not taken. It is understood that within a reach the loss or gain pattern may differ from that represented by the average reach difference. For example, a reach 6 km long may lose  $600 \text{ l s}^{-1}$  from comparison of the upstream and downstream flow measurements. This reach would be represented as losing surface water at a rate of  $100 \text{ l s}^{-1}$  per km. However, with the time and resources one could measure that same reach at 1 km locations and find that the above averaging is incorrect when compared specifically to 1 km locations within the reach. This was also the finding in the de Joux study above.

**“The conclusion of the report that the North Ashburton would not go dry under “natural” conditions is inevitable because of the simple assumption that the downstream flow equals the upstream flow plus all abstractions.”**

Incorrect – the assumption was that downstream flow or residual was close to natural if the upstream abstractions were added to it. The abstractions were never added to the upstream flow as this would in most cases double account the abstractions.

When reviewing this report de Joux has informed the writer that he mistakenly wrote “**upstream flow plus all abstractions**” when he meant to say “downstream flow plus all abstractions”

### **3.5 Natural flow record for the Ashburton at State Highway One**

This data set was revised and the details are shown in Appendix 1. Three modifications were applied to this data set

- (i) one stockwater take removed (SCY690643)
- (ii) restrictions of 50% applied on two occasions, 4/2/1998 and 5/3/1998
- (iii) four groundwater abstractions with a calculated depletion rate were included (CRC921407, SCY690426, CRC921449 and SCY700015)

**Table 3.8 Results of changes to natural flow estimates at Ashburton Mainstem at State Highway One ( $\text{m}^3 \text{s}^{-1}$ )**

Analysis	2001	2003
Mean flow	30.05	29.11
Median flow	23.48	22.71
7DMALF	14.23	13.93

### 3.6 Natural flow record for the North Ashburton at Digby's Bridge

This data set was revised and the details are shown in Appendix 1. Two modifications were applied to this data set

- (i) three small groundwater abstractions with a calculated depletion rate were included (CRC921550F, CRC921550G, CRC920653)
- (ii) restrictions of 50% applied on one occasion, 20/1/1999

**Table 3.9 Results of changes to natural flow estimates at Digby's Bridge ( $\text{m}^3 \text{s}^{-1}$ ).**

Analysis	2001	2003
Mean flow	7.39	7.44
Median flow	5.03	5.08
7DMALF	3.18	3.35

## 4 Additional natural flow regimes for spring fed tributaries of the North Branch

Natural flow regimes for the Ashburton North Branch tributaries Mt Harding Creek and the combined flows of O'Shea and Snowden Creeks were constructed. Attempts were made during the 2001 analysis, however poor  $r^2$  results negated the opportunity to take the analysis further.

Corrections to the relevant; abstraction rates, restriction conditions, consent locations, improved the results so that flow regime results could be included here. Data sets are listed in Appendix 1.

### 4.1 Natural flow record for Mt Harding Creek

Gauging runs were undertaken on Mt Harding Creek at Aitken Road and abstractions added back to reconstruct natural flows. The natural flows were then regressed against mean daily flows at the North Ashburton River at Old Weir site to arrive at the following predictive equation:

$$\text{Natural flow at Aitken Road (l s}^{-1}\text{)} = 1530 \times \log_{10}(\text{Old Weir Daily Mean flow (l s}^{-1}\text{)}) - 4352$$

The number of values in the data set was 11, and the coefficient of determination ( $r^2$ ) was 0.78 with a standard error of  $\pm 134 \text{ l s}^{-1}$

## 4.2 Natural flow record for O’Shea and Snowden Creeks

Natural flows were deduced from concurrent measurements of:

- Greenstreet Irrigation Scheme take from the South Ashburton
- total abstraction from the ponded water into the irrigation canal
- residual flows to the North Branch,

Upstream abstractions were added back at the reviewed rates.

The natural flows were then regressed against mean daily flows at the North Ashburton River at Old Weir site and groundwater levels at the Forks well to arrive at the following predictive equation:

$$\text{Natural flow of O’Shea and Snowden Creeks ( l s}^{-1}\text{)} = 513 \times \log_{10}(\text{Old Weir Daily Mean flow ( l s}^{-1}\text{)}) + \text{Forks groundwater} \times 0.638 + 4$$

The number of values in the data set was 10, and the coefficient of determination ( $r^2$ ) was 0.83 with a standard error of  $\pm 79 \text{ l s}^{-1}$ .

Assumptions in this review were applied to the O’Shea /Snowden data set.

## 4.3 Reviewed regression results

Table 4.1 presents the regression results used as predictive equations for flows displayed in Table 4.2 for:

- South Ashburton River at Valetta
- Taylors Stream at the confluence with the South Branch
- South Branch at the North Branch confluence
- North Branch at South Branch confluence
- North Branch at Digby’s Bridge and the Ashburton River Main Stem at SH1.

This now includes Mt Harding Creek, Snowden and O’Shea tributaries based on the data sets in Appendix 1 and the regression analysis in Sections 4.1 and 4.2.

**Table 4.1 Reviewed regression results**

Regression equations	Adjusted $r^2$	Standard Error $\text{l s}^{-1}$	Number of values
South Ashburton at Valetta = (Mt Somers x 0.892) – 141	.94	413	12
Taylors = (Old Weir x 0.272) + (Hill View x 0.708) + 4094	.84	508	17
South Branch at Nth Confl = (Valetta + Taylors) x 1.242 + 2306	.98	509	10
North Branch at Sth Confl = (Old Weir x 0.384) + (Hill View x 0.384) + (Near Ashburton Forks x – 0.259) + 3414	.78	421	16
SH1 = ( Sth Branch at Confl + Nth Branch at Confl) x 1.049 + 75	.99	460	13
Digby’s Bridge = (Nth Branch at Confluence x 0.982 - 443	.99	152	9
Mt Harding = ( $\log_{10}$ Old Weir x 1530 ) - 4352	.78	134	11
O’Shea and Snowden = ( $\log_{10}$ Old Weir x 513) + ( Ashburton Forks x 0.638 ) + 4	.83	79	10

**Table 4.2 Flow statistics for recorded and natural time series data**

Flow sites	Recorded period	Natural period	Mean flow	Median flow	7DMALF	Monthly Mean Flows											
						January	February	March	April	May	June	July	August	September	October	November	December
South Ashburton at Mt Somers	28/4/1967 - 1/1/2000	28/4/1967 - 1/1/2000	11.16	9.09	4.65	9.95	8.36	8.68	8.83	8.19	9.38	9.58	12.07	14.32	16.60	14.78	12.25
South Ashburton at Valetta	21/7/1995 - 1/1/2000	21/7/1995 - 1/1/2000	7.48	4.60	0.89	4.04	6.34	5.74	6.55	7.40	7.03	11.27	9.96	10.89	15.88	5.18	4.87
		8/5/1982 - 1/1/2000	9.97	8.49	4.51	7.78	7.78	7.69	8.76	8.16	6.82	9.67	10.18	12.76	17.80	10.70	10.29
		8/5/1982 - 1/1/2000	9.90	8.08	4.21	8.73	7.61	8.64	7.21	7.15	7.98	8.62	11.61	11.62	15.87	11.99	11.21
Taylor's Stream at South Ashburton confluence		8/5/1982 - 1/1/2000	4.07	2.93	1.08	2.27	2.45	3.45	2.44	2.58	3.26	3.78	5.34	4.69	8.34	5.83	4.25
South Ashburton at Nth confluence		8/5/1982 - 1/1/2000	19.66	15.96	9.17	15.97	14.80	17.31	14.29	14.39	16.26	17.70	23.34	22.55	32.38	24.44	21.50
North Branch at Old Weir	6/5/1982 - 1/1/2000	6/5/1982 - 1/1/2000	8.86	6.54	3.01	6.02	5.88	7.14	5.72	6.50	7.64	7.76	9.82	10.79	15.82	12.41	9.66
North Ashburton at Sth confluence		8/5/1982 - 1/1/2000	8.02	5.62	3.87	5.13	5.75	7.49	5.47	5.77	6.92	7.41	9.78	8.60	14.94	10.76	8.12
North Branch at Digby's Bge		8/5/1982 - 1/1/2000	7.44	5.08	3.35	4.60	5.21	6.91	4.94	5.22	6.35	6.84	9.16	8.00	14.22	10.13	7.53
Ashburton at SH1	21/6/1996 - 1/1/2000	21/6/1996 - 1/1/2000	16.70	12.41	3.88	9.65	9.89	8.21	7.34	10.55	13.48	24.47	21.82	17.87	27.61	22.41	10.70
		8/5/1982 - 1/1/2000	25.00	21.81	14.34	18.97	20.72	19.85	18.78	16.66	16.56	28.83	29.31	28.55	46.75	26.13	20.72
		8/5/1982 - 1/1/2000	29.11	22.71	13.93	22.21	21.64	26.10	20.81	21.22	24.39	26.42	34.83	32.75	49.71	36.93	31.15
O'Shea and Snowden		8/5/1982 - 1/1/2000	0.96	0.95	0.59	0.95	0.90	0.92	0.89	0.87	0.92	0.97	0.99	0.99	1.08	1.04	1.03
Mt Harding Stream		8/5/1982 - 1/1/2000	1.52	1.49	0.95	1.38	1.28	1.30	1.28	1.37	1.46	1.47	1.67	1.69	1.94	1.81	1.65
Lagmhor Creek			0.2 est														
Pudding Hill above ADC intake		27/5/1964 - 1/1/2000	1.27	0.88	0.44	0.78	0.82	1.05	1.11	1.11	1.33	1.63	1.77	1.75	1.63	1.19	1.00

Numbers in bold are natural flows  
 Numbers unbolded are recorded flows  
 7 day mean annual low flow (7DMALF)  
 Natural period 8/5/1982 - 1/1/2000 is the constructed natural time series

All flows in cumecs m<sup>3</sup> s<sup>-1</sup>

Table 4.3 Comparison of flow statistics with previous analyses

River / Stream	Location	flow statistic	Scarf 1983	Scarf 1999	Young 1992	Horrell 2001	This report
South Branch	Valetta bridge	mean	12.8	12.6	10.1	10.52	9.90
		median		9.4	7.6	8.59	8.08
		7DMALF	5.6	4.7	3.6	4.48	4.21
Taylors	near confluence with the South Branch	mean	5.2	2.9	5.35	4.05	4.07
		median		2.1	3.4	2.9	2.93
		7DMALF	1.4	1	0.4	1.05	1.08
South Branch	above confluence with the North Branch	mean		19.1	15.9	20.59	19.66
		median		13.8	13.1	16.76	15.96
		7DMALF		6.8	6.3	9.72	9.17
Pudding Hill	above Ashburton District Council abstraction	mean		0.8	1.87	1.27	1.27
		median			1.23	0.88	0.88
		7DMALF			0.46	0.44	0.44
O'Shea & Snowden		mean		1		1.19	0.96
		median					0.95
		7DMALF					0.59
Mt Harding Creek	Aitken Road	mean		1		> 1.0	1.52
		median					1.49
		7DMALF					0.95
North Branch	Digby's Bridge	mean			6.20	7.39	7.44
		median			4.40	5.03	5.08
		7DMALF			0.80	3.18	3.35
North Branch	above confluence with the South Branch	mean		9.9	6.8	7.98	8.02
		median		7.2	5	5.57	5.62
		7DMALF		3.2	1.8	3.69	3.87
Ashburton	State Highway One	mean	27.6	29		30.05	29.11
		median		21		23.48	22.71
		7DMALF	10.8	10		14.23	13.93

7DMALF is 7 day mean annual low flow

1982-2008

↓  
2009

9.50  
7.83  
4.03  
5.27  
2.62  
0.92  
20.73  
15.25  
8.80  
1.18  
0.82  
0.43  
0.94  
0.93  
0.56  
1.48  
1.46  
0.92  
6.70  
4.55  
3.17  
7.28  
5.08  
3.68  
29.56  
21.33  
13.46

#### 4.4 Discussion of regression results

- The de Joux adjustment for Valetta losses had the greatest influence on the estimates of natural flow regimes (Table 4.3) at other downstream locations; South Branch at North Branch confluence and the Ashburton main stem at SH1.
- This review makes only slight changes to Taylors and the North Branch natural flows estimates, due to the average abstraction rate changes being countered by other consent related corrections.
- Regression analysis on O'Shea and Mt Harding Creeks improved using corrections to the relevant; abstraction rates, restriction conditions, consent locations, so that flow regime results could be included here.
- Statistics of natural flow time series appear in Table 4.2 with comparisons to previous analyses on Table 4.3. Pudding Hill Stream and Lagmhor Creek are included for completeness although no changes were made in this review.
- Table 4.2 includes short-term recorded flows at Valetta and SH1 for interest and comparison with the same period values for natural flows are listed. Some anomalies in the monthly values are evident due to the missing record at primary sites when constructing natural flows. This would also impact upon the short term natural statistics of mean, median and 7 day mean annual low flow.

#### 4.5 Standard error (St)

Standard error of the estimates for Digby's Bridge and at the most downstream location Ashburton River at State Highway One are assessed using the equation:

$$St = \sqrt{\sum (Spt^2)}$$

Spt = standard error of the regression between tertiary and primary sites

St for Digby's Bridge is  $\pm 448 \text{ l s}^{-1}$

St for State Highway One is  $\pm 1038 \text{ l s}^{-1}$

### 5 The North Branch flow regime

The North Branch requires more explanation than that given in the 2001 report. From attending public meetings in Ashburton there appear to be five main areas of uncertainty:

- (i) disbelief by many local residents (perhaps 3 generations) of the notion that the North Branch would flow continually under natural conditions at Digby's Bridge.
- (ii) marked concern of Greenstreet Irrigation Scheme members who when under restriction, discharge the O'Shea and Snowden groundwater fed streams of 700 to 900  $\text{l s}^{-1}$  into a dry North Branch river bed, only to see this water disappear into the gravels within a few hundred metres downstream.
- (iii) disbelief of Greenstreet Irrigation Scheme members that their abstraction is the main reason why the North Branch in recent years can be dry for up to 6 months of the year.
- (iv) that the North Branch "leaks like a sieve" over it's full reach while crossing the plains and that low flows from the foothills will always equate to zero flows at Digby's Bridge.

- (v) the de Joux comment that "The configuration of groundwater contours both to the north and south of the North Ashburton River clearly shows that surface water flows into the surrounding aquifers, which results in a permanent loss of water from the river. The assumption that all of the water at the upper part of the river will be present at the lower end is not justified and is technically incorrect"

## 5.1 Background

This background is to provide a brief overview of how the North Branch flows in summer as it crosses the plains.

