In the Matter	of the Proposed Central Plains Water Enhancement Scheme
To	Environment Canterbury and Selwyn District Council
Submitter	Te Runanga o Ngai Tahu

SUPPLEMENTARY EVIDENCE OF PAUL ALBERT WHITE

1. QUALIFICATIONS AND EXPERIENCE

1.1 My full name is Paul Albert White.

1.2 I hold a Bachelor of Science with Honours (1st), Victoria University of Wellington (1980) and have been a member of the New Zealand Geophysical Society since 1982. I am a member of the New Zealand Hydrological Society (from 1980) and was President of this Society between 2000 and 2006. I have been a member of the New Zealand Geological Society since 1985, a member of the Royal Society of New Zealand since 2002 was a Councillor of the Royal Society between 2002 and 2006 representing earth sciences. I am also a member of the National Groundwater Association of the United States of America.

1.3 I am a Senior Scientist employed by the Institute of Geological and Nuclear Sciences, a New Zealand government-owned research institute. I have 26 years of experience in the assessment of groundwater systems and have authored approximately:

- 40 published papers and book chapters;
- 53 conference papers;
- 61 commercial reports.

1.4 I have read the Code of Conduct for Expert Witnesses (Rule 330A, High Court Rules and Environment Court Practice Note) and agree to comply with it. I confirm that I have complied with it in the preparation of this statement of evidence.

2. SCOPE OF SUPPLEMENTARY EVIDENCE

2.1 This supplementary evidence provides an assessment of the effects of a reduction of flow in the Waimakariri River reported by Tipler (2008) on the:

- width of channels in the Waimakariri River between Coutts Island and Courtenay; and
- area of channels in the Waimakariri River between Coutts Island and Courtenay;

- groundwater discharge from the Waimakariri River between Coutts Island and Courtenay.

2.2 These are presented as supplementary evidence as I have received new information since completing my evidence-in-chief:

- an analysis of seven Waimakariri River cross sections relevant to this study;
- estimates of Waimakariri River flow with CPWES irrigation, and other irrigation (Tipler 2008).

2.3 Together, this new information allows estimates of the effects of CPWES irrigation that I was not able to present in my evidence-in-chief.

2.4 The technical information that I use to complete this assessment is summarised in Appendix A to this supplementary evidence.

3. WAIMAKARIRI RIVER CROSS SECTIONS

3.1 Seven Waimakariri River cross sections (Appendix A, Figure 1) collected by Environment Canterbury are processed to estimate:

- number of wet sections (river channels) as a function of river level (Appendix A, Figure 2);
- wetted width of river channels as a function of river level (Appendix A, Figure 3);
- river flow (assuming constant velocity, a very simple model) as a function of river level (Figure 4).

4. WAIMAKARIRI RIVER FLOWS AND IRRIGATION

4.1 Tipler (2008) estimates daily flows in the Waimakariri River with the '20/25/240' scenario:

- before NPTL irrigation take from the Waimakariri River;
- after NPTL irrigation take from the Waimakariri River and before CPWES irrigation take from the Waimakariri River;
- after CPWES irrigation take from the Waimakariri River.

4.2 The CPWES irrigation take generally reduces flow in the Waimakariri River to less than the flow after the NPTL irrigation take (e.g. Appendix A: Figure 10, Figure 11 and Figure 12).

5. WAIMAKARIRI RIVER CHANNEL WIDTH AND IRRIGATION

5.1 Reductions in Waimakariri River flow will generally lead to reductions in wet widths of channels in the river bed between Coutts Island and Courtenay.

5.2 For example the averages of estimated river bed wetted width between Coutts Island and Courtenay for the period of flow data (1st June 1967 to 31st May 2001) are:

- 364 m for 'unmodified' daily average flow (De Joux);
- 338 m before NPTL irrigation take from the Waimakariri River;
- 333 m after NPTL irrigation take from the Waimakariri River and before CPWES irrigation take from the Waimakariri River;
- 314 m after CPWES irrigation take from the Waimakariri River.

6. WAIMAKARIRI RIVER CHANNEL WET AREA AND IRRIGATION

6.1 Reductions in Waimakariri River flow will generally lead to reductions in the wet area of channels in the river bed between Coutts Island and Courtenay.

6.2 For example the averages of estimated river bed wetted area between Coutts Island and Courtenay for the period of flow data (1st June 1967 to 31st May 2001) are:

- 11.6 million m^2 for 'unmodified' daily average flow (De Joux);
- 10.8 million m^2 before NPTL irrigation take from the Waimakariri River;
- 10.6 million m^2 after NPTL irrigation take from the Waimakariri River and before CPWES irrigation take from the Waimakariri River;
- 10.0 million m^2 after CPWES irrigation take from the Waimakariri River.

6.3 The decrease in wetted area in summer may be larger than average. For example the average (1 Jan 1991 to 1 April 1991) wetted area of 11.4 million m^2 with 'unmodified' flow (Appendix A, Table 3) declines to 9.5 million m^2 with all irrigation ('after CPWES', Appendix A, Table 3).

7. WAIMAKARIRI RIVER GROUNDWATER DISCHARGE AND IRRIGATION

7.1 Reductions in Waimakariri River flow will generally lead to reductions in groundwater discharge through the bed of the Waimakariri River between Coutts Island and Courtenay.

7.2 Groundwater discharge through the Waimakariri River bed is estimated from observations of stream flow as at least 10.1 m^3/s to Christchurch groundwater and to Christchurch spring-fed streams.

7.3 Average groundwater discharges from the Waimakariri River between Coutts Island and Courtenay for the period flow data (1st June 1967 to 31st May 2001), estimated with a seepage of 75 mm/day through the river bed, are:

- 10.1 m^3/s estimated from observations of stream flow for 'unmodified' daily average flow (De Joux);
- 9.4 m^3/s before NPTL irrigation take from the Waimakariri River;
- 9.2 m^3/s after NPTL irrigation take from the Waimakariri River and before CPWES irrigation take from the Waimakariri River;
- 8.7 m^3/s after CPWES irrigation take from the Waimakariri River.

7.4 The decrease in groundwater discharge from the Waimakariri River in summer may be larger than average. For example the average groundwater discharge of 9.9 m^3/s with 'unmodified' flow (Appendix A, Table 4) declines to 8.3 m^3/s with all irrigation ('after CPWES', Appendix A, Table 4) in the period 1 Jan 1991 to 1 April 1991.

8. WAIMAKARIRI RIVER GROUNDWATER DISCHARGE AND CPWES IRRIGATION TAKE

8.1 Groundwater discharge from the Waimakariri River between Coutts Island and Courtenay is estimated 'after NPTL' irrigation take and 'after CPWES' irrigation take.

8.2 Groundwater discharge 'after CPWES' is estimated as approximately 0.5 m^3/s less than groundwater discharge 'after NPTL' for the period of flow data (1st June 1967 to 31st May 2001).

8.3 The difference in groundwater discharge (i.e. 'after NPTL' minus 'after CPWES') from the Waimakariri River between Coutts Island and Courtenay may be larger than average in summer. For example estimated average groundwater discharge 'after CPWES' (Appendix A, Table 5) is 0.7 m^3/s less than 'after NPTL' in the period 1 Jan 1991 to 1 April 1991.