Firstly, under natural conditions all of Pudding Hill Stream (12 % area of North Branch) flows entered the North Branch as visible surface flows or non-visible subsurface flow (evident as gains to the North Branch flow, Horrell (2001)). Also the spring fed (or groundwater fed) Mt Harding, O'Shea and Snowden Creeks add to the North Branch flow as it crosses the plains assisting in maintaining flows to the North Branch over losing reaches during summer when contributions from the foothills reduce. On occasions the North Branch channel loses water over its full reach, however there are other times when the groundwater levels are high so that the channel gains water over parts of these reaches.

There are further occasions when the sum of the inflows from the three lower tributaries exceeds the channel losses, which results in a net gain to the river. Hence, the North Branch has a more complex flow regime in contrast to the simple correction factor applied to the South Branch between the RDR intake and Valetta in 3.1.

The key to understanding the loss and gain rates throughout the North Branch reach is knowledge of the state of groundwater systems at the time of the flow measurements. This information was not available in the locations or periods required to model the loss or gains over the full reach. This had a major impact upon the regression relationship for the North Ashburton River above the South Ashburton confluence, which resulted in an  $r^2$  of 0.78. In other words the regression relationship explains only 78% of the variation in flow found at the South Branch confluence. Furthermore some of this unexplained variation could be influenced to some degree by the points raised by de Joux regarding the portion of abstraction added to but not reaching the downstream site, and errors in irrigation assessment.

## 5.2 Discussion of the five questions

- (i) **Disbelief by many local residents (perhaps 3 generations) of the notion that the North Branch would flow continually under natural conditions at Digby's Bridge.**

Between 1878 and 1966 there is evidence of the North Branch going dry somewhere in the vicinity between Waklins Road and Rawles Crossing on 3 occasions (Digby's Bridge is located between these two locations).

1. 1890 as reported in the Guardian 8<sup>th</sup> February 1890. (Horrell, 2001)
2. 1930 or 1931 as reported by Flint Hill (Horrell, 2001), 1932-33 would coincide with the reported rare event of the dry Irwell River, a spring fed tributary of Lake Ellesmere (Brooks, *et al*, 1999).
3. 1945 as reported by Ray Walkham (Horrell, 2001).

These are perhaps the only occasions in an 88 year period, of the river being reported as dry. It should be remembered that the stockwater abstractions totalled  $2.5 \text{ m}^3 \text{ s}^{-1}$  on these occasions with an additional unknown abstraction for Winchmore Estate during the early period. Listed below are the known abstractions (Leadley, 1952):

Pudding Hill	February 1881
Mill race	February 1873
Methven auxillary	1880s
Winchmore Main (Fairton to Seafield)	1880s
Winchmore Estate	1870s

From two (insufficient) concurrent runs of flow measurements down the river a crude loss /gain pattern was determined (Section 2.2, Horrell, 2001). Approximately  $1.4 \text{ m}^3 \text{ s}^{-1}$  is lost down to Digby's Bridge after consideration of gains from Pudding Hill, O'Shea, Snowden and Mt Harding Streams. It can be roughly deduced that if the catchment was so dry that the only water left flowing was that being abstracted ( $2.5 \text{ m}^3 \text{ s}^{-1}$ ), and if this was released back to the river then at least  $1 \text{ m}^3 \text{ s}^{-1}$  would have remained in the river on those three occasions.

The naturalised data set for the North Branch at Digby's Bridge shows over 17 years of record that the lowest daily flow was  $2.31 \text{ m}^3 \text{ s}^{-1}$ , indicating that the river would never have dried up at Digby's Bridge over those 17 years under natural flow conditions.

Many observations of the river running dry in the vicinity of Digby's Bridge and upstream, since the late 1960's are less simple to explain due to the multiple effects of:

- river straightening
- willow planting
- increased irrigation abstraction from the North Branch and tributaries
- build up of gravel in Bland's Reach
- low rainfall for 8 out of 10 years from 1960 to 1969
- groundwater level change
- deepening of drains on the Martin property
- drains dug at the toe of the stop bank on Bland's property
- increased flows in Snowden, O'Shea and Mt Harding streams (anecdotal evidence)

Many of the above are irreversible but would have reduced flows.

Figure 5.1 displays graphically how the flow at Digby's Bridge would maintain an all year round flow:

The first plot

- (1) is of monthly mean natural recorded flows of the North Ashburton at Old Weir;
- (2) is the derived natural flows of Pudding Hill stream.
- (3) is the groundwater level at Hill View influenced by rainfall recharge and downslope movement of groundwater.
- (4) is groundwater levels measured Near Ashburton Forks. This displays a similar pattern to that described by Jim Martin (farmer east of Thompsons Track Bridge). "When Jim first arrived, there was a sizeable swamp on his property that displayed high water levels in summer and low levels in winter (similar to the local groundwater trend), which is in direct contrast to the flow patterns of the North Branch"(Horrell, 2001).
- (5) shows the combined derived natural flows for Snowden, O'Shea and Mt Harding Creek as mean monthly flows, which displays consistent flow throughout the year.
- (6) shows the derived natural flow at Digby's Bridge, which follows a similar pattern to the Old Weir. However, summer flows are influenced by the spring fed streams.

These results show that without abstraction in summer months when the North Branch at Old Weir is at it's lowest:

- (a) There is a flow contribution from Pudding Hill stream as underflow
- (b) When the North Branch crosses the plains spring fed tributaries enter which have regular flows due to high groundwater levels.

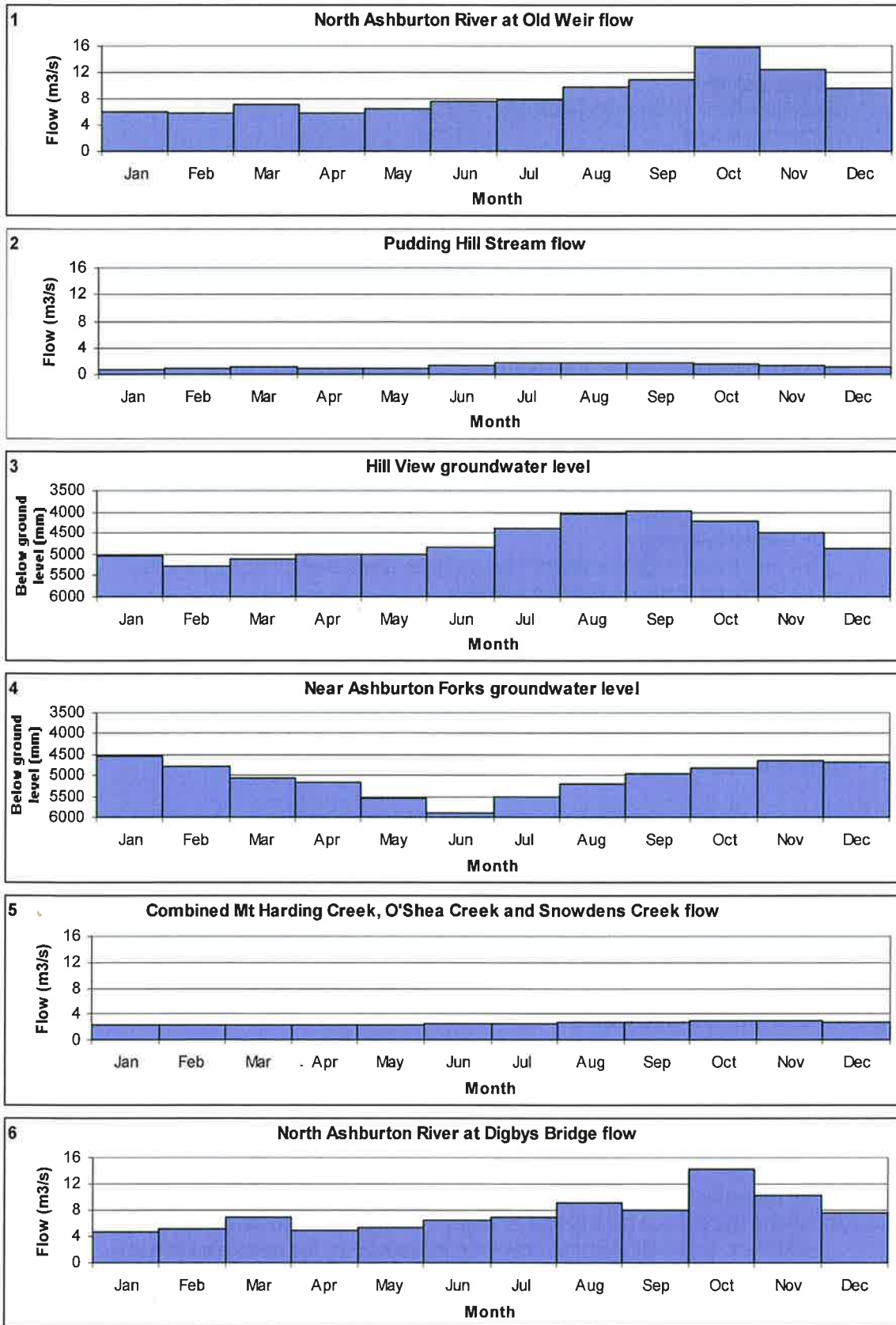
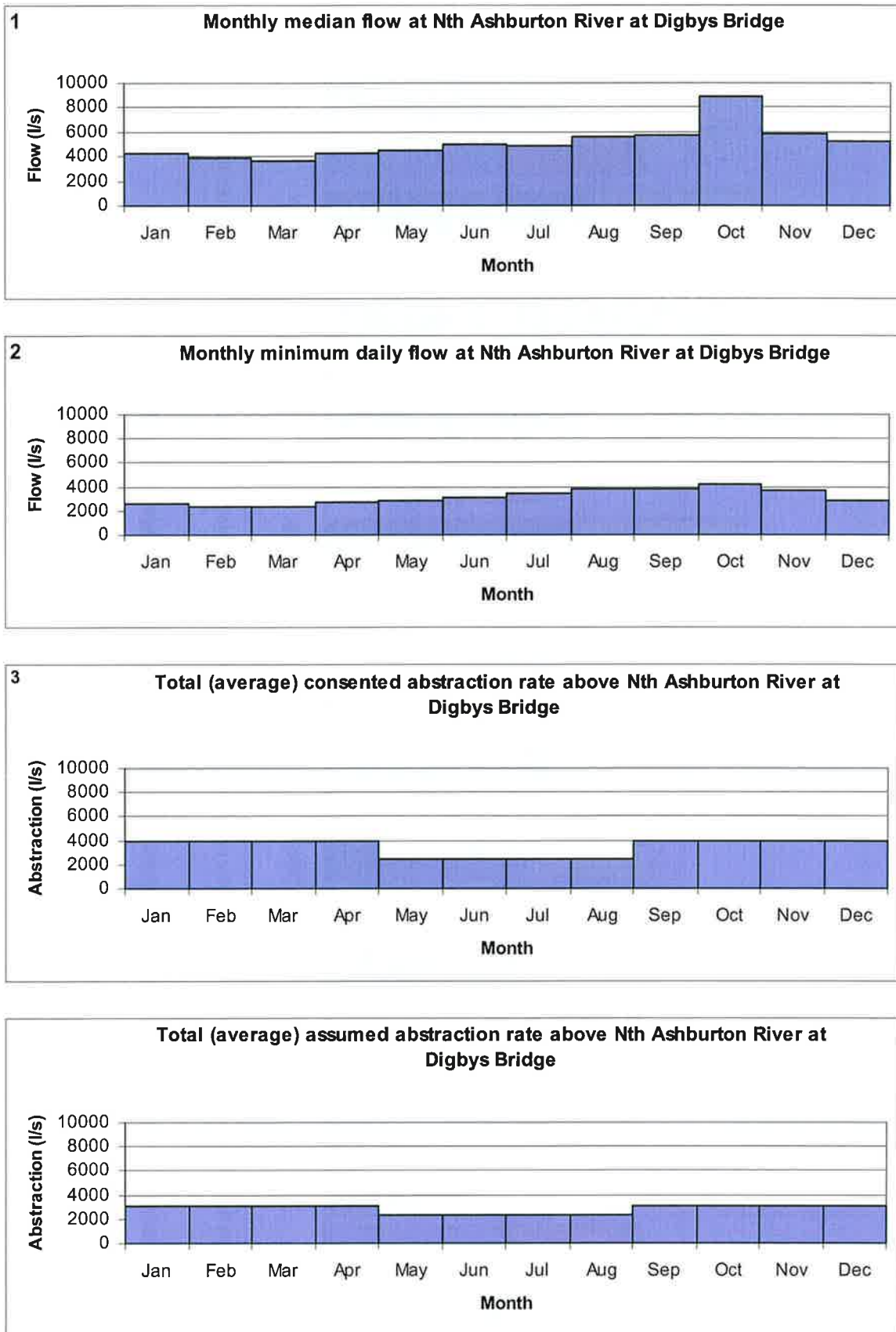


Figure 5.1 Comparison of mean monthly (period May 1982 – Dec 1999) tributary flows and groundwater levels that influence the North Ashburton River flow



**Figure 5.2 North Ashburton River monthly median and monthly minimum daily flows compared to total (average) consented abstraction and assumed (average) consented abstraction above Digbys Bridge**

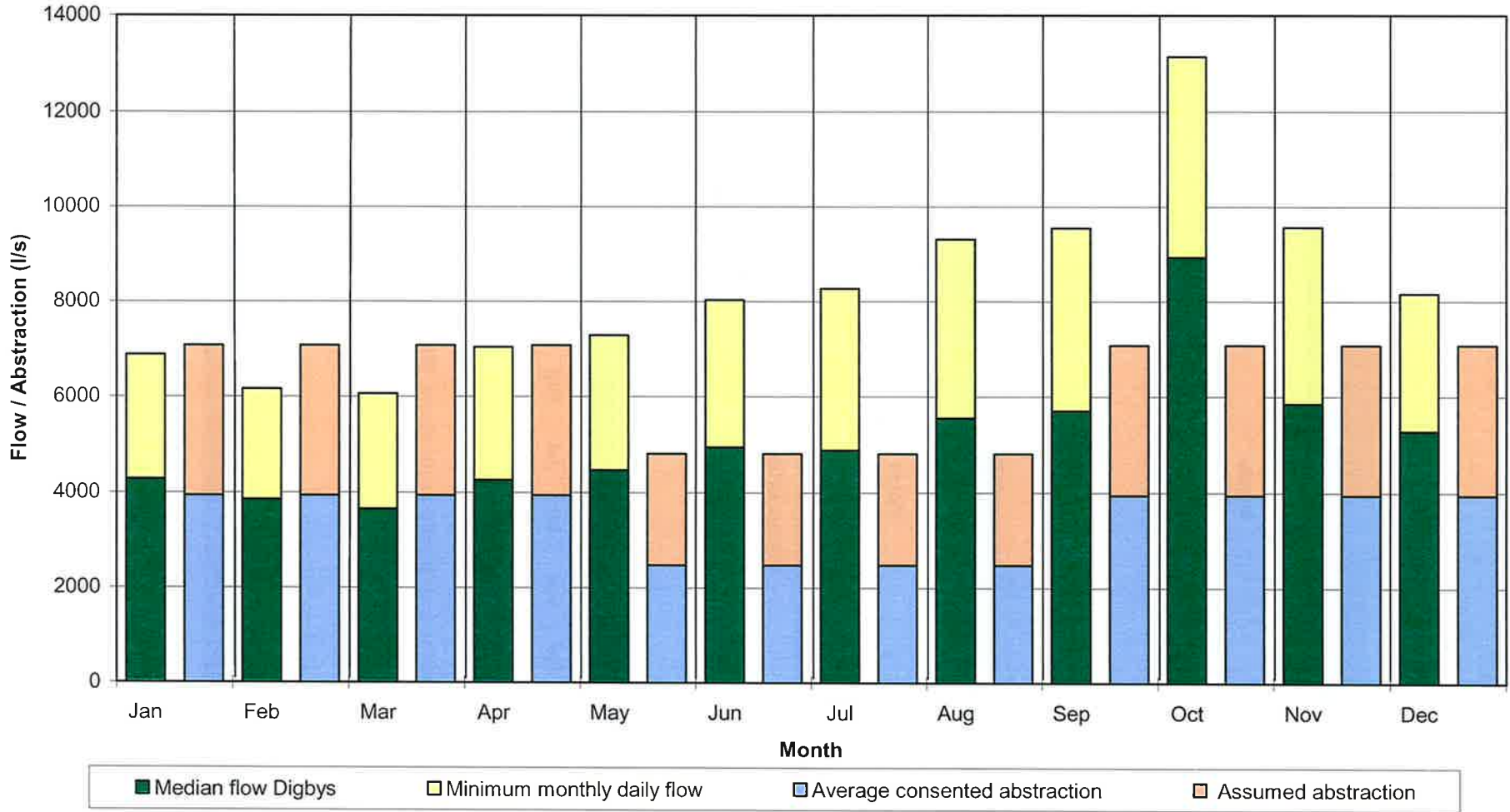


Figure 5.3 Comparison of North Ashburton River at Digbys Bridge natural flow with upstream abstraction

- (c) Losing reaches of the North Branch lessen the flows that reach Digby's Bridge.
- (d) The flow at Digby's Bridge is continuous.

Figure 5.2 provides graphical evidence as to how the North Branch at Digby's Bridge can run dry:

- (1) is of the median monthly flow at Digby's Bridge. For each month the flow is higher than the median for 50% of the time while it is also below this value for 50% of the time.
- (2) is of the lowest daily flow for each month over the 17 year natural flow record.
- (3) is the total consented average rate of abstraction above Digby's Bridge
- (4) is the total assumed average rate of abstraction used in this analysis.

With the top two plots if one was to regard a summer low flow (January, February, March) as between the median and lowest daily flow, and then compare this flow with the bottom plot of average assumed abstraction rate; then, if this quantity was removed (remember abstractions could be as high as the third graph) the river would be dry at Digby's Bridge.

Figure 5.3 is a simplification of the comparison described above in Figure 5.2. This displays two columns for each month. The base of the first column is the median flow for Digby's Bridge while the top portion is the lowest daily flow for that month. The second column base is the average consented abstraction rate above Digby's Bridge with the top portion being the assumed amount abstracted.

To interpret this figure one must consider the month being dry with below average rainfall with the river below the median but perhaps above the lowest daily flow for that month. In this case these values are added together the same with the abstractions where the average rate (not the instantaneous maximum) and the assumed rate were also added together. Comparison of column heights in January to March show abstractions exceed flow while April values are similar, the remaining winter and spring months natural flow exceed abstractions.

This figure is conceptual: it is not scientifically established but does provide an indication of what probably happens, and goes some way to explain why the river can be dry for some months at Digby's Bridge.

Prolonged dryness in April and May might arise from the river replacing the groundwater resource deficit accrued when dry. This is discussed further in regard to question 2 below.

- (ii) **marked concern of Greenstreet Irrigation Scheme members who when under restriction, discharge the O'Shea and Snowden groundwater fed streams of 700 to 900 l s<sup>-1</sup> into a dry North Branch river bed, only to see this water disappear into the gravels within a few hundred metres downstream.**

Figure 5.4 is an aerial photo (approximate scale 1:12,000) taken on 18 February 1999 showing the location of spring fed tributaries in the middle reaches of the North Branch. The photo was taken during a considerable dry period. The Ashburton River had been on full restriction the day before. Therefore O'Shea and Snowden water entered the North Branch and can be seen as surface flow for only a few hundred metres.

With the current abstractions for stockwater and irrigation coupled with natural losses to groundwater, it is understandable that surface flows throughout the North Branch are not continuous.



**Figure 5.4** North Ashburton River – middle reaches, aerial photo on 18 February 1999.  
The Ashburton River was on full restriction the previous day. Approx scale 1:12,000

From the O'Shea confluence with the North Branch to Digby's Bridge it is estimated that approximately  $0.7 \text{ m}^3 \text{ s}^{-1}$  is naturally lost from the river channel to the groundwater to the east, while some resurfaces before the confluence with the South Branch. Under the current regime the river can be dry throughout this reach for many months of the year. For example, if it were dry for 6 months, this would equate to a groundwater storage deficit of 11 million cubic metres (13% of Opuha Dam). Coupled with current abstractions from the North Branch and Mt Harding Creek, the release of O'Shea and Snowden water, when on restriction, would never satisfy the needs of the groundwater system, resulting in no surface flow throughout the reach to Digby's Bridge for months until a major rainfall event occurred.

Further evidence of the large requirements of the groundwater system was provided in 1999 when Digby's Bridge had been dry for some months. Three freshes were recorded at the Old Weir recorder within 30 days, one at the end of February, one in mid March, with the last at the end of March. The three peaks were 23, 19 and  $13 \text{ m}^3 \text{ s}^{-1}$ . The volume of these events was calculated with a small allowance for input from Pudding Hill Stream. The approximate total was 8 million cubic metres, but the North Branch remained dry at Digby's Bridge.

The reasons why the release of natural flows from O'Shea and Snowden Creeks disappears into the gravels a short distance downstream of the North Ashburton confluence is the high allocation of abstractions from the North Branch and the depleted groundwater levels.

**(iii) disbelief by Greenstreet Irrigation Scheme members that their abstraction is the main reason why the North Branch in recent years can be dry for up to 6 months of the year.**

As explained in ii) above, if only a small portion of the groundwater needs are met then there will be a considerable deficit and extended period of time with no surface flow.

Greenstreet's abstraction (maximum rate  $1,200 \text{ l s}^{-1}$  and average rate  $897 \text{ l s}^{-1}$ ) is the second largest abstraction from the North Branch water resource. (The largest is Methven Auxillary  $1,130 \text{ l s}^{-1}$  which has existed since the 1880's). Also below the O'Shea confluence with the North Branch there are considerable natural losses to the groundwater system to the east.

Figure 5.5 shows clearly the change of slope when concurrent gaugings of flow are compared between the Old Weir or SH 72 and the residual at Digby's bridge after the Greenstreet Scheme started. There are other factors that coincide with this change:

(a) build up of gravel on Blands Reach

(b) increased abstraction from the North Branch and tributaries

- but it is thought that the main reason for this change in slope is due to the Greenstreet abstraction.

**(iv) that the North Branch leaks like a sieve over it's full reach while crossing the plains and that low flows from the foothills will always equate to zero flows at Digby's Bridge.**

It is true that on certain occasions there is a considerable amount of water lost to the groundwater system. The 3 freshes discussed in question ii) above is a further example. However, if the groundwater system was maintained adequately with these natural losses, and the river were to drop, there would be occasions when the surface flows would be enhanced by these high groundwater levels. Figure 5.1 (4) displays the high groundwater levels in summer mid-way down the North Branch reach, plus the consistent summer flows in the lower groundwater fed tributaries. Photos in Figures 5.6 and 5.7 show the flow in Snowden Creek and a tributary of Mt Harding (sourced from North Branch or intercepted drainage destined for the North Branch). The combined flow of these two photos is estimated to be over  $2.5 \text{ m}^3 \text{ s}^{-1}$ . Figure 5.10 shows the North Branch above O'Shea confluence struggling to maintain a surface flow on the same day as the Snowden measurement in Figure 5.6.

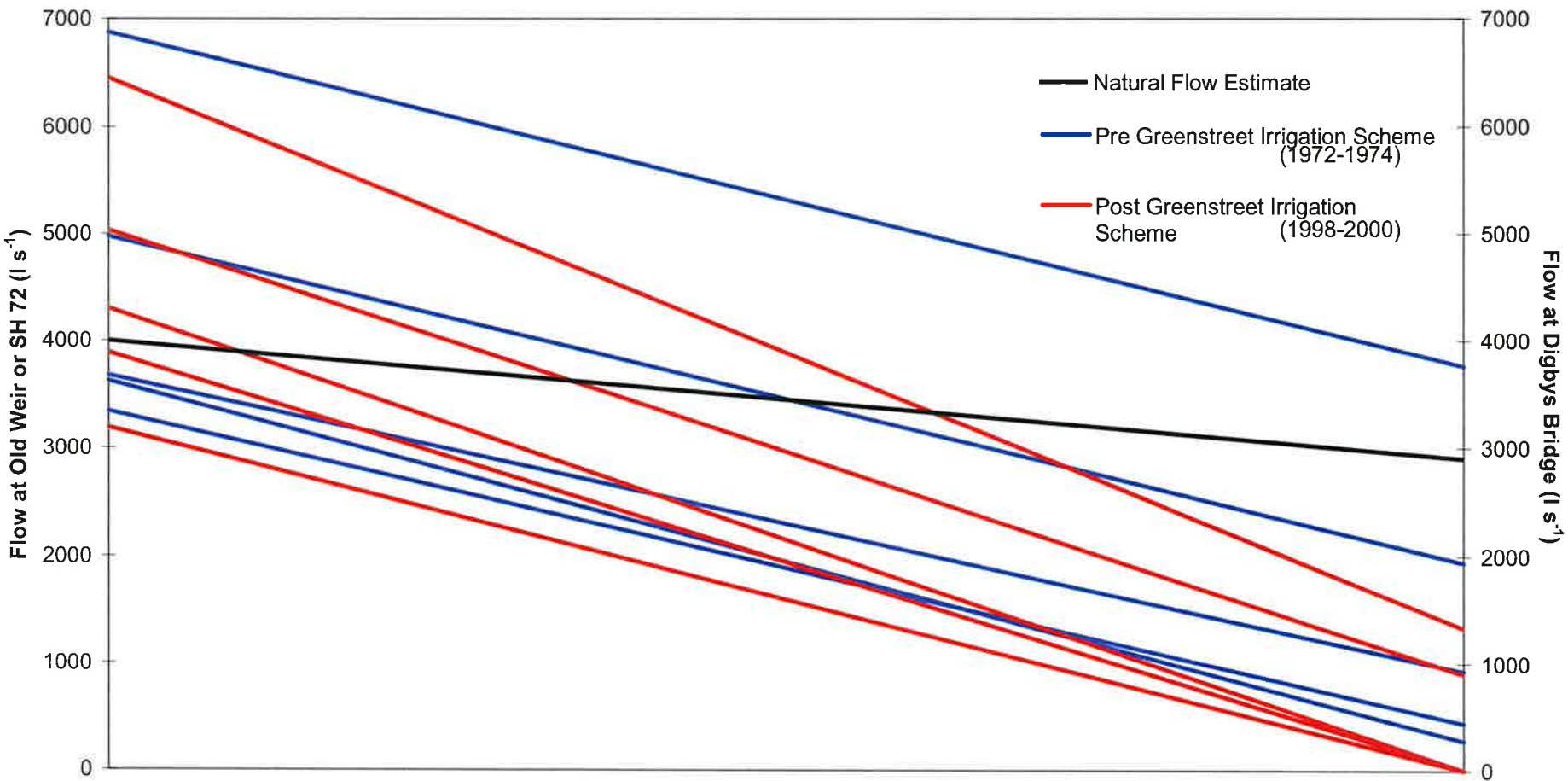


Figure 5.5 Impact of abstraction on flows at Digbys Bridge



**Figure 5.6** Snowden Creek looking upstream from Greenstreet Irrigation Scheme pond,  $611 \text{ l s}^{-1}$ , 29<sup>th</sup> February 2000.



**Figure 5.7** Tributary of Mt Harding Creek above Winchmore Main Race and Sub-Main Diversions, estimated flow  $2000 \text{ l s}^{-1}$ , 7<sup>th</sup> February 2001.



**Figure 5.8** Methven Auxillary. 4<sup>th</sup> June 2003. Approximate flow 600 l s<sup>-1</sup> (Consented 1133 l s<sup>-1</sup>)



**Figure 5.9** Pudding Hill intake. 4<sup>th</sup> June 2003. Abstracting approximately 380 l s<sup>-1</sup>



**Figure 5.10** North Ashburton above O'Shea Confluence looking downstream,  $531 \text{ l s}^{-1}$ , 29<sup>th</sup> February 2000.



**Figure 5.11** Greenstreet Irrigation Scheme intake and fish screen,  $911 \text{ l s}^{-1}$ , 29<sup>th</sup> February 2000.



**Figure 5.12** O'Shea bywash from Greenstreet Irrigation Scheme to the North Ashburton River,  $19 \text{ l s}^{-1}$ , 29<sup>th</sup> February 2000.

Figure 5.11 displays the Greenstreet abstraction on the same day while Figure 5.12 is the bywash allowed to enter the North Branch. For completeness other major abstractions are shown in Figure 5.8 Methven Auxillary and Pudding Hill abstraction Figure 5.9.

In conclusion naturally occurring low flows in the foothills do not necessarily equate to zero flows at Digby's Bridge, owing to the high influence groundwater levels on tributary flow in the middle reaches of the North Branch, during these periods.

- (v) **De Joux and Young comment** "The configuration of groundwater contours both to the north and south of the North Ashburton River clearly show that surface water flows into the surrounding aquifers, which results in a permanent loss of water from the river. The assumption that all of the water at the upper part of the river will be present at the lower end is not justified and is technically incorrect"

This statement is accepted. Some of these losses will be permanently removed from the surface water resource. However some will return as subsurface flow to the channel while more will return as surface flows via Snowden, O'Shea Creeks and tributaries of Mt Harding Creek.

No assumption was made that all of the water at the upper part of the river will be present at the lower end, as the lower end site was measured and this represented those losses and gains over the full North Branch River reach as it crosses the plains.