9. THE WATER BUDGET OF CHRISTCHURCH AND WAIMAKARIRI RIVER GROUNDWATER DISCHARGE WITH CPWES IRRIGATION TAKE

9.1 Irrigation takes from the Waimakariri River will probably reduce groundwater discharge from the Waimakariri River to Christchurch groundwater and to Christchurch spring-fed streams.

9.2 I estimate the reduction in average groundwater discharge from the Waimakariri River to Christchurch groundwater and to Christchurch spring-fed streams as approximately 0.5 m^3/s due to the CPWES irrigation take.

9.3 A reduction in average groundwater discharge from the Waimakariri River of approximately 0.5 m^3/s is a significant issue for the water budget for Christchurch, in my opinion.

9.4 I hold the opinion that this is a significant issue because:

- the estimated sum of inflows to the Christchurch/West Melton groundwater system is 1.3 m^3/s to 4.1 m^3/s greater than the sum of outflows from the system, exclusive of off-shore groundwater discharge, (White 2008, Table 5.10). A reduction in inputs by 0.5 m^3/s increases the risk that off-shore groundwater discharge will decline and therefore increases the risk of salt water intrusion to the Christchurch groundwater system;
- groundwater use by Christchurch City is increasing over time and a reduction in groundwater discharge from the Waimakariri River may reduce groundwater availability in the future;

- groundwater discharge from the Waimakariri River will decline by greater than average in summer periods, possibly impacting on spring flows and groundwater availability in Christchurch City.

DATED this day of 2008

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P A WHITE

REFERENCES

Tipler, C. J. M. 2008. Evidence presented to the Central Plains hearing on the 14th April.

White, P.A. 2008. Central Plains Water – technical assessment for Te Runanga o Ngai Tahu.

Appendix A. Technical summary of assessment of Waimakariri River flows, channel width, channel area and groundwater discharge from the Waimakariri River, Coutts Island to Courtenay.

A1 Waimakariri River bed cross sections

A1.1. Seven Waimakariri River bed cross sections

Seven Waimakariri River cross sections (Figure 1) collected by Environment Canterbury are processed to estimate:

- number of river channels as a function of river level (Figure 2);
- wetted width of river channels as a function of river level (Figure 3);
- river flow (assuming constant velocity, a very simple model) as a function of river level (Figure 4).

Flow in the Waimakariri River at Old State Highway bridge was an average of 50 m^3/s on the days that these cross sections were measured.

Relatively small changes in river level can result in quite large changes in wetted area of the river bed. For example an increase in river level from that observed during measurement of the cross section (0 m on the x axis of Figure 2) to 0.2 m (i.e. 0.2 m higher than observed river level during measurement of the cross section) can increase the wetted width of channels from about 250 m to about 500 m.

The average number of channels in the seven sections generally declines with increasing flow (Figure 5). The average width of channels in the seven sections increases with increasing flow (Figure 6).

A1.2 Representation of Waimakariri River channels

All cross sections (i.e. cross sections coloured red and blue in Figure 1) are processed to estimate channel position as a GIS dataset for the main channel and other channels (Figure 7). The main river channel is defined as the channel with the largest cross-sectional area on each cross section.

A1.3 Area of channels between Coutts Island and Courtenay.

The section of the Waimakariri River from about Coutts Island (cross section 610, Figure 1) to about Courtenay (cross section 662, Figure 1) is relevant to groundwater discharge to Christchurch City groundwater and Christchurch City spring flow.

The area of channels (Figure 8) in the Waimakariri River (i.e. the wetted area) from about Coutts Island to about Courtenay is estimated by two methods:
1) multiplying the average wetted widths on seven cross sections (Figure 6) and the distance (31780 m) between cross section 610 and cross section 662. ECan measure:

- cross section 610 at 11670 m from the coast;
- cross section 662 at 43450 m from the coast.

2) estimating the areas of channels with the GIS representations of Waimakariri River channels at three flows (Table 1).

Table 1. Estimated channel area between Coutts Island and about Courtenay with cross sections and with GIS.

Average flow, seven cross sections	Estimated channel area, seven cross sections	Average flow (GIS model)	Estimated channel area, GIS model
m^3/s	million m^2	m^3/s	million m^2
34	5.9		
50	7.8	50, average of observed	6.1
106	11.2		
169	14.2		
248	16.9		
351	19.2	300 to 4000, estimated	19.0
983	34.4	1000, approximately, estimated	36.2

A2 Waimakariri River channel area and unmodified Waimakariri flow

The area of the river channel between Coutts Island and about Courtenay is estimated with the 'unmodified' daily average flow estimates of De Joux (pers. comm.) using the flow and estimated channel area from seven cross sections (Table 1 and Figure 8). The method used TIDEDA rating for the period of data (1st June 1967 to 31st May 2001) to estimate a average channel area of 11.6 million m^2.

A3 Waimakariri River flows and irrigation takes

Tipler (2008) estimates daily flows in the Waimakariri River with the '20/25/240' scenario:

- before NPTL irrigation take from the Waimakariri River;
- after NPTL irrigation take from the Waimakariri River and before CPWES irrigation take from the Waimakariri River;
- after CPWES irrigation take from the Waimakariri River.

I understand that estimated daily flows 'before NPTL irrigation' include 'other' irrigation (i.e. irrigation abstractions from the Waimakariri River exclusive of NPTL and CPWES). Therefore the Tipler (2008) estimates of flows 'after CPWES irrigation' includes the effects on Waimakariri River flows of all existing and proposed (i.e. CPWES) irrigation.

The impacts on 'unmodified' daily average flow (De Joux) of 'other', NPTL and CPWES irrigation takes on river flow are estimated on Waimakariri River flow for:

- a period of low flow (January 1971 and April 1971), Figure 9;
- a period of near- average flow (January 1975 and April 1975), Figure 10;
- a period of relatively high flows (January 1991 and April 1991), Figure 11.

Irrigation reduces flow in the Waimakariri River and CPWES irrigation take generally reduces flow in the Waimakariri River to less than the flow after the NPTL irrigation take (e.g. Figure 9, Figure 10 and Figure 11).

A4 Waimakariri River channel wet width and irrigation takes

Reductions in Waimakariri River flow will generally lead to reductions in wet widths of channels in the river bed between Coutts Island and Courtenay.

For example the averages of estimated river bed wetted width between Coutts Island and Courtenay for the period flow data (1st June 1967 to 31st May 2001) are:

- 364 m for 'unmodified' daily average flow (De Joux);
- 338 m before NPTL irrigation take from the Waimakariri River;
- 333 m after NPTL irrigation take from the Waimakariri River and before CPWES irrigation take from the Waimakariri River;
- 314 m after CPWES irrigation take from the Waimakariri River.

The decrease in wetted width with irrigation may be larger than average in summer. For example the average (1 Jan 1991 to 1 April 1991) wetted width decreases from 359 m ('unmodified', Table 2) to 300 m with all irrigation ('after CPWES', Table 2).