## 6 Other abstractions

Estimates of other abstractions from the Ashburton River water resource above State Highway One were made. These are groundwater abstractions adjacent to the tributaries and mainstem of the Ashburton River, not accounted for in the natural flow estimation, as negligible

### 6.1 Ashburton River Catchment domestic use

The rate used by all domestic wells within the Ashburton Catchment above State Highway One was calculated, using the ECan GIS database for all Domestic wells within 2,000m of the Ashburton River and tributaries, upstream of State Highway 1. The buffer zone also included the plains between the two main branches. A total of 251 wells were found within this buffer zone.

A number of assumptions/constraints were made:

- Only those wells listed as Domestic wells on ECan's Wells Database were included,
- Wells of all depths were included,
- There is one well per household,
- That each person uses 250 litres per day,
- That the NZ average household number of persons is accurate for rural Mid-Canterbury,
- These wells are only used for domestic needs and not for stock needs also.

The Proposed Waimakariri River Regional Plan (2000) definition for actual and reasonable use:

"Individual's needs for the purpose of providing drinking and cooking water and for hygiene purposes, of up to 250 litres per person per day;..." was considered. The 2001 Statistics NZ Census shows an average of 2.67 persons per household.

Taking these figures into account, a daily volume of **167.5 m<sup>3</sup>d** (instantaneous rate of 1.9 litres per second) was calculated to be abstracted from all 251 wells for domestic purposes. This is considered to be negligible.

## 6.2 Additional irrigation use

Use of groundwater for irrigation was only partially accounted for in the analysis for natural flows as the interest was in the stream depletion effect. Average irrigation pumping rates for deep and shallow wells for the Ashburton River catchment above State Highway One were summed (stream depletion excluded) to give an irrigation season potential of 1,457 l s<sup>-1</sup>.

**Table 6.1 Groundwater abstraction**

Abstraction	l s <sup>-1</sup>
Deep wells	<b>807</b>
Shallow wells	<b>1,478</b>
Total	<b>2,285</b>
Stream depletion already accounted for	<b>828 (subtracted)</b>
Additional groundwater removed	<b>1,457</b>

While this extra water is removed from the Ashburton River catchment, it should be noted a large portion is sourced from rainfall on the plains and perhaps a portion is from irrigation drainage.

## 7 Further reply to de Joux and Young review

### 7.1 De Joux and Young asserted errors within the report

#### 7.1.1 Overestimation of abstraction rates from various locations;

The overall purpose of this review was to follow their recommendations and redo the analysis:

- (i) average abstraction rates
- (ii) reduce abstractions to restriction level when in restriction

These were revised in Sections 3.1 to 3.6.

#### 7.1.2 A failure to account for inflows of water from tributaries that do not flow past the South and North Branch flow recorder sites;

Ideally 20 years of continuous flow records are required on those tributaries below the Mt Somers recorder in particular Woolshed Creek with Bowyers and Taylors Streams, and furthermore Pudding Hill, O'Shea, Mt Harding on the North Branch, coupled with 20 years of continuous flow record at all proposed minimum flow sites. Also desirable are continuously measured abstractions such as stockwater takes, private border dyke takes and diversions from Greenstreet and most importantly the RDR take from the South Branch, plus records of all bywash. All this information would benefit the accuracy of this analysis. Unfortunately we do not have this data. So spot gaugings with assumptions for abstractions and regression

analyses were made at proposed minimum flow sites. In brief the inflows from those tributaries of concern are accounted for within the residual gaugings at the downstream locations such as referred to in section 3.1 for the case of the South Ashburton at Valetta.

### **7.1.3 Failure to ascertain whether abstractions were actually occurring at the time of flow measurements;**

There are 77 abstractions from the Ashburton River, which affect the surface flows; it was beyond our resources to measure each one of these. Future water metering of all abstractions would capture this information. The only practical solution was to measure some of the larger abstractions.

Of the 77, 9 were gauged by our ECan team, which accounted for 7,710 l s<sup>-1</sup> of the 10,796 l s<sup>-1</sup> taken (those not measured were estimated from the consent database or if groundwater, the calculated depletion rates). Whilst it was beyond our resources to measure all takes the assumptions were made to cover only 28 % of abstracted flow. Furthermore the 55% assumption rule (Sanders, 1998) resulted in 14% of abstractive volumes having assumptions estimated. This was further reduced in this 2003 analysis (average abstraction rate) only 17% were not measured, and with the 55% assumption applied **only** 8.5% were not measured.

In other words of the remaining 68 abstractions, if no one actually irrigated when the analysis had assigned 55% of the averaged consented takes, then the maximum error in the estimate of this abstraction would be 8.5%.

## **7.2 Further criticism**

### **7.2.1 Historical flow measurements**

An estimation of the natural flow record of the tributaries of the Ashburton River has been made using a series of flow measurements carried out concurrently at various sites within each river tributary. Most of the gauging data used has been collected recently (ie 1999 to 2001) by Environment Canterbury. There is also historic gauging data available since 1972 (South Canterbury Catchment Board records), but with the exception of one gauging carried out on the North Ashburton at Digbys Bridge, that data is not used in the analyses.

De Joux is correct. Earlier gaugings were omitted from the analysis, and it was unfortunate but appropriate to do so, the reason being that these gaugings were incomplete. In other words not all the locations of interest were measured. John Young has noted that RDR spill water back to the North Branch more frequently in those years. However, concurrent gaugings down the river did not measure or mention any bywash. To use these flows at face value without knowledge of bywash would have been incorrect and would result in inflated natural flows.

Recent advice (J Young pers com) suggests it was appropriate to use gaugings in 1972-73 (Section 2.3.7, Horrell 2001) as bywash was probably limited due to the severe drought during that time.

### **7.2.2 Addition of upstream abstraction to downstream residual flow**

In attempting to determine the “natural flow”, Horrell uses the basic assumption that:

*Natural flow at downstream site = measured flow at downstream site + all upstream abstractions*

This supposition does not take into account the pattern of flow gains or losses within various sections of the river, and is at variance with the reports' own statements within section 2.2.2 that

*"...there may be losses where gains were calculated, e.g. the gain between Shearers and Ollivers created by one inflow (Mt Harding Creek)".* The report notes in section 2.1.4.1 that *"Therefore to add all takes to the residual flow is not totally correct as some of this surface flow without abstractions may actually be lost to the groundwater system."* Despite that statement, the methodology used makes no attempt to adjust for any such losses. Logically, if water is being lost within a reach, then only a portion of any upstream abstraction can be assumed to reach any downstream site. This is a major flaw in the analyses that, in conjunction with errors in assessing abstraction rates at various locations, leads to a gross overestimation of the natural flow rates within the system.

This raises a good point about changes in loss rates owing to abstraction effects, and is an area that introduces uncertainty.

An adjustment has been made in this analysis for the South Branch at Valetta (Section 3.1). However as discussed in Section 5 there can be considerable gains to a reach as (Section 2.3.7 Horrell, 2001) the North Branch between Thompsons Track and Digby's Bridge with raised groundwater levels, which would refute the statement *"only a portion of any upstream abstraction can be assumed to reach any downstream site"*. The example in Section 3.4.2, ceasing of the Greenstreet abstraction in the de Joux flow loss measurements made a considerable difference. Also Figure 7.1 shows the change in slope to Digby's Bridge equates to the total Greenstreet abstraction, even though the majority of the reach below O'Shea confluence is a losing reach. It appears the total Greenstreet take should be added to the downstream site to preserve the slope prior to Greenstreet abstractions.

The type of adjustment applied to Valetta flows is not appropriate to all reaches of the North Branch.

This was an area of most concern to the author with insufficient time series information. However it is not a *"major flaw"* and neither *"leads to a gross overestimation of the natural flow rates"*, as to not 'add back' abstractions would be a greater error. (re-assessment of abstraction rates was done to the specifications of de Joux and Young within this report).

In summary the addition of upstream abstractions to the North Branch over losing reaches, and expecting to find the full amount at downstream locations when the river and groundwater levels are low, does introduce uncertainty but provides the best estimate of natural flows for the available data.

### **7.2.3 Application of the 55% assumption**

An attempt has been made to account for irrigation abstractions by assuming that they are exercised for 55% of the time. However, this assumption has been applied during times when irrigation restrictions were imposed and a complete ban on abstraction was in place. A number of the larger flow rates of abstraction are for border dyke systems that only allow for a limited number of hours per return period (ie they are not continuous takes at the maximum flow rate).

A more reasonable approach would have been to use the equivalent continuous flow rate, however even this provides an overestimation if the flow gaugings were carried out at a time when these consents were not being exercised.

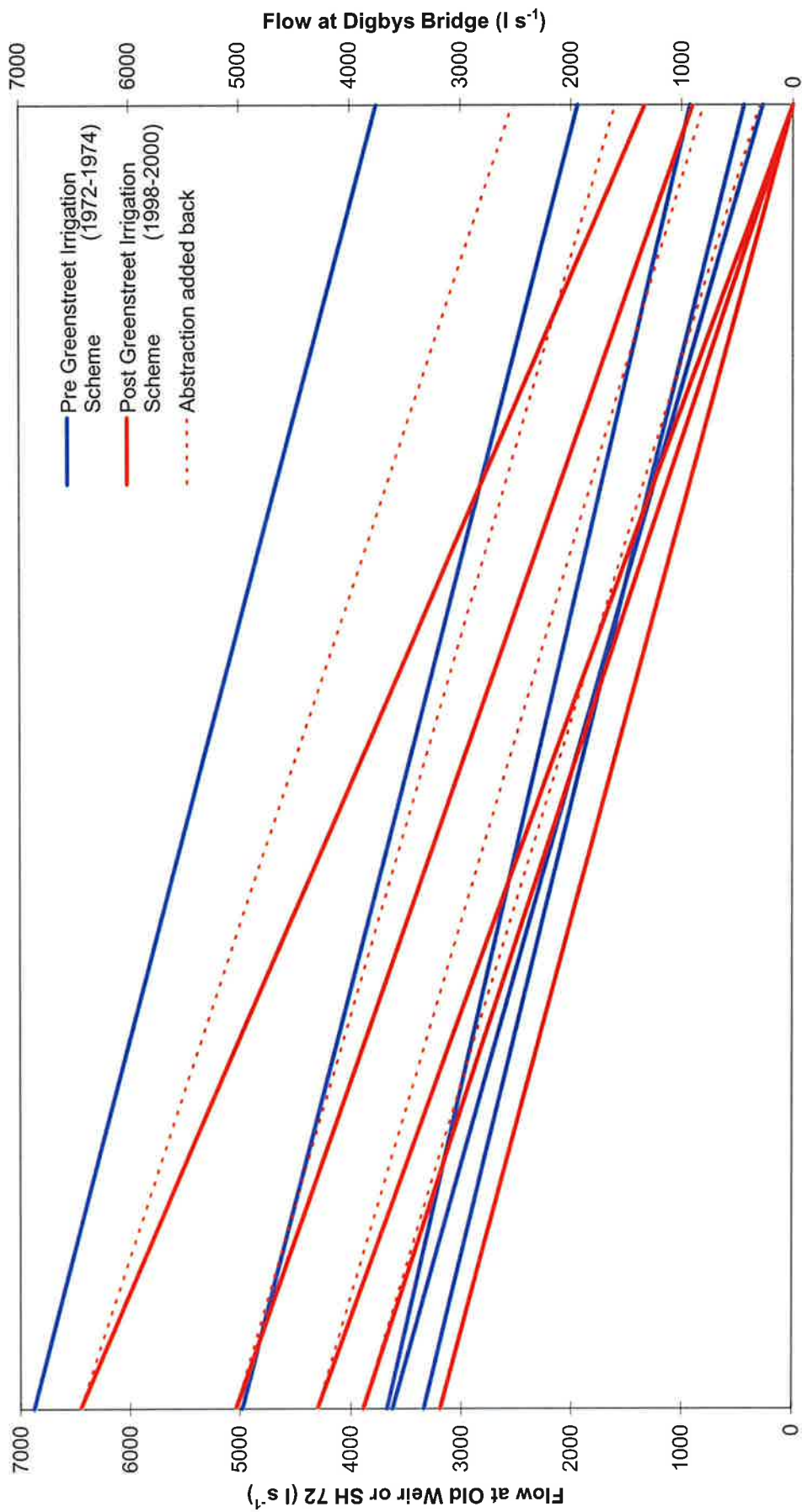


Figure 7.1 Greenstreet abstraction added back at Digbys Bridge

There are four occasions within the data set where restrictions applied. These were addressed.

The five largest non-measured irrigation abstractions are border dyke, these are selected as examples to show the change in the estimated use from the 55% of maximum rate assumption, to the 55% of average rates (based on allocated volume).

**Table 7.1 Comparison of maximum and average rate abstraction assumptions.**

Consent	Maximum rate (l s <sup>-1</sup> )	Average rate (allocated volume) (l s <sup>-1</sup> )
Greenstreet CRC921547H	230	47
Greenstreet CRC921547J	230	26
D Aschen CRC951747	240	10
C Galloway CRC952441	240	62
G Lowe CRC 942232	341	72
Total	1281	217
55 % assumption	<b>704</b> Horrell (2001)	<b>119</b> this review

In the Table 7.1 example, abstractions added back to gauging runs down the river will change from 704 l s<sup>-1</sup> to 119 l s<sup>-1</sup> (the largest adjustment in this review). However, in reality if just one border dyke irrigator was operating he would take at least 230 l s<sup>-1</sup>. But this is represented by 119 l s<sup>-1</sup>, and if two irrigators operated it could be 470 l s<sup>-1</sup>, again represented by 119 l s<sup>-1</sup>. This assumption may on occasions be an underestimate, although if no one irrigated it would be over estimated by 119 l s<sup>-1</sup>.

In reality the 55% assumption is actually used to reflect that at any one time 55% of irrigators are irrigating at a rate equivalent to their consented volume (given an individual irrigator taking at full rate but not all irrigating at once).

Sanders analysis showed that approximately 55% of seasonal allocation was utilised in the extreme 1997/98 season, but when compared with instantaneous flow of surface water abstraction, it could be very different (R Sanders pers com).

Further Horrell (2001) when describing the natural flows (Appendix 3) states the 55% assumption "adds uncertainty to the analysis".

Overall the assumption for the unmeasured abstracted flow rate had a minor affect upon the abstractions added back, with the worst case being a total of 14% (Horrell, 2001) and this figure is reduced in this review to 8.5%.

## **8 Ashburton District Council stockwater race bywash to the Ashburton River**

Visits to the Ashburton District Council (ADC) water race bywash locations accompanied by Water Rangers, were completed with the purpose of gaining knowledge on how the races were managed especially during the periods when the river and tributaries were in low flow. Of the 112 consents for bywash discharges only those that have direct contact with the river were located (Table 8.1).

Overall a total of approximately  $30 \text{ l s}^{-1}$  is estimated to be bywashed back to tributaries or the main stem above State Highway One, during periods of low flow.

Allowances for this bywash although small was made during this review.