Table 2. Estimates of average Waimakariri River channel wetted width between Coutts Island and Courtenay in three summers.

Period	Flow	Average Waimakariri River channel wetted width (m)			
		Unmodified	Before NPTL	After NPTL	After CPWES
1 Jan '71 - 1 Apr '71	Low	206	196	194	189
1 Jan '75 - 1 April '75	Av.	334	295	285	251
1 Jan '91 - 1 April '91	High	359	331	325	300

Irrigation reduces flow in the Waimakariri River and CPWES irrigation take generally reduces channel wetted width in the Waimakariri River to less than after the NPTL irrigation take (e.g. Figure 12, Figure 13 and Figure 14).

A5 Waimakariri River channel wet area and irrigation takes

Reductions in Waimakariri River flow will generally lead to reductions in the wet area of channels in the river bed between Coutts Island and Courtenay.

For example the averages of estimated river bed wetted area between Coutts Island and Courtenay for the period flow data (1st June 1967 to 31st May 2001) are:

- 11.6 million m^2 for 'unmodified' daily average flow (De Joux);
- 10.8 million m^2 before NPTL irrigation take from the Waimakariri River;
- 10.6 million m^2 after NPTL irrigation take from the Waimakariri River and before CPWES irrigation take from the Waimakariri River;
- 10.0 million m^2 after CPWES irrigation take from the Waimakariri River.

The decrease in wetted area with irrigation may be larger than average in summer. For example the average (1 Jan 1991 to 1 April 1991) wetted area of 11.4 million m^2 with 'unmodified' flow (Table 3) decreases to 9.5 million m^2 with all irrigation ('after CPWES', Table 3).

Table 3. Estimates of average Waimakariri River channel wetted area between Coutts Island and Courtenay in three summers.

Period	Flow	Average Waimakariri River channel wetted area (million m^2)			
		Unmodified	Before NPTL	After NPTL	After CPWES
1 Jan '71 - 1 Apr '71	Low	6.6	6.2	6.2	6.0
1 Jan '75 - 1 April '75	Av.	10.6	9.4	9.1	8.0
1 Jan '91 - 1 April '91	High	11.4	10.5	10.3	9.5

Irrigation reduces flow in the Waimakariri River and CPWES irrigation take generally reduces channel wetted area in the Waimakariri River to less than after the NPTL irrigation take (e.g. Figure 15, Figure 16 and Figure 17).

A6 Waimakariri River groundwater discharge and irrigation takes

Groundwater seepage through the Waimakariri River bed is estimated as at least 75 mm/day at average river flow. This figure is calculated from:

- Waimakariri River seepage to Christchurch groundwater and spring-fed streams of at least 10.1 m^3/s; over an
- average wetted area of 11.6 million m^2 for 'unmodified' daily average flow (De Joux), 1st June 1967 to 31st May 2001.

The average groundwater discharge from the Waimakariri River between Coutts Island and Courtenay for the period flow data (1st June 1967 to 31st May 2001), with a seepage of 75 mm/day through the river bed, are:

- 10.1 m^3/s for 'unmodified' daily average flow (De Joux);
- 9.4 m^3/s before NPTL irrigation take from the Waimakariri River;
- 9.2 m^3/s after NPTL irrigation take from the Waimakariri River and before CPWES irrigation take from the Waimakariri River;
- 8.7 m^3/s after CPWES irrigation take from the Waimakariri River.

The decrease groundwater discharge with irrigation from the Waimakariri River between Coutts Island and Courtenay may be larger than average in summer. For example the average (1 Jan 1991 to 1 April 1991) groundwater discharge of 9.9 m^3/s with 'unmodified' flow (Table 4) declines to 8.3 m^3/s with all irrigation ('after CPWES', Table 4).

Table 4. Estimates of average Waimakariri River groundwater discharge between Coutts Island and Courtenay in three summers.

Period	Flow	Average Waimakariri River groundwater discharge (m^3/s)			
		Unmodified	Before NPTL	After NPTL	After CPWES
1 Jan '71 - 1 Apr '71	Low	5.7	5.4	5.4	5.3
1 Jan '75 - 1 April '75	Av.	9.2	8.2	7.9	7.0
1 Jan '91 - 1 April '91	High	9.9	9.1	9.0	8.3

A7 Waimakariri River groundwater discharge and CPWES irrigation take

The effects of CPWES irrigation on groundwater discharge from the Waimakariri River between Coutts Island and Courtenay is estimated as follows:

- calculate Waimakariri River groundwater discharge (m^3/s) from estimates of wet area with Tipler (2008) 'after NPTL' daily flow estimates and an estimated seepage of 75 mm/day (Section 6);
- calculate Waimakariri River groundwater discharge (m^3/s) from estimates of wet area with Tipler (2008) 'after CPWES' daily flow estimates and an estimated seepage of 75 mm/day (Section 6);
- calculate the difference in these two estimates of Waimakariri River groundwater discharge (e.g. Figure 18 for the period 1 Jan 1991 to 1 April 1991).

The average change in groundwater discharge with CPWES irrigation of approximately 0.5 m^3/s is estimated for the period of flow data (1st June 1967 to 31st May 2001).

The difference in groundwater discharge (i.e. 'after NPTL' minus 'after CPWES') from the Waimakariri River between Coutts Island and Courtenay may be larger than average in summer. For example the average (1 Jan 1991 to 1 April 1991) groundwater discharge 'after CPWES' (Table 5) is 0.7 m^3/s less than 'after NPTL'.

Table 5. Estimates of average Waimakariri River groundwater discharge between Coutts Island and Courtenay in three summers.

Period	Flow	Average Waimakariri River groundwater discharge (m^3/s)		
		After NPTL	After CPWES	Difference
1 Jan '71 - 1 Apr '71	Low	5.4	5.3	0.1
1 Jan '75 - 1 April '75	Av.	7.9	7.0	0.9
1 Jan '91 - 1 April '91	High	9.0	8.3	0.7

A8 Reference

Tipler, C. J. M. 2008. Evidence presented to the Central Plains hearing on the 14th April.

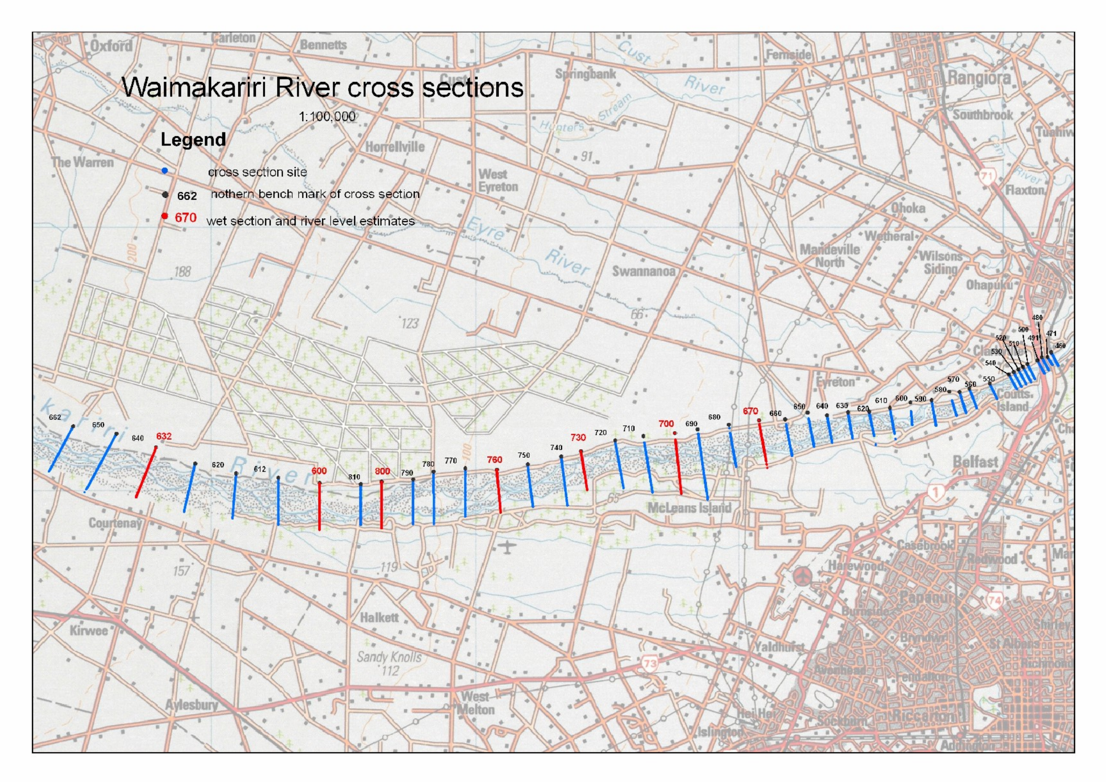

Figure 1. Location of Environment Canterbury Waimakariri River cross sections with seven cross sections (670, 700, 730, 760, 800, 600 and 640) highlighted in red.

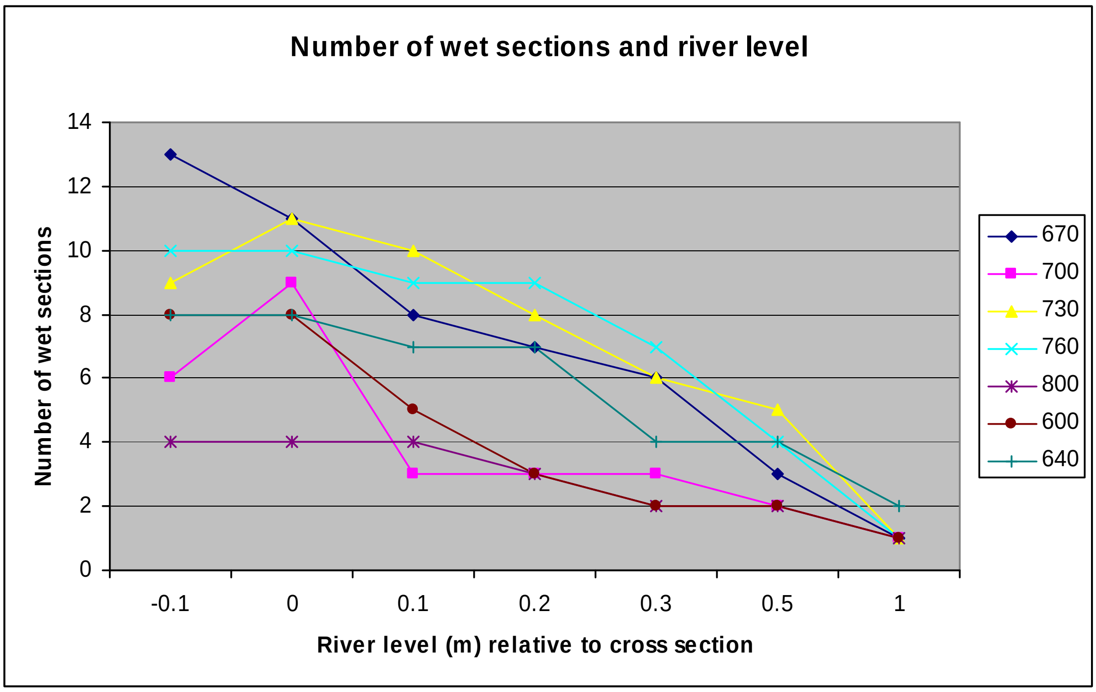

Figure 2. Number of river channels (wet sections) in each cross section.

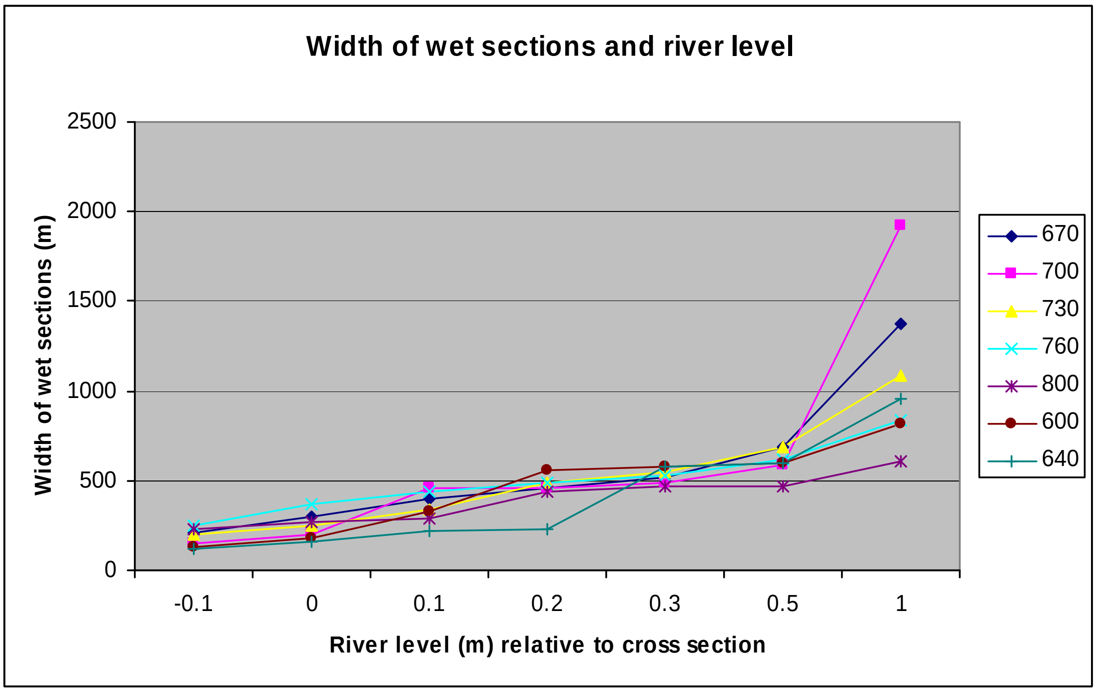

Figure 3. Total width of channels (wet sections) in each cross section.