## **9 Frequency of 7 day mean annual low flows (7DMALF)**

Low flow frequency analysis was completed for all locations where flow records are measured, and also the locations where natural flow records were derived using regressions described in Section 3. The 7DMALF, 5 year and 10 year return period low flows are displayed in Table 9.1 and Figure 9.1.

**Table 8.1 Ashburton District Council bywash races discharging to tributaries or main stem of the Ashburton River**

<b>South of South Branch and Main Stem Ashburton River</b>						
ADC code	Map reference	Location	Discharges to	Comments	Estimated discharge	
1	DA42	K37:034-030	Lagmhor Creek at Timaru Track	South Ashburton above North Branch confluence	This is a dual purpose bywash (Timaru Track) shared with RDR, however during occasions of summer low flow only sufficient flow to service the stockwater needs of a few downstream farms occurs	summer zero flows after excessive rain
2	DA54	K36:961-143	On Gregory's property	South Ashburton above North Branch confluence	Langdons Creek - never used except during floods	Zero
3			At the back of Sim property	South Ashburton above North Branch confluence	Langdons Creek - never used except during floods	Zero
4	DA55	K36:970-135	Main Langdons bywash on Snowdon's property	South Ashburton above North Branch confluence	Is only used if conditions are wet, and discharges no water if dry or rivers are low. This is effectively the 120 l s-1 take from Langdons for Westerfield Main and Lagmhor Creek, any more creates flooding problems further down Lagmhor Creek where the springs also increase flows.	summer zero in winter varies
5		K36:914-169	Brothers bywash to Valetta swamp	Langdons Creek to South Ashburton above Nth confluence	A very small flow of a few litres flows from the Brothers system into Valetta swamp. At the outlet of Valetta swamp, flow enters the South Ashburton,	2 l/s
6	DA62	K37:017-077	Lagmhor bywash back of Deer farm (ex Watson farm)	South Ashburton above North Branch confluence	Due to natural springs in the area this bywash has considerable flow in winter but during dry summers only 10 l s-1 for 90% of the time. Enters the South Ashburton in the vicinity of Shepards Brook. Effectively this bywash is natural spring flow not required in the regulated Lagmhor Creek flow. Therefore not part of the Langdons 120 l/s abstraction.	10 l/s but not Langdons in winter varies
7	DA63	L37:127-873	Smalls Race	Ashburton Mainstem below SH1	Estimated to be 1 l/s at Smalls Road, not sure if it reaches and discharges into the Main stem	0 - 1 l/s
8	DA64	L37:863-124	Anderson No 1 Terrace Road	Ashburton Mainstem below SH1	Estimated to be 1 l/s at Terrace Road, not sure if it reaches and discharges into Wheatstone Drain	0-1 l/s
9	DA65	L37:847-129	Anderson No 2 Terrace Road	Ashburton Mainstem below SH1	Estimated to be 1 l/s at Terrace Road, not sure if it reaches main stem	0-1 l/s
10	DA66	L37:840-130	Anderson No 3 Terrace Road	Ashburton Mainstem below SH1	Estimated to be 1 l/s at Terrace Road, not sure if it reaches main stem	0-1 l/s
11		L37:136-827	Anderson No 4 Terrace Road	Ashburton Mainstem below SH1	Estimated to be 1 l/s at Beach Road, seeps into gravel.	1 l/s
<b>Between Bowyers and South Branch</b>						
12	DA24	K36:817-215	Behind Mt Somers School	NA	Race does not exist	Na
13	DA49	K36:912-185	Bottom of Tramway Road	Taylor's above South Ashburton confluence	Maximum rate would be 10 l/s in winter. During summer the end of race flow reduces to zero.	summer zero Winter maximum 10 l/s

14	DA50	K36:920-177	Taylor's Bridge Thompsons Track	Taylor's above South Ashburton confluence	Never reaches the river	Zero
15	DA51	K36:855-231	Bowyers near Gorse Fence Road	Bowyers Stream	Never gets to the river, disappears into the paddocks	Zero
16	DA52	K36:901-175	Top of terrace	South Ashburton above Valetta	3 l/s drops off the terrace into gravel, with no direct contact with the stream	3 l/s
17	DA53	K36:887-172	Top of terrace	South Ashburton above Valetta	3 l/s drops off the terrace into gravel, with no direct contact with the stream	3 l/s
<b>Between Taylor's and Bowyers</b>						
18	DA6	K36:870-229	emergency bywash to Bowyers	Bowyers Stream	10 l/s continuously	10 l/s
<b>Between North Branch and Taylor's/South Branch</b>						
19	DA1	K36:938-177	McFarlanes into O'shea	O'Shea Creek	Approximately 2 l/s is continuously discharged into O'Shea Creek	2 l/s
20		K36:949-167	McFarlanes into O'shea	O'Shea Creek	Approximately 2 l/s is continuously discharged into O'Shea Creek	2 l/s
21	DA2	K36:924-200	irrigation race Alford Station	South Ashburton above North Branch confluence	Stockwater race discharges approx 8 l/s into this irrigation/stockwater race, however large quantities of spring flow also enters. The eventual discharge to the South Branch is considerable, it is unknown what portion of the original 8 l/s is bywashed.	0-8 l/s
22	DA3	K36:911-215	irrigation race Alford Station	South Ashburton above North Branch confluence	Stockwater race discharges approx 8 l/s into this irrigation/stockwater race, however large quantities of spring flow also enters. The eventual discharge to the South Branch is considerable, it is unknown what portion of the original 8 l/s is bywashed.	0-8 l/s
23	DA5	K36:913-201	emergency bywash to Taylor's	Taylor's above Bowyers confluence	Never used	zero
<b>North of North Branch and Main Stem Ashburton</b>						
24	DA72	K37:072-068	Winchmore near Waklin Road	North Ashburton above Digbys Bridge	Emergency bywash never used	zero
25	DA74	K37:042-100	Near Ollivers Road	North Ashburton above Digbys Bridge	Emergency bywash never used	zero
26	DA100	K37:074-029	North Ashburton - Mill creek	North Ashburton above Digbys Bridge	Never used	zero
27	DA103	L37:117-954	Mill Creek bywash	Ashburton Mainstem below SH1	Never used in summer, although some natural springs may discharge at this point Upstream springs increase flows in winter requiring bywash to occur.	zero

*34 l/s*

**Table 9.1 Low flow frequency**

River / Stream	Location	Period	7DMALF (m <sup>3</sup> s <sup>-1</sup> )	5 year 7DMALF (m <sup>3</sup> s <sup>-1</sup> )	10 year 7DMALF (m <sup>3</sup> s <sup>-1</sup> )
South Branch	Mt Somers	1967-1999	4.70	3.62	3.42
South Branch	Valetta Bridge	1982-1999	4.21	3.2	3.01
Taylor's	near confluence with the South Branch	1982-1999	1.08	0.07	0.03
South Branch	above confluence with the North Branch	1982-1999	9.17	7.13	6.8
North Branch	Old Weir	1982-1999	3.01	2.20	2.10
Pudding Hill	above Ashburton District Council abstraction	1965-1999	0.44	0.38	0.37
Mt Harding Creek	Aitken Road	1982-1999	0.95	0.78	0.75
O'Shea & Snowden		1982-1999	0.59	0.40	0.24
North Branch	Digby's Bridge	1982-1999	3.35	2.68	2.56
North Branch	above confluence with the South Branch	1982-1999	3.87	3.25	3.04
Ashburton	State Highway One	1982-1999	13.93	11.12	10.68

7DMALF = 7 day mean annual low flow

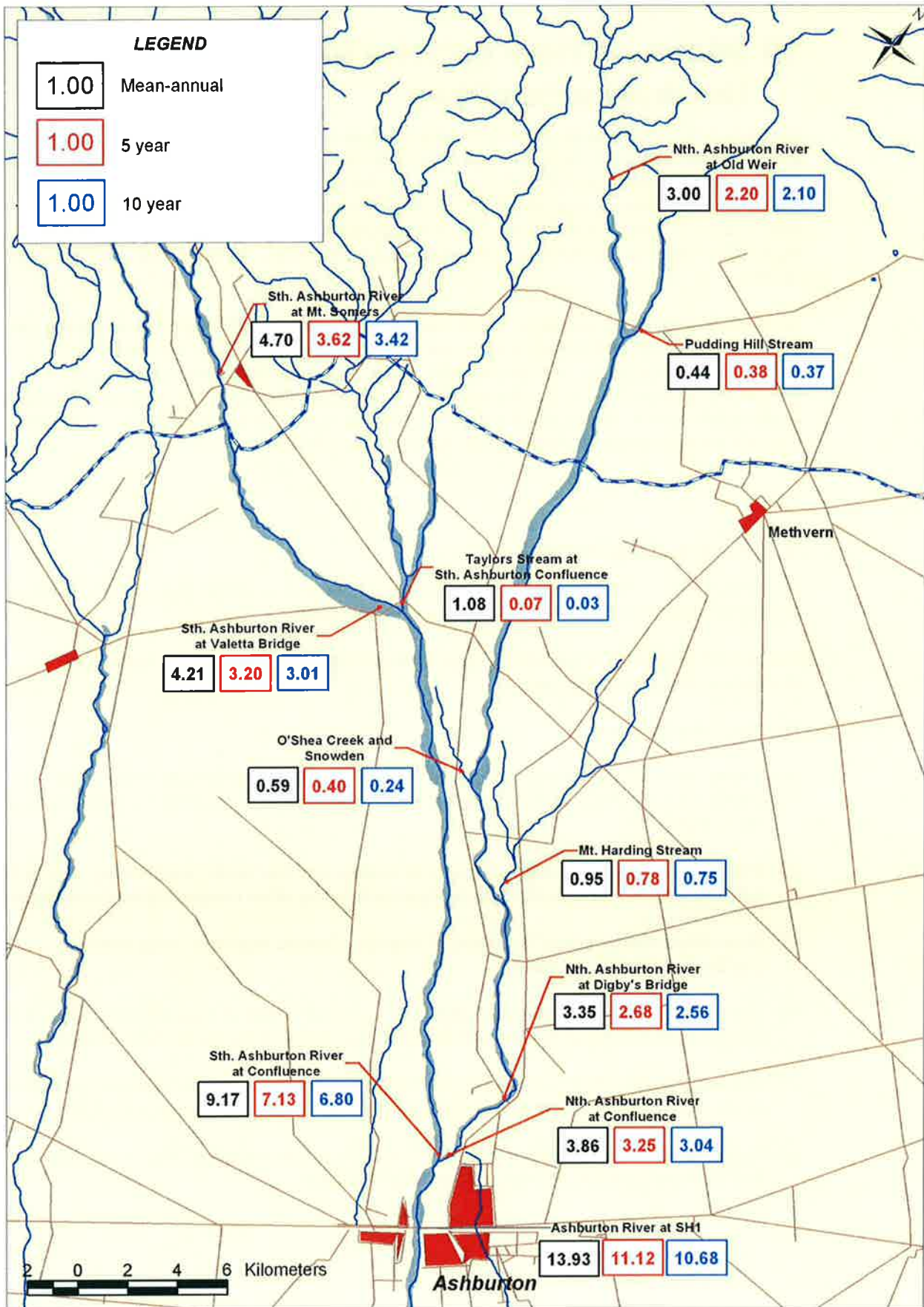


Figure 9.1 Frequency of 7 day mean annual low flow

## **10 Minimum flow options for management of the Ashburton River**

Minimum flow options suggested by the draft Natural Resources Regional Plan, Ashburton and Rangitata Instream Interest Group and Strategy 2000, appear on Figure 10.1. Important downstream residual flows at SH1 are also calculated and included; for the given minimum flow options an average abstraction of  $1.2 \text{ m}^3 \text{ s}^{-1}$  from the Ashburton South Branch downstream of Valetta is assumed. This includes the total Greenstreet surface water abstraction from the South Branch in preference to abstraction from O'Shea and Snowden Creeks.

None of the upstream minimums would result in the SH1 proposed minimum occurring, as the residuals do not balance to the proposed minimums (Figure 10.1). The NRRP and Ashburton and Rangitata Instream Interest Group proposed minimums would result in greater than the planned residual flows at SH1, whilst the Strategy 2000 proposed minimums would result in less than planned flows as a residual. It is fundamental that any upstream proposed minimums must balance with downstream minimums.

## **11 Conclusions**

Modifications have been made to the data sets that were used to calculate natural flows, largely as suggested by Richard de Joux and John Young.

Pudding Hill Stream and Lagmhor Creek are included for completeness although no changes were made in this review.

The main findings were:

- (1) The de Joux adjustment for Valetta losses had the greatest influence on the other downstream locations South Branch at North Branch confluence and the Ashburton main stem at SH1.
- (2) This review makes only slight changes to Taylors and the North Branch flows, due to the average abstraction rate changes being countered by other consent related corrections.
- (3) Regression analysis on O'Shea and Mt Harding Creeks improved using average (consented) abstraction rates.
- (4) The North Branch flows are described fully. However a lack of detailed knowledge of the groundwater system at the time of the field investigation detracts from the analysis.
- (5) Before abstraction it is considered that the North Branch flowed permanently over its full reach, and abstraction is the main reason why it is dry for extended periods today.
- (6) Proposed minimum flows in the draft Natural Resources Regional Plan do not balance with the residual flow required at State Highway One.