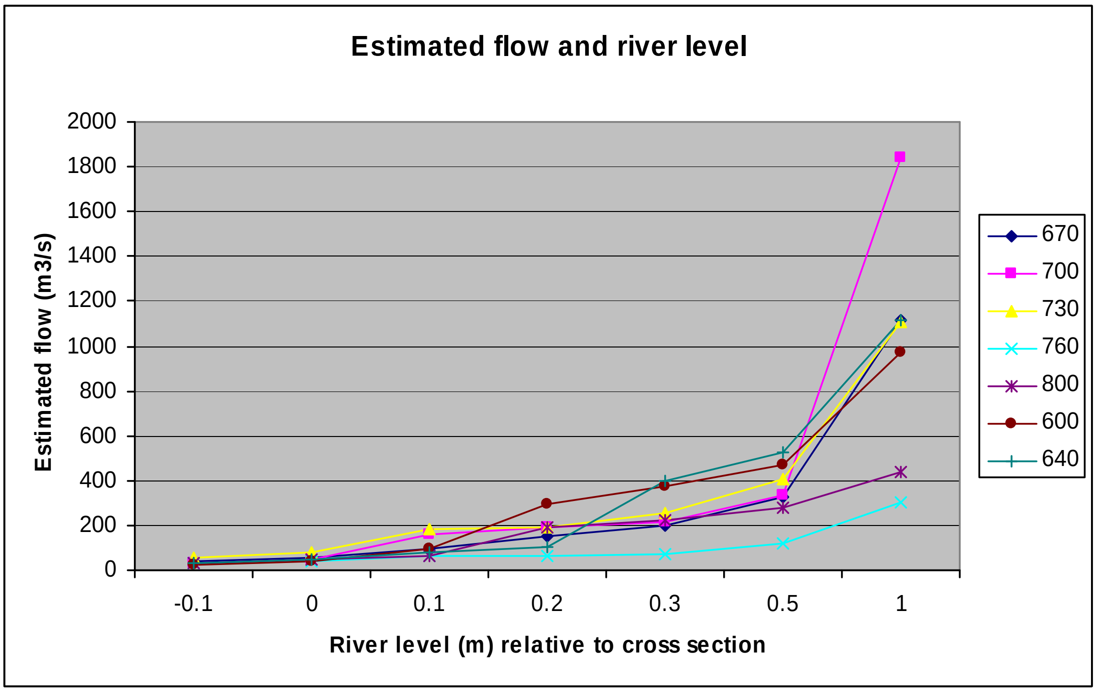

Figure 4. Estimated river flow in all channels (wet sections) in each cross section.

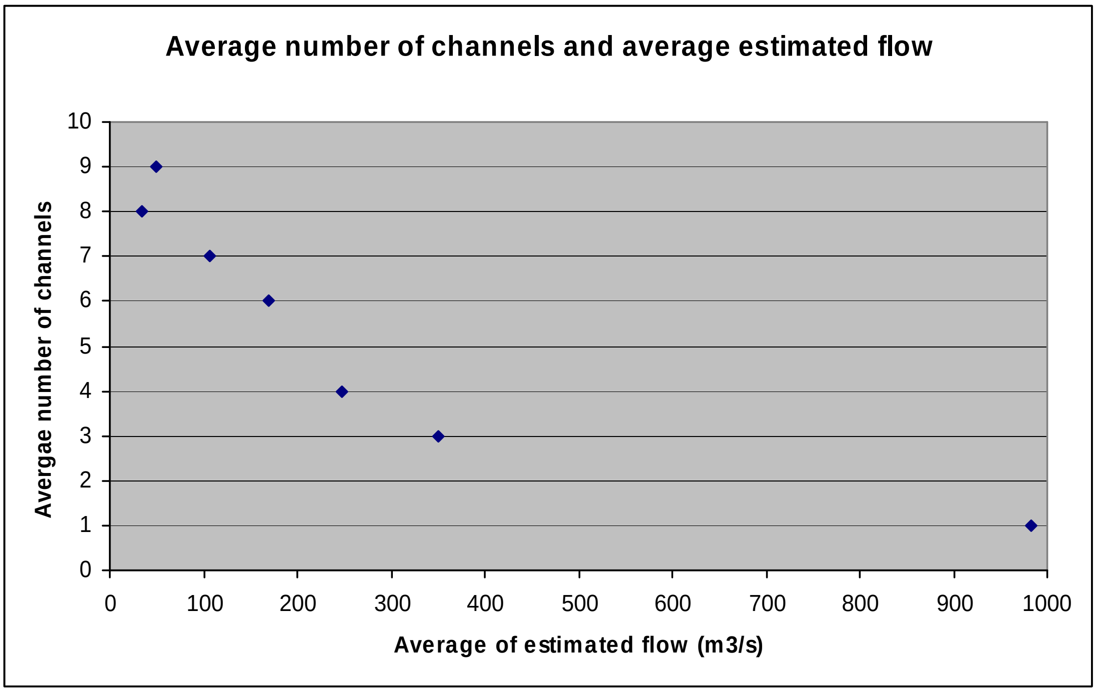

Figure 5. Average number of channels and average of estimated flow for seven Waimakariri River sections.

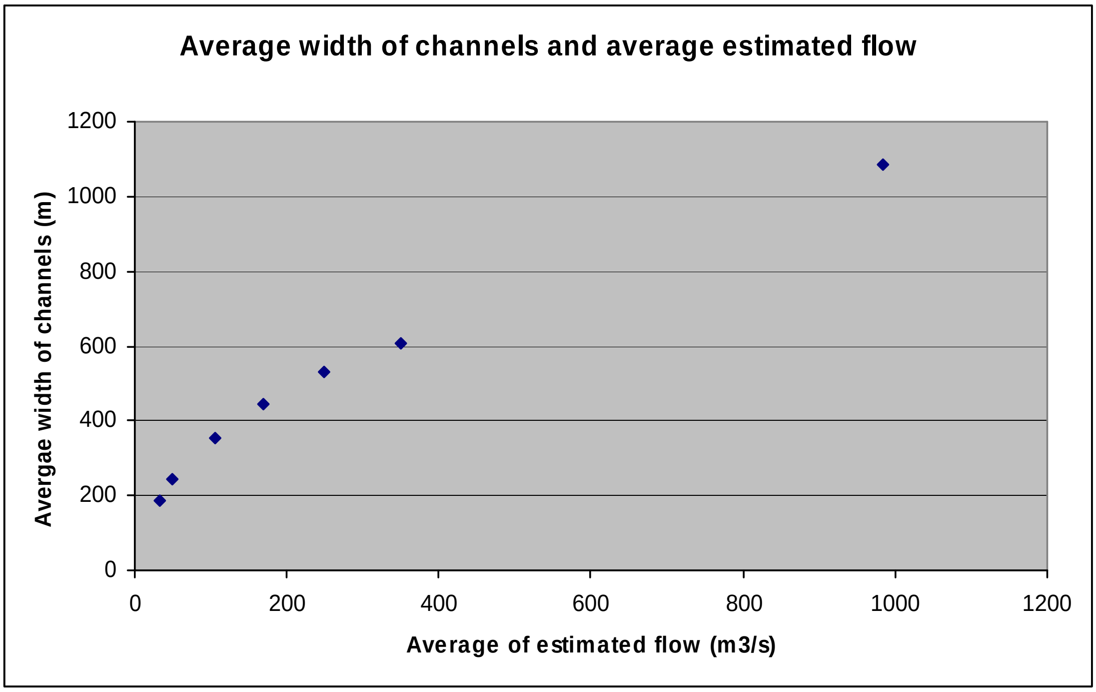

Figure 6. Average width of channels and average of estimated flow for seven Waimakariri River sections.

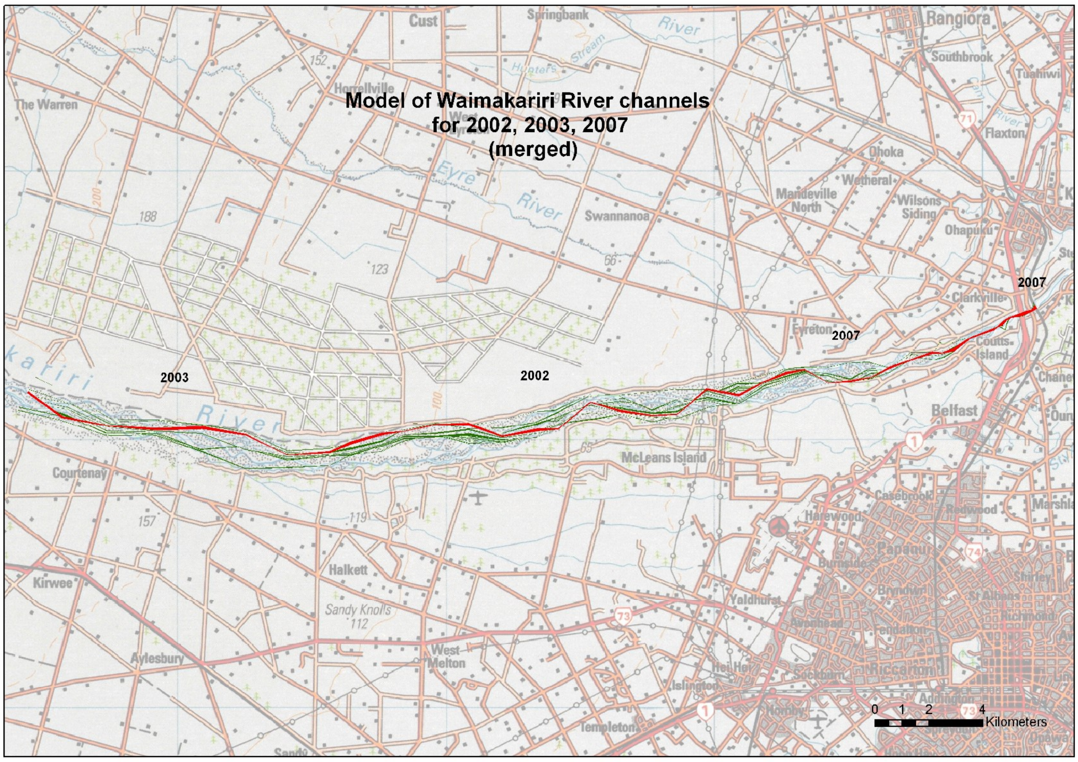

Figure 7. GIS model of Waimakariri River channels for 2002, 2003, 2007 cross sections. Red = main channel, green = other channels.

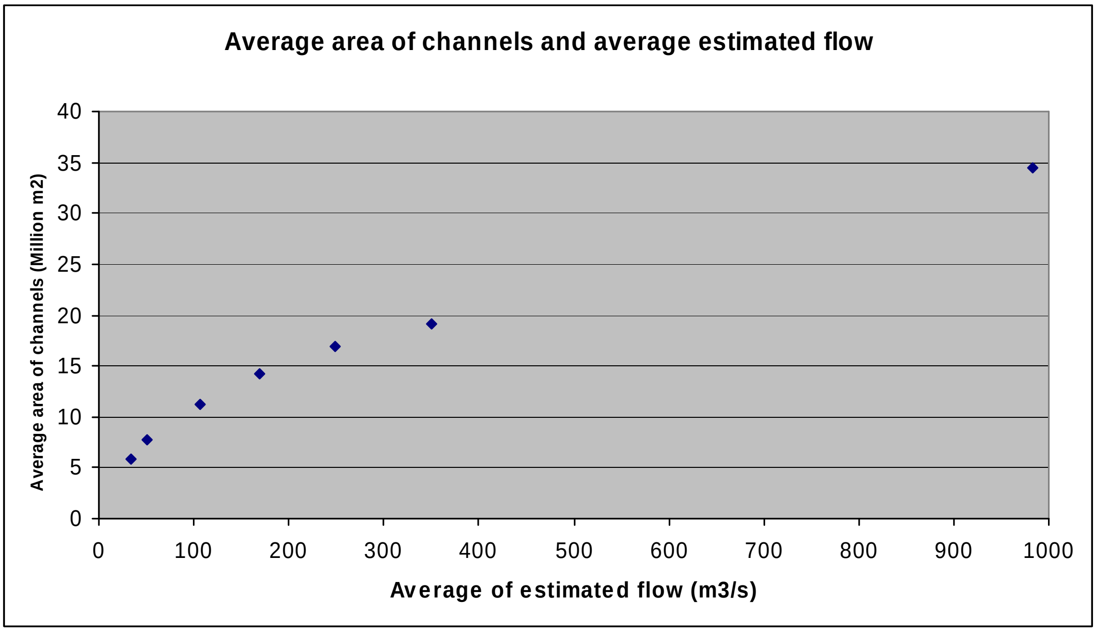

Figure 8. Average area of channels between Coutts Island and Courtenay and average estimated flow.

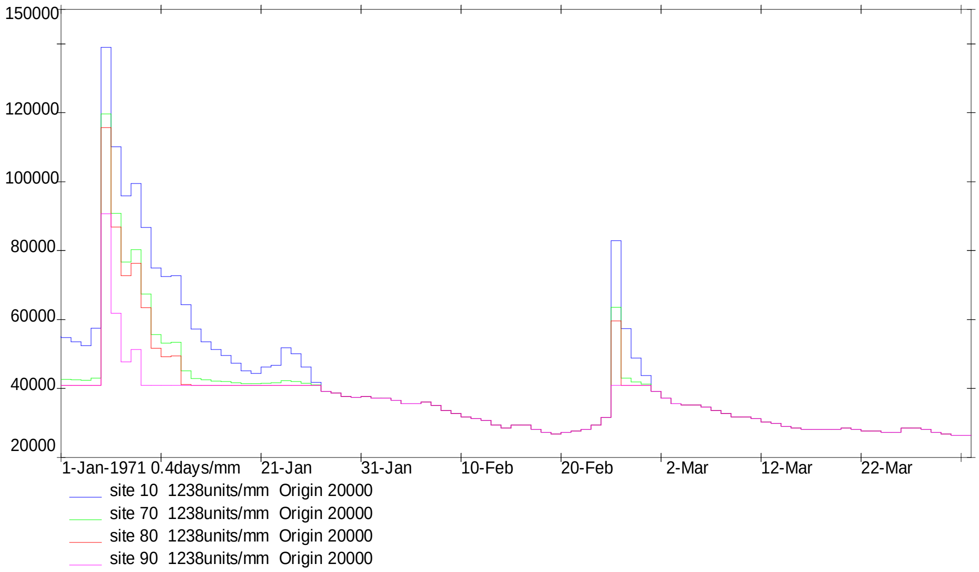

Figure 9. Waimakariri River daily flows (L/s) for flows 1 Jan 1971 to 1 April 1971 (low flows for months): 'unmodified' daily average flow (blue), De Joux (pers. comm.); 'before NPTL' (green), 'after NPTL and before CPWES' (red) and 'after CPWES' (pink), Tipler (2008).