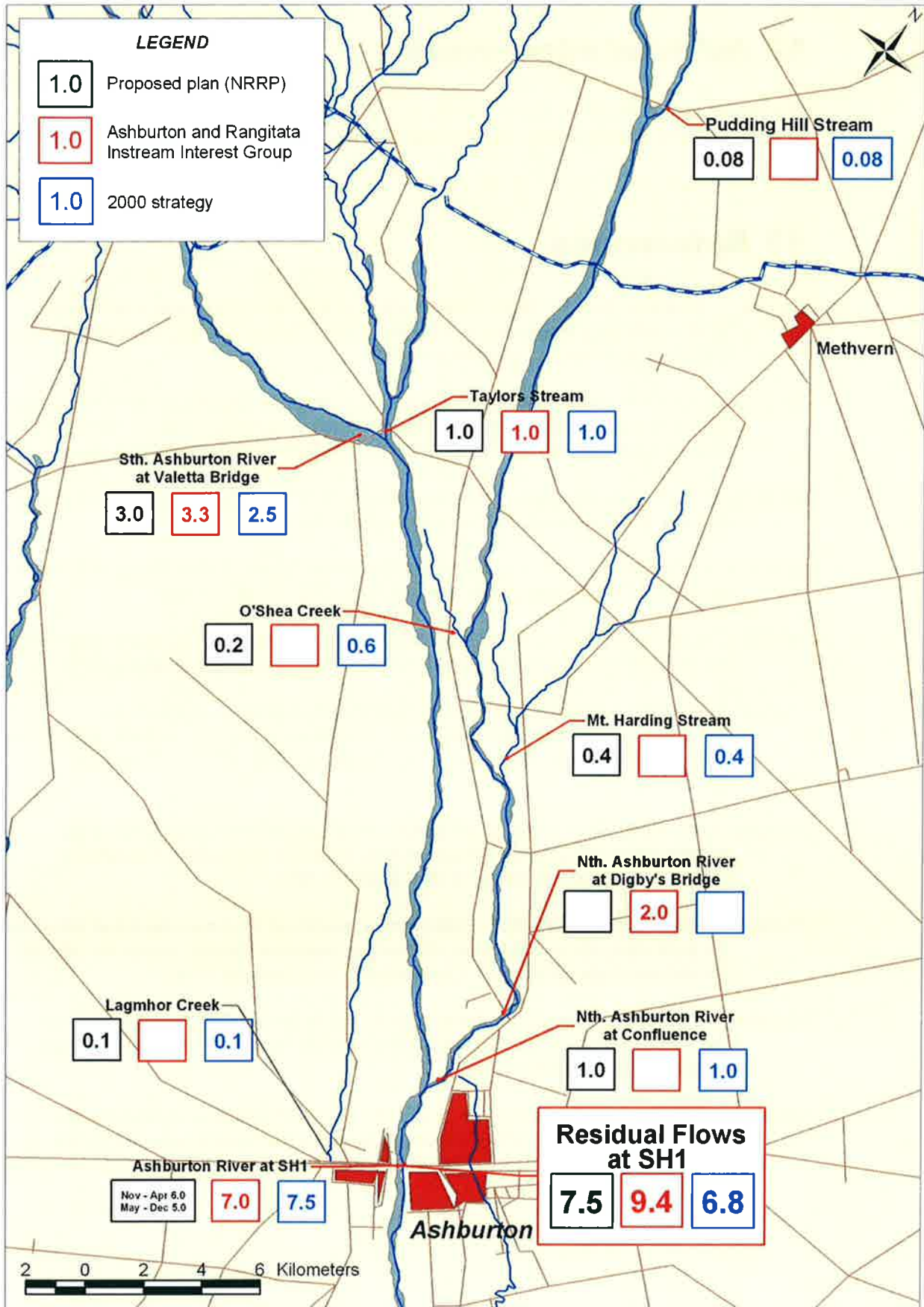


Figure 10.1 Minimum flow options for management of the Ashburton River

## 12 Acknowledgements

This report was reviewed by Richard de Joux, Frank Scarf, John Young, Suzanne Facer, Russell Sanders, Mandy Chater, and George Griffiths.

## 13 References

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- Leadley, B.W., 1952. *Stock water races in Ashburton County: their contribution to its development*. Unpublished Master of Arts. Thesis in Geography, Canterbury University College, University of New Zealand, 89 p.
- Pattle Delamore Partners Ltd, 1997. *Preliminary assessment of stream depletion effects in the Ashburton River Catchment*. Canterbury Regional Council, report No U96/49, Canterbury Regional Council, Christchurch, New Zealand, 57 p.
- Sanders, R., 1998. *Irrigation water use survey: report on the 1997/98 Irrigation Season*. Canterbury Regional Council Report No. U98/45, Canterbury Regional Council, Christchurch, New Zealand, 25 p.
- Scarf, F., 2003. Evidence submitted on behalf of Fish and Game New Zealand to the Hearing Committee deciding Rangitata Diversion Race Management Limited consent applications CRC 011245 CRC 011246 CRC 011247 CRC 011248, 10<sup>th</sup> to 24<sup>th</sup> February 2003, 28 p.

# Appendix 1 Data sets used in regressions

## Reviewed consented abstractions

### 1 South Branch downstream to Valetta Bridge

Purpose	Consent Number	Type	Rate $l\ s^{-1}$	Depletion rate $l\ s^{-1}$	Min flow condition
<b>Stock Water</b>					
ADC Lincoln Race(Brothers)	SCY 710033	Surface Water	gauged	NA	No
ADC Woolshed Creek	SCY 730026	Groundwater	5	5	No
RDR at Syphon	SCY690788	Surface Water	340	within RDR	No
ADC Stoney Creek	SCY 710044	Surface Water	113	NA	No
<b>Irrigation</b>					
RDR at Syphon	SCY690786	Surface Water	gauged	NA	Yes
Hammond N	CRC951604	Surface Water	73	NA	Yes
Ryan J	CRC952164	Surface Water	19	NA	Yes
Hydes S	CRC921499	Groundwater	5	4	No

### Seasonal assumptions applied to abstractions

Irrigation season total	=	Gauged RDR + ( 73 + 19 + 4 ) x 55% = RDR + 53 $l\ s^{-1}$
Stock Water	=	Gauged Lincoln +5 +113
Stock Water bywash	=	6 $l\ s^{-1}$
<b>Irrigation season abstraction</b>	=	<b>171 <math>l\ s^{-1}</math> + gauged Lincoln (default 1243) + RDR - bywash</b>
<b>Non-irrigation season abstraction</b>	=	<b>118 <math>l\ s^{-1}</math> + gauged Lincoln (default 1243) + RDR - bywash</b>



## Reviewed consented abstractions

### 2 Taylors and Bowyers Streams down to South Ashburton confluence

Purpose	Consent Number	Type	Rate l s <sup>-1</sup>	Depletion rate l s <sup>-1</sup>	Min flow condition
<b>Stock Water</b>					
ADC Bushside	SCY 710045	Surface Water	gauged	NA	No
ADC Durrans Carneys RD	SCY 730026	Surface Water	gauged	NA	No
ADC Goughs	SCY710048	Surface Water	gauged	NA	No
ADC Alford Forest	SCY710047	Surface Water	42	NA	No
<b>Irrigation</b>					
Allen C J	CRC950885	Surface Water	gauged	NA	Yes
Allen C J	CRC972504	Surface Water	gauged	NA	Yes
Ron Cocks	CRC950930	Surface Water	gauged	NA	Yes
Hydes S K	CRC921499	Groundwater	33	25	No
Allen C J	CRC950931	Surface Water	gauged	NA	Yes
Hydes S K	CRC951862	Surface Water	12	NA	Yes

#### Seasonal assumptions applied to abstractions

Irrigation season total	=	37 x 55% + gauged takes = gauged takes + 20 l s <sup>-1</sup>
Stock Water	=	3 gauged + 42
Stock Water bywash	=	10 l s <sup>-1</sup>
<b>Irrigation season abstraction</b>	=	<b>62 l s<sup>-1</sup> + gauged stockwater and irrigation takes - bywash</b>
<b>Non-irrigation season abstraction</b>	=	<b>gauged stockwater takes + 42 - bywash</b>

### Taylor's at South Branch Confluence Dataset

Flows in Litres per second (l s<sup>-1</sup>)

Date	Recorder		Abstractions						ADC bywash	Gauged	
	Old Weir (6 am)	Hillview GW (negative)	ADC Durrans <i>Consented</i>	ADC Bushside <i>Consented</i>	ADC Goughs <i>Consented</i>	Ungauged stockwater Alford forest	Allen/Cocks	ungauged irrigation		residual at Confluence with South Br	Residual + abstractions - bywash
			42	141	142	42					
* 50495	3428	.	75	79	27	42	51	17	10	2310	2591
* 190495	7817	.	40	81	35	42	128	17	10	2523	2856
60296	4844	.	83	68	14	42	923	20	10	1002	2142
200396	8313	3640	98	46	44	42	113	20	10	3579	3932
220396	5462	3640	73	75	45	42	96	20	10	3133	3474
270396	4756	3650	55	52	53	42	103	20	10	2620	2935
290396	4589	3650	52	45	42	42	99	20	10	2430	2720
91297	4676	5271	49	52	25	42	53	20	10	672	903
210198	3286	5740	63	51	14	42	277	20	10	153	610
* 40298	2576	5900	64	55	15	42	39	17	10	7	229
260298	3287	6111	56	49	16	42	617	20	10	22	912
* 50398	2358	6188	53	49	6	42	104	17	10	7	268
260398	3889	6253	62	52	14	42	12	20	10	359	551
70498	5385	6394	59	48	15	42	115	20	10	698	987
290498	5902	6639	58	65	18	42	637	20	10	1026	1856
240698	4080	5577	71	63	18	42	8	0	10	1970	2162
160798	7037	3976			average of three 145	42	0	0	10	3540	3717
220798	5464	4030			145	42	0	0	10	2274	2451
40898	10100	4203			145	42	0	0	10	3117	3294
51098	6008	5260	56	55	12	42	17	20	10	1291	1483

\* 50% restriction

366 Consented

**Reviewed consented abstractions**

**3 South Branch from Taylors confluence down to North Branch confluence**

Purpose	Consent Number	Type	Rate l s <sup>-1</sup>	Depletion rate l s <sup>-1</sup>	Min flow condition
<b>Stock Water</b>					
ADC	SCY690644	Groundwater	269	128	No
ADC <i>Langdons Mt (Spring)</i>	SCY710035	Surface Water	42	included in 120 l/s	No
ADC <i>Langdons Creek</i>	CRC980746	Surface Water	120	NA	No
ADC	SCY710050	Surface water	4247	Never used	No
<b>Irrigation</b>					
Delos Farm Limited	CRC921798	Groundwater	25	21	No
Greenstreet irrigation	CRC921550A	Groundwater	6	6	No
Greenstreet irrigation	CRC921550G	Groundwater	5	2	No
Stewart D	CRC920653	Groundwater	11	2	No
Aschen D	CRC951747	Surface Water	10	NA	Yes
Ashburton Contracting	CRC960507	Surface Water	3	NA	No
Greenstreet irrigation	CRC921547C	Surface Water	gauged	NA	Yes
Greenstreet irrigation	CRC921547H	Surface Water	47	NA	Yes
Greenstreet irrigation	CRC921547J	Surface Water	26	NA	Yes
Scott D	CRC952061	Surface Water	54	NA	Yes
Tait R	CRC951956	Surface Water	25	NA	Yes
Greenstreet irrigation	CRC921550D	Groundwater	1	1	No
Greenstreet irrigation	CRC921550E	Groundwater	6	3	No

*recently, 2006 deformed*

**Seasonal assumptions applied to abstractions**

Irrigation season total = (200 x 55%) + gauged Greenstreet take = gauged Greenstreet + 110 l s<sup>-1</sup>

Stock Water = 248 l s<sup>-1</sup>

Stock Water bywash = 10 l s<sup>-1</sup>

**Irrigation season abstractions = 358 l s<sup>-1</sup> + gauged Greenstreet Take - bywash**

**Non-irrigation season abstractions = 248 l s<sup>-1</sup> - bywash**

### South Branch at North Branch Confluence Dataset

Flows in Litres per second ( $l\ s^{-1}$ )

Date	Recorder	Taylors at Confluence	Greenstreet	Abstractions		ADC	Gauged	
	Valetta (6 am)			ungaugged irrigation	ungaugged stockwater	bywash	residual at Confluence with North Br	Residual + abstractions - bywash
* 4/02/1998	1651	7	430	66	248	10	2968	3702
26/02/1998	891	22	497	110	248	10	2960	3805
* 5/03/1998	1447	7	100	66	248	10	3382	3786
26/03/1998	486	359	247	110	248	10	2912	3507
7/04/1998	936	698	282	110	248	10	4333	4963
29/04/1998	3658	1026	394	110	248	10	7473	8215
24/06/1998	1285	1970	0	0	248	10	6329	6567
5/10/1998	1795	1291	300	110	248	10	5935	6583
23/03/1999	455	1603	77	110	248	10	3588	4013
26/03/1999	4421	5664	83	110	248	10	14326	14757

Ga. 2.

2044

2892

2332

2662

3329

3531

3312

3497

1955

4672

3022 average

\* 50% restriction

## Reviewed consented abstractions

### 4 North Branch from Gorge down to South Branch confluence

Purpose	Consent Number	Type	Rate l s <sup>-1</sup>	Depletion rate l s <sup>-1</sup>	Min flow condition
<b>Stock Water</b>					
ADC Pudding Hill	SCY710052	Surface water	Gauged	NA	No
ADC	SCY710058	Groundwater	18	15	No
ADC Melrose	SCY690643	Groundwater	41	25	No
ADC McFarlanes Tce	SCY710049	Surface water	84	NA	No
ADC Rawles Crossing	SCY710051	Surface water	226	Never used	No
ADC Methven Auxillary	SCY710053	Surface water	Gauged	NA	No
ADC Winchmore Main	SCY710054	Surface water	Gauged	NA	No
ADC Mill Intake	SCY710055	Surface water	283	No longer used	No
ADC Winchmore Sub Main	SCY710054	Surface water	190	estimated	No
ADC	SCY690644	Groundwater	6	4	No
ADC below SH72	SCY800153	Groundwater	25	23	No

### Irrigation

#### North Branch Main stem

Aschen B R	CRC951596	Groundwater	8	7	No
Aschen D G	CRC951553	Groundwater	12	10	No
Brown J	CRC922073	Groundwater	22	14	No
Champion Farms LTD	CRC921498	Groundwater	13	7	No
Champion Farms LTD	CRC921676	Groundwater	7	3	No
Champion Farms LTD	CRC921677	Groundwater	16	10	No
Clark W G	CRC970931	Groundwater	4	3	No
Greenstreet irrigation	CRC921550D	Groundwater	25	11	No
Greenstreet irrigation	CRC921550E	Groundwater	17	8	No
Greenstreet irrigation	CRC921550F	Groundwater	2	1	Yes
Greenstreet irrigation	CRC921550G	Groundwater	12	5	No
Mcllroy B K	CRC922038	Groundwater	11	5	No
Shearer D	CRC921565A	Groundwater	6	6	No
Shearer D	CRC921565B	Groundwater	1	1	Yes
Southmark Horticulture	CRC921494	Groundwater	13	8	No
Stewart D	CRC920653	Groundwater	6	1	No
Willowdale Farm Limited	CRC921678	Groundwater	17	13	No
Galloway C	CRC952441	Surface water	62	NA	Yes
Leslie B G	CRC960065	Surface water	360	Water not removed	No
Lowe G A	CRC951934	Surface water	72	NA	Yes
Shearer D	CRC951530	Surface water	9	NA	Yes

Willowdale Farm Limited	CRC951232	Surface water	17	NA	Yes
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**Mt Harding Stream**

Clark W G	CRC970931	Groundwater	41	29	No
Shearer D	CRC921565A	Groundwater	9	9	No
Shearer D	CRC921565B	Groundwater	14	14	Yes
Ashburton Lyndhurst	CRC990718	Surface water	114	NA Rangitata water	No
Methven Golf Club	SCY880013	Surface water	24	NA	Yes
Rooney M	CRC951486	Surface water	9	NA	Yes

**Osheas Creek**

Aschen B R	CRC951596	Groundwater	14	12	No
Aschen D G	CRC951553	Groundwater	37	31	No
Champion Farms LTD	CRC921498	Groundwater	13	7	No
Champion Farms LTD	CRC921676	Groundwater	10	4	No
Champion Farms LTD	CRC921677	Groundwater	13	8	No
Greenstreet irrigation	CRC921550A	Groundwater	18	18	No
Low N	CRC921447	Groundwater	44	11	No
Snowden R	CRC950584	Groundwater	32	32	Yes
Greenstreet irrigation	CRC921547F	Surface water	gauged	NA	Yes

**Seasonal assumptions applied to abstractions**

Irrigation season total = (481 x 55%) + gauged Greenstreet take = 265 l s<sup>-1</sup> + Greenstreet take  
 Stock Water = 341 + gauged Pudding Hill, Methven Auxillary, Winchmore Main

Stock Water bywash = 4 l s<sup>-1</sup>

**Irrigation season abstraction = 606 l s<sup>-1</sup> + gauged takes, Pudding Hill, Methven Auxillary, Winchmore Main, Greenstreet Irrigation - bywash**

**Non-irrigation season abstraction = 341 l s<sup>-1</sup> + gauged takes, Pudding Hill, Methven Auxillary, Winchmore Main - bywash**

**North Branch at South Branch Confluence Dataset**

Flows in litres per second (l s<sup>-1</sup>)

Date	Recorder	Abstractions						Bywash			residual at Sthbr conflu	correct flow at South Confl	Nth branch at sth con + takes
	Old Weir	Pudding Hill	Methven Aux	Greenstreet	Winchmore Main	ungauged irrigation	ungauged stockwater	lateral spill	ADC	Greenstreet			
	Daily mean		1113					Coniston					
* 40298	2551	258	1195	695	289	224	341	28	4		320	288	3290
260298	3111	342	937	529	208	265	341	22	4		516	490	3112
* 50398	2352	255	1168	435	178	224	341	40	4		270	226	2827
260398	3849	399	1248	882	203	265	341	25	4		270	241	3579
70498	5275	353	1166	612	206	265	341	79	4		430	347	3290
290498	5521	540	1145	666	232	265	341	1218	4		2360	1138	4327
240698	4014	458	1164	0	276	0	341	0	4		284	280	2519
51098	5838	495	1068	892	100	265	341	1332	4		3878	2542	5703
*200199	2620	217	1285	651	298	224	341	28	4		270	238	3254
290199	2596	405	1448	gain 109	260	265	341	0	4		170	166	2776
50299	2684	370	1272	593	339	265	341	0	4		184	180	3360
110299	2544	359	1507	485	428	265	341	7	4		143	132	3517
250299	2120	243	1514	gain 84	200	265	341	0	4		110	106	2585
* 90399	2318	452	1329	399	361	224	341	0	4		115	111	3217
230399	3595	433	1108	709	375	265	341	0	4		207	203	3434
260399	4749	375	1192	662	319	265	341	0	4		1428	1424	4578
211299	6446	447	1155	857	533	265	341	121	4	381	2317	1811	5409
290200	4299	407	1223	824	334	265	341	51	4	536	624	33	3427

# 25% restriction  
 \* 50% restriction

378av18 2204  
 1 229av  
 5109  
 Av 285

4-29-04

## Reviewed consented abstractions

### 5 Between the North and South Confluences and State Highway One

Purpose	Consent Number	Type	Rate l s <sup>-1</sup>	Depletion rate l s <sup>-1</sup>	Min flow condition
<b>Irrigation</b>					
Ashburton Contracting	CRC921485	Groundwater	7	6	No
Brook G T	SCY820104	Groundwater	9	8	No
Donaldson F L	SCY690106	Groundwater	13	5	No
Watson P	CRC921407	Groundwater	58	28	No
Ashburton Woolscour	SCY690426	Groundwater	3	1	No
Bennett R	CRC921449	Groundwater	2	2	Yes
Lynn Consolidated	SCY700015	Groundwater	3	1	No

#### Seasonal assumptions applied to abstractions

Irrigation season total = 51 l s<sup>-1</sup> x 0.55 = 28 l s<sup>-1</sup>

**Irrigation season  
abstraction = 28 l s<sup>-1</sup>**

**Non-irrigation season = 0 l s<sup>-1</sup>  
abstraction**

**Ashburton at SH1 Dataset**

Flows in Litres per second (l s<sup>-1</sup>)

Date	South Branch at confluence	North branch at confluence	Combined South and North Branch flows	Abstractions		gauged	
				ungauged irrigation	ungauged water supply	Ashburton at SH1	Ashburton at SH1 + takes
3/04/1996	6703	752	7455	28	0	8200	8228
*4/02/1998	2968	320	3288	14	0	3751	3778
26/02/1998	2960	516	3476	28	0	3656	3684
*5/03/1998	3382	270	3652	14	0	3616	3643
26/03/1998	2912	270	3182	28	0	3541	359
7/04/1998	4333	430	4763	28	0	4846	4874
29/04/1998	7473	2360	9833	28	0	9318	9346
24/06/1998	6329	284	6613	0	0	6767	6767
5/10/1998	5935	3878	9813	28	0	10496	10524
23/03/1999	3588	207	3795	28	0	4222	4260
26/03/1999	14326	1428	15754	28	0	16674	16702
21/12/1999	6738	2196	8934	28	0	10274	10302
29/02/2000	4513	573	5086	28	0	5126	5154

\* 50 % restriction

## Reviewed consented abstractions

### 6 Between Digbys Bridge and the North Branch Confluence with the South

Purpose	Consent Number	Type	Rate l s <sup>-1</sup>	Depletion rate l s <sup>-1</sup>	Min flow condition
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#### Stockwater

ADC Rawles Crossing	SCY710051	Surface water	226	never used	No
ADC Mill intake	SCY710055	Surface water	283	no longer used	No

#### Irrigation

Greenstreet Irrigation	CRC921550D	Groundwater	25	11	No
Greenstreet Irrigation	CRC921550E	Groundwater	17	8	No
Mcllroy B.K	CRC922038	Groundwater	11	5	No
Greenstreet Irrigation	CRC921550F	Groundwater	2	1	No
Greenstreet Irrigation	CRC921550G	Groundwater	12	5	No
Stewart D	CRC920653	Groundwater	6	1	No

#### Seasonal assumptions applied to abstractions

Irrigation season total =  $31 \text{ l s}^{-1} \times 0.55 = 17$

Irrigation season  
abstractions =  $17 \text{ l s}^{-1}$

Non-irrigation season =  $0 \text{ l s}^{-1}$   
abstractions

**North Ashburton at Digbys Bridge Dataset**

Flows in Litres per second (l s<sup>-1</sup>)

Date	gauged	Takes	gauged	Coniston Waste race (subtract from confluence)	<i>Corrected</i>
	North Branch at Digbys Bridge	ungauged irrigation (add to confluence)	North Ashburton at South Confluence Residual		<del>Natural</del> North Branch at South confluence
18/07/1974	5060	0	5540	0	5540
* 20/01/1999	0	17	242	28	231
26/03/1999	899	17	1428	0	1445
21/05/1999	0	0	405	0	405
23/06/1999	2044	0	2413	0	2413
25/06/1999	1352	0	1778	0	1778
30/06/1999	178	0	678	0	678
21/12/1999	1331	17	2196	121	2092
29/02/2000	0	17	573	51	539

\* 50% restriction

## Consented abstractions

### 7 Mt Harding

Purpose	Consent Number	Type	Rate l s <sup>-1</sup>	Depletion rate l s <sup>-1</sup>	Min flow condition
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#### Stock Water

ADC Winchmore Main	SCY710054	Surface water	Gauged	NA	No
ADC Winchmore Sub Main	SCY710054	Surface water	190	estimated	No

#### Irrigation

Clark W G	CRC970931	Groundwater	41	29	No
Shearer D	CRC921565A	Groundwater	9	9	No
Shearer D	CRC921565B	Groundwater	14	14	Yes
Ashburton Lyndhurst	CRC990718	Surface water	114	NA Rangitata water	No
Methven Golf Club	SCY880013	Surface water	24	NA	Yes
Rooney M	CRC951486	Surface water	9	NA	Yes

#### Seasonal assumptions applied to abstractions

Irrigation season total = (85 x 55%) = 47 l s<sup>-1</sup>  
 stock water = gauged Winchmore Main and estimated Winchmore Sub Main

**Irrigation season abstraction = 47 l s<sup>-1</sup> + Gauged Winchmore Main and estimated Sub Main abstraction**

**Non-irrigation season abstraction = Gauged Winchmore Main and estimated Sub Main abstraction**

<b>Mt Harding dataset</b>				Flows in litres per second (l s <sup>-1</sup> )			
Date	Abstractions			Mt Harding residual	Mt Harding Natural flow	GW44 Forks	Recorder
	Winchmore Main	Winchmore Sub main estimate	ungauged irrigation				Old Weir Daily mean
51098	100	190	47	954	1291	-1790	5838
* 200199	298	190	34	184	706	-1613	2620
290199	260	190	47	416	913	-1728	2596
50299	339	190	47	261	837	-1772	2684
110299	428	190	47	371	1036	-1777	2544
250299	200	190	47	123	560	-1941	2120
* 90399	361	190	34	398	983	-1831	2318
230399	375	190	47	436	1048	-1612	3595
260399	319	190	47	693	1249	-1397	4749
211299	533	190	47	775	1545	-1520	6446
290200	334	190	47	733	1304	-1665	4299

\* 50% restriction

## Consented abstractions

### 8 O'Shea and Snowdon

Purpose	Consent Number	Type	Rate l s <sup>-1</sup>	Depletion rate l s <sup>-1</sup>	Min flow condition
<b>Stock Water</b>					
ADC	SCY690644	Groundwater	6	4	No
<b>Irrigation</b>					
Aschen B R	CRC951596	Groundwater	14	12	No
Aschen D G	CRC951553	Groundwater	37	31	No
Champion Farms LTD	CRC921498	Groundwater	13	7	No
Champion Farms LTD	CRC921676	Groundwater	10	4	No
Champion Farms LTD	CRC921677	Groundwater	13	8	No
Greenstreet irrigation	CRC921550A	Groundwater	18	18	No
Lowe N	CRC921447	Groundwater	44	11	No
Snowden R	CRC950584	Groundwater	32	32	Yes
Greenstreet irrigation	CRC921547F	Surface water	gauged	NA	Yes

#### Seasonal assumptions applied to abstractions

Irrigation season total = (123 x 55%) + gauged Greenstreet take = 68 l s<sup>-1</sup> + Gauged Greenstreet

Stock Water = 4 l s<sup>-1</sup>

Stock water bywash = 4 l s<sup>-1</sup>

**Irrigation season abstraction = 72 l s<sup>-1</sup> + gauged Greenstreet take - bywash**

**Non-irrigation season abstraction = 0 l s<sup>-1</sup>**

**O'Shea and Snowden Dataset**

Flows in litres per second (l s-1)

Date	Abstraction from South Branch	Greenstreet take Recorded	Residual to North Branch	O'Shea & Snowden abstraction to Greenstreet	Ungauged irrigation	Ungauged stock water	stock water bywash	O'Shea & Snowden natural flow	North Branch Old Weir
* 20/01/1999	159	810	12	651	68	4	4	731	2659
29/01/1999	174	65	588	0	68	4	4	547	2631
5/02/1999	103	696	31	593	68	4	4	696	2693
11/02/1999	107	592	33	485	68	4	4	590	2570
25/02/1999	123	39	506	0	68	4	4	490	2084
* 9/03/1999	608	1007	34	399	68	4	4	501	2256
23/03/1999	77	786	58	709	68	4	4	835	2723
26/03/1999	83	745	255	662	68	4	4	985	4889
21/12/1999	14	871	24	857	68	4	4	949	6673
29/02/2000	87	911	19	824	68	4	4	911	4311

\* 50 % restriction



## **Appendix 2 Review: Horrell, G A, 2001. Ashburton River Low Flow Regime**

Type in **red** is included for discussion within this report.

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### **Review:**

**Horrell G A. 2001. Ashburton River Low Flow Regime**

**Environment Canterbury Report No. U01/26**

### **Introduction**

This review has been requested by RDR Management Ltd. to assist in the preparation of comments and submissions on the minimum flow requirements specified within the report. Although RDR Management Ltd will be primarily concerned with the report's conclusions for the South Branch Ashburton River, the assumptions and conclusions made for predicting "natural" flows throughout the entire river catchment have also influenced the recommended flow sharing regimes throughout the catchment, which will also impact on the ability of RDR Management Ltd. to maintain a reliable water supply during the irrigation season.

The report contains valuable water resource information and summarises flow measurements taken at numerous locations within the catchment. In this respect, the report is a useful summary of the existing knowledge of the hydrology of the Catchment. Using that data, an attempt is then made to determine what the natural flow regime of the Ashburton River would be if there were no abstractions of surface water or groundwater. A brief review of various factors that may have altered the river flow pattern, such as changes in climate and rainfall, is made.

However, the hydrology and flow profiles within the various tributaries today are a direct response to the factors that affect runoff and river flow within the present catchment. There is ample evidence to show that the catchment has undergone significant modification since the late 1880's, and that changes in land use, river control works, wetland drainage and vegetation clearance have all altered the hydrology and flow profile within the catchment. In the absence of historical data, efforts to predict historical flow patterns cannot be verified. Regardless of any historical flow patterns, the hydrology of the river today is a product of the present day rainfall, land uses, abstractions and modified river channels.

### **Methodology used**

An estimation of the natural flow record of the tributaries of the Ashburton River has been made using a series of flow measurements carried out concurrently at various sites within each river tributary. Most of the gauging data used has been collected recently (ie 1999 to 2001) by Environment Canterbury. There is also historic gauging data available since 1972 (South

Canterbury Catchment Board records), but with the exception of one gauging carried out on the North Ashburton at Digbys Bridge, that data is not used in the analyses.

In attempting to determine the “natural flow”, Horrell uses the basic assumption that :

*Natural flow at downstream site = measured flow at downstream site + all upstream abstractions*

This supposition does not take into account the pattern of flow gains or losses within various sections of the river, and is at variance with the reports’ own statements within section 2.2.2 that “...there may be losses where gains were calculated, e.g. the gain between Shearers and Ollivers created by one inflow (Mt Harding Creek)”. The report notes in section 2.1.4.1 that “Therefore to add all takes to the residual flow is not totally correct as some of this surface flow without abstractions may actually be lost to the groundwater system.” Despite that statement, the methodology used makes no attempt to adjust for any such losses. Logically, if water is being lost within a reach, then only a portion of any upstream abstraction can be assumed to reach any downstream site. This is a major flaw in the analyses that, in conjunction with errors in assessing abstraction rates at various locations, leads to a gross overestimation of the natural flow rates within the system.