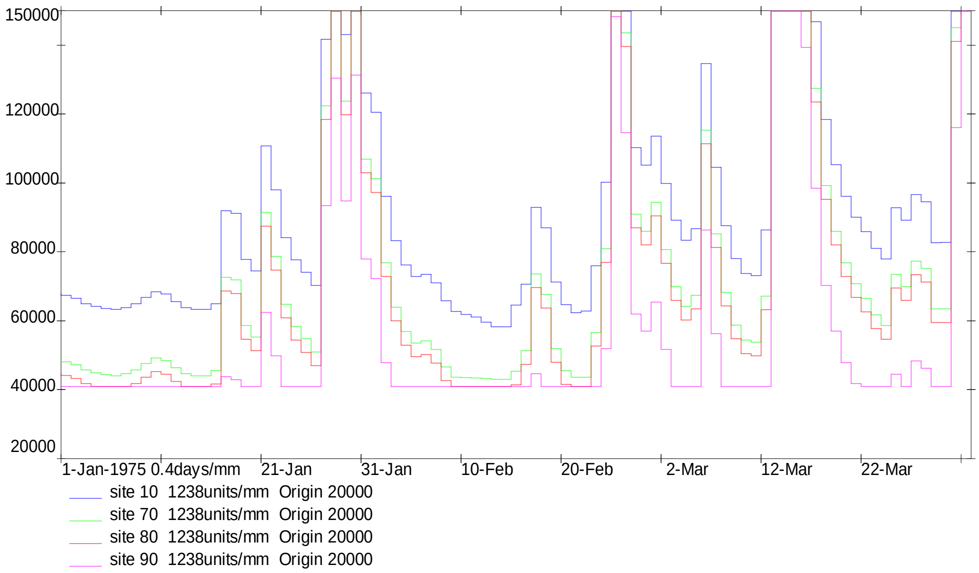

Figure 10. Waimakariri River daily flows (L/s) for flows 1 Jan 1975 to 1 April 1975 (near-average flows for months): 'unmodified' daily average flow (blue), De Joux (pers. comm.); 'before NPTL' (green), 'after NPTL and before CPWES' (red) and 'after CPWES' (pink), Tipler (2008).

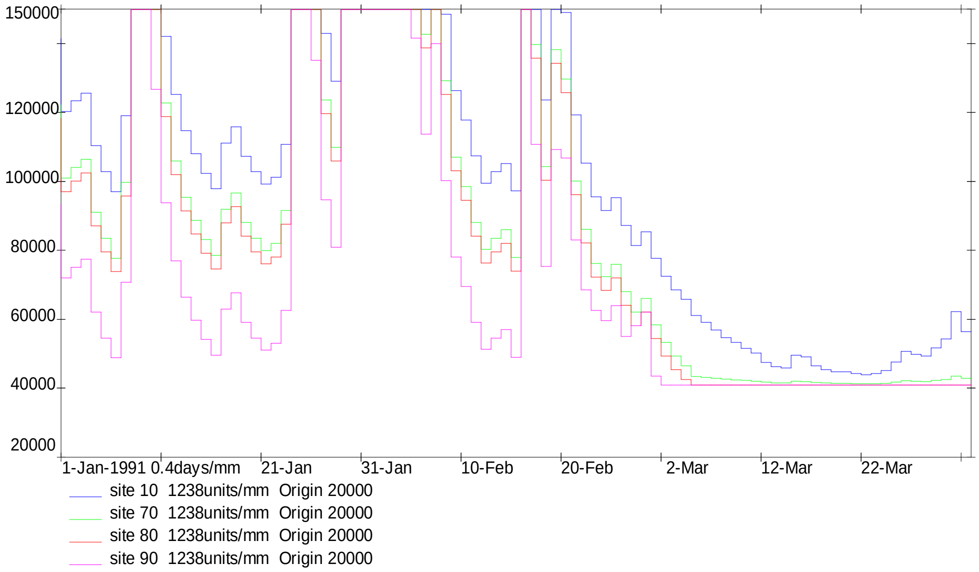

Figure 11. Waimakariri River daily flows (L/s) for flows 1 Jan 1991 to 1 April 1991 (relatively high flows for months): 'unmodified' daily average flow (blue), De Joux (pers. comm.); 'before NPTL' (green), 'after NPTL and before CPWES' (red) and 'after CPWES' (pink), Tipler (2008).

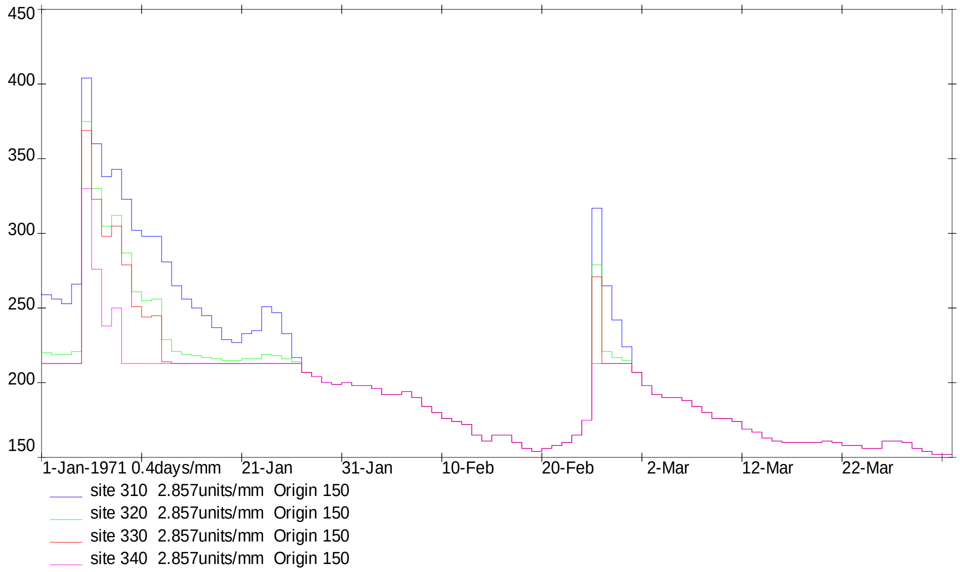

Figure 12. Waimakariri River estimated channel cross section width (m) for 1 Jan 1971 to 1 April 1971 (low flows for months): 'unmodified' daily average flow (blue), De Joux (pers. comm.); 'before NPTL' (green), 'after NPTL and before CPWES' (red) and 'after CPWES' (pink).