For the South Ashburton reach between Mt Somers recorder and Valetta Bridge the analysis attempts to account for abstractions either by direct measurement (eg RDR abstraction and ADC Sth Ashburton Main intake) or by assuming 55% of the authorised abstractions (this was applied even when irrigation restrictions were imposed, eg 07/04/98, 29/04/98, 01/02/99). However, no attempt is made to account for the inflows from both Woolshed Creek and Stony Creek, which have a combined inflow in excess of all of the consented abstractions apart from RDR and ADC. The analysis fails to make allowance for the considerable losses to groundwater between the RDR and the Valetta Bridge, and merely assumes that the total flow rate of all of the upstream abstractions would occur at Valetta under “natural” conditions.

The comment is made in section 2.1.1 that “in winter the natural record matches closely to that actually recorded”. This comment raises concerns over the validity of the methodology and assumptions used, because the only difference between “winter” and “summer” demand is 124 l/s attributed to irrigation season abstractions<sup>1</sup> (table 1, appendix 2)<sup>2</sup>. Given the relatively small irrigation demand of 124 l/s, there is no reason why the “natural” flow relation should provide a better prediction of winter flows than summer ones.

The analyses used for Taylors and Bowyers Streams introduce an additional source of data error and uncertainty by attempting to derive a relation between those tributaries, depths to groundwater at Hill View and the flow in the North Ashburton. While the report recognises that this approach introduces errors in the analysis, there is no attempt to modify the results obtained from the analysis.

It is not appropriate to use a relatively short period of recent groundwater data for the purposes of predicting a longer term natural flow. The report refers to the significant amount of wetlands within Bowyers and Taylors Stream that have been drained since 1980. It is reasonable to expect that this drainage has also affected depths to groundwater within the area, and to also have affected the previous relation between the depth to groundwater and surface water flow.

The North Ashburton River has a very complex hydrology, and this is adequately described and acknowledged in section 2.1.4.1 of the report. The acknowledgement in that section that the

uncertainties over the hydrology detracts from the accuracy of the natural flow model are unfortunately not reinforced later in the report. No account has been taken of the fact that a significant portion of the flow in Mt Harding Creek is sourced from water outside the North Ashburton River (ie the water did not flow past the North Ashburton flow recorder site).

The configuration of groundwater contours both to the north and south of the North Ashburton River clearly show that surface water flows into the surrounding aquifers, which results in a permanent loss of water from the river. The assumption that all of the water at the upper part of the river will be present at the lower end is not justified and is technically incorrect.

The analysis of the North Ashburton River concentrates on the available flow at the bottom end of specific reaches without having regard to the pattern of flow losses or gains within those reaches. There is reference to this in section 2.2.2 of the report, which describes the reach between Shearers Road and Ollivers Road. The report refers to an overall gain of flow in this section, and refers to it in Figure 2.5 as having a gain of 870 l/s. On every occasion when there were sufficient flow gaugings carried out, the reach between Shearers Road (which is downstream of O'Sheas Creek confluence) and Ollivers Road losses water<sup>3</sup>. This loss is despite the inflow of Mt Harding Creek (which obtains at least ½ of its flow from water outside the Nth Ashburton river).

Any attempt to predict downstream river flows must take account of the actual rates of gain or loss within each river reach. The analysis carried out in the report fails to do so. The conclusion of the report that the North Ashburton would not go dry under “natural” conditions is inevitable because of the simple assumption that the downstream flow equals the upstream flow plus all abstractions.

### **Errors within the report**

Errors within the report include an

- o Overestimation of abstraction rates from various locations;
- o A failure to account for inflows of water from tributaries that do not flow past the South and North Branch flow recorder sites;
- o Failure to ascertain whether abstractions were actually occurring at the time of flow measurements;

An attempt has been made to account for irrigation abstractions by assuming that they are exercised for 55% of the time. However, this assumption has been applied during times when irrigation restrictions were imposed and a complete ban on abstraction was in place. A number of the larger flow rates of abstraction are for border dyke systems that only allow for a limited number of hours per return period (ie they are not continuous takes at the maximum flow rate).

A more reasonable approach would have been to use the equivalent continuous flow rate, however even this provides an overestimation if the flow gaugings were carried out at a time when these consents were not being exercised.

There are a number of technical errors within the datasets presented in Appendix 2 of the report. These include:

#### **South Branch to Valetta**

- o Webbs Transport consent CRC921562, 30 l/s is located upstream of the Mt Somers

recorder.

o H Hammond CRC951604 flow rate of 180 l/s is only permitted for 9.8 hours per day, the average flow rate of 73 l/s should have been used in the calculations.

o Abstractions were on total restriction during the South Branch flow measurements on 7/04/98 and 29/04/98, and partial restrictions for 1/02/99. This has not been allowed for in the subsequent calculations.

o Total irrigation season use should be  $(119 \text{ l/s} \times 55\%) + 118 \text{ l/s} = 184 \text{ l/s}$  (not 257 l/s)

### **South Branch from Taylor to North Branch confluence**

o D Ashcen CRC951747 flow rate of 240 l/s is only permitted for 31 hours per month, the average flow rate of 10 l/s should have been used in the calculations.

o Greenstreet Irrigation CRC921547H flow rate of 230 l/s is only permitted for 34 hours per week, the average flow rate of 47 l/s should have been used in the calculations.

o Greenstreet Irrigation CRC921547J flow rate of 230 l/s is only permitted for 19 hours per week, the average flow rate of 26 l/s should have been used in the calculations.

o Total irrigation season use should be  $(285 \text{ l/s} \times 55\%) + 128 \text{ l/s} = 285 \text{ l/s}$  (not 624 l/s)

### **North Branch from gorge to South Branch confluence**

o There is no allowance made for the contribution of flow within Mt Harding Creek that is sourced from outside the North Ashburton riverbed. During summer time, a significant portion of Mt Harding Creek is derived from water that did not pass the North Ashburton flow recorder site.

o G Galloway CRC952441 flow rate of 240 l/s is only permitted for 43 hours per week, the average flow rate of 62 l/s should have been used in the calculations.

o B Leslie CRC952441 flow rate of 240 l/s is a non-consumptive use of water for a salmon farm. The water is not abstracted from the river and should not be used in the calculations.

o G Lowe CRC942232 flow rate of 341 l/s is only permitted for 157 hours per 31 days, the average flow rate of 72 l/s should have been used in the calculations.

o Ashburton Lyndhurst CRC990718 flow rate of 114 l/s from Mt Harding Creek can only be exercised while the equivalent rate of water is being discharged from the irrigation scheme races into the Creek upstream of the abstraction point. There is no gross abstraction from the creek and the flow rate should not be used in the calculations.

o Total irrigation season use should be  $(554 \text{ l/s} \times 55\%) + 141 \text{ l/s} = 305 \text{ l/s}$  (not 952 l/s)

The consequence of the above errors is to grossly overestimate the amount of water that was abstracted from the system – in effect it is adding in water that does not exist.

### **Conclusion**

The analyses and assumptions used have introduced a large number of uncertainties that, for the most part, may never be adequately resolved. The greatest cause of uncertainty is the assumption that any water abstracted within the upper catchment would have remained “instream” and would have been present at the lower end of the river reaches.

The conclusion in respect of the North Ashburton River is not supported with adequate scientific evidence. Rather it is based on suppositions and anecdotal information. This provides an overestimation of the “natural” flow rate and an unrealistically high expectation from environmental groups that the residual flows within the River and its tributaries are actually achievable and will significantly improve the instream habitat through the implementation of the proposed minimum flow regime.

Reviewed by :

R T de Joux, Environmental Consultancy Services Ltd

J R Young, RDR Management Ltd

<sup>1</sup> Stockwater abstractions remain constant throughout the year. RDR demand for water from the Sth Ashburton is also relatively constant throughout the winter period because of the seasonally lower flows in the Rangitata River.

<sup>2</sup> Webbs Transport consent for the abstraction of water is located upstream of the Mt Somers recorder, and should therefore not be included in the assumed stockwater component of the analysis.

<sup>3</sup> The reach from Shearers Road to immediately above the Mt Harding Creek junction losses significant quantities of water.



## Appendix 3 Natural River Flows (Section 2.1, Horrell, 2001)

Precise reconstruction of natural river flows is impossible owing to changes to the natural system that have occurred. These include:

- stockwater takes
- surface irrigation takes (Rangitata Diversion Race (RDR) takes sometimes include power generation)
- groundwater irrigation and domestic takes
- draining of wetlands
- possible recharge to the groundwater system from border dyke irrigation
- lateral bywash from the RDR and Greenstreet Irrigation Scheme back to the river
- willow plantings
- narrowing of river channels for flood protection works
- stockwater re-entering the river

The above all effect the surface water flows as well as the groundwater system that is recharged by, or discharges into, the river (Figure 3.1).

A precise analysis would require:

- waterlevel recorders at all potential minimum flow locations
- monitoring of groundwater levels in all the various groundwater systems
- records of volumes of border dyke irrigation applied spatially and in time over the total area
- all surface water stockwater and irrigation takes monitored on a daily basis
- all groundwater domestic and irrigation takes monitored
- monitoring of irrigation scheme and stockwater bywash back to the river

The cost of these measurements is well beyond the funding capability of Environment Canterbury, so a less rigorous method was employed to estimate natural flows.

The method involved measuring concurrent river flows at various locations for a range of summer flows, coupled with spot measurements of stockwater takes and major irrigation takes. A data set of surface water and groundwater consented takes between the selected river locations was compiled.

Two assumptions were made about how to treat irrigation takes. **Firstly it was assumed that the irrigation season ran from 1 September to 30 April and that outside those dates no irrigation water was abstracted. Secondly that during the irrigation season 55% of the takes were being exercised.** These assumptions cut out the enormous task of measuring all takes, but add uncertainty to the analysis. The 55 % factor was applied to 20 % of the takes by volume, as 80 % of the consented take were actually measured by spot gaugings. There is some basis for selecting 55% as follows. Sanders (1998) looked at the 1997/98 summer for Ashburton District (between the Rakaia and Rangitata Rivers) and compared the estimated groundwater pumpage for irrigation to the consented allocation, for a 120-day or half irrigation season. Results showed that on a regional scale the estimated total abstraction for the whole season was equal to 55% of the volume that would be pumped in 120 days if all the consented takes were using their maximum allocation.

Daily time series of natural flows were derived using linear regression from primary flow recorder stations and in some cases multiple linear regression using groundwater levels.

During measurement of concurrent gaugings automatic groundwater recorders were installed at four locations (Hillview, Ashburton Forks, Westerfield and Allenton Nurseries). However only data from Hillview was used (Figure 3.1).

For the construction of natural flows using groundwater levels, historic monthly groundwater readings were used and interpolated for each day. This procedure also contributes errors to the analysis. Figure A3.1 displays a sensitivity plot of Hillview monthly readings interpolated as daily values with the actual recorded values plotted in bold. This example shows that the interpolated values are very similar to the recorded but it may be coincidental, with monthly readings occurring just before major changes in waterlevel.

Stream depletion affects of groundwater abstraction takes, as assessed by Pattle Delamore (1997), were used in the analysis.

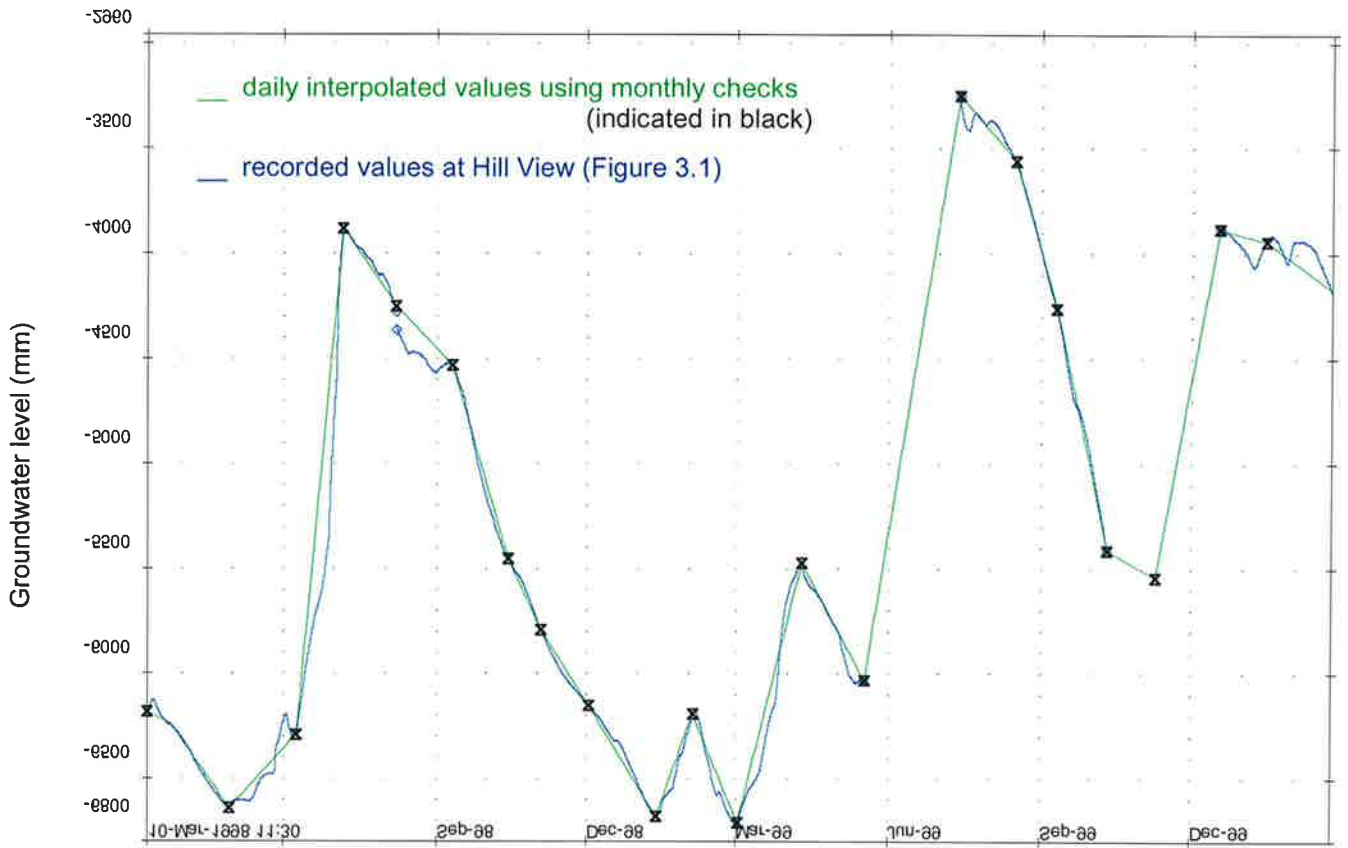


Figure A3.1 Monthly groundwater levels interpolated to daily values, compared to recorded levels