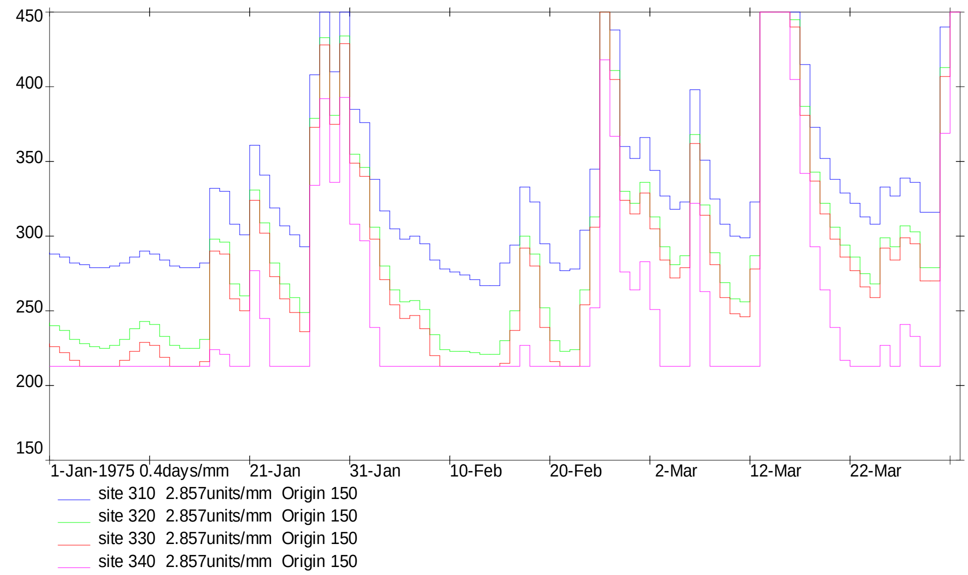

Figure 13. Waimakariri River estimated channel cross section width (m) for 1 Jan 1975 to 1 April 1975 (near - average flows for months): 'unmodified' daily average flow (blue), De Joux (pers. comm.); 'before NPTL' (green), 'after NPTL and before CPWES' (red) and 'after CPWES' (pink).

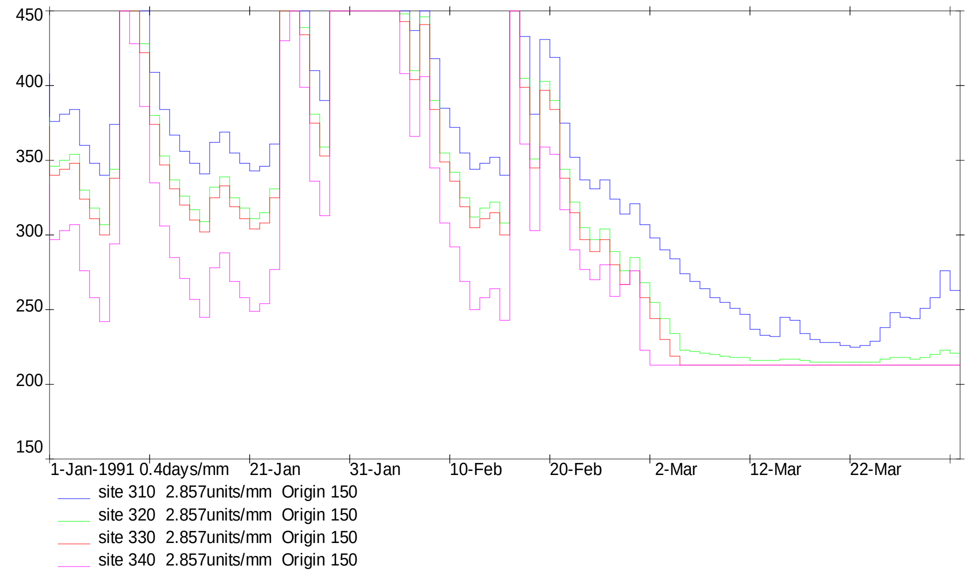

Figure 14. Waimakariri River estimated channel cross section width (m) for 1 Jan 1991 to 1 April 1991 (high flows for months): 'unmodified' daily average flow (blue), De Joux (pers. comm.); 'before NPTL' (green), 'after NPTL and before CPWES' (red) and 'after CPWES' (pink).

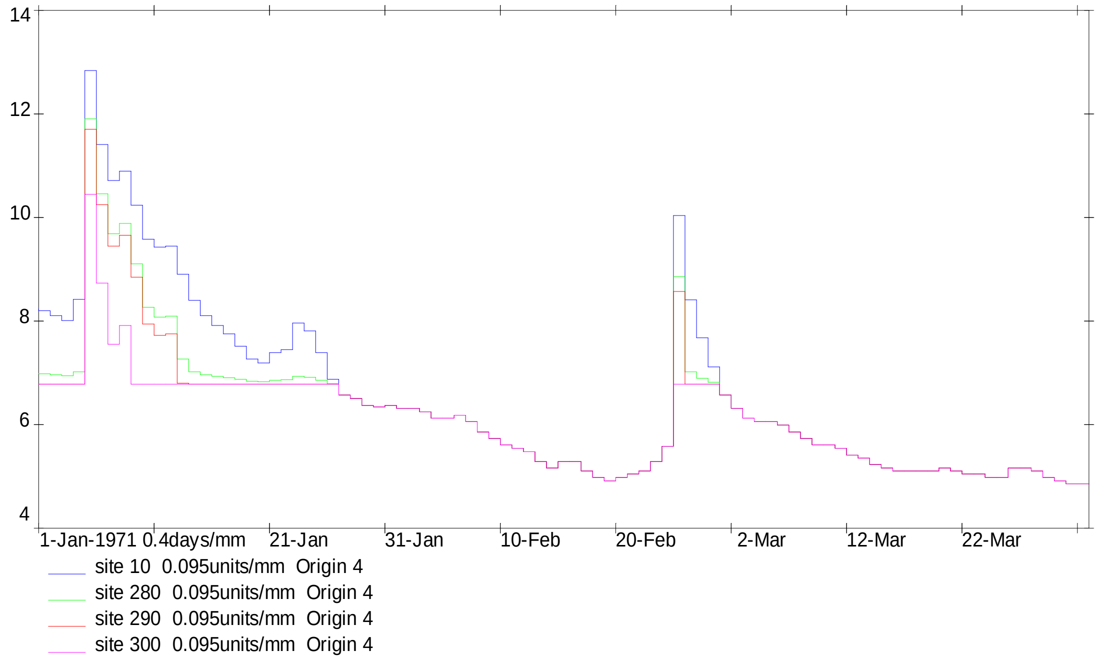

Figure 15. Waimakariri River estimated channel cross sectional area between Coutts Island and Courtenay (million m^2) for 1 Jan 1971 to 1 April 1971 (low flows for months): 'unmodified' daily average flow (blue), De Joux (pers. comm.); 'before NPTL' (green), 'after NPTL and before CPWES' (red) and 'after CPWES' (pink).

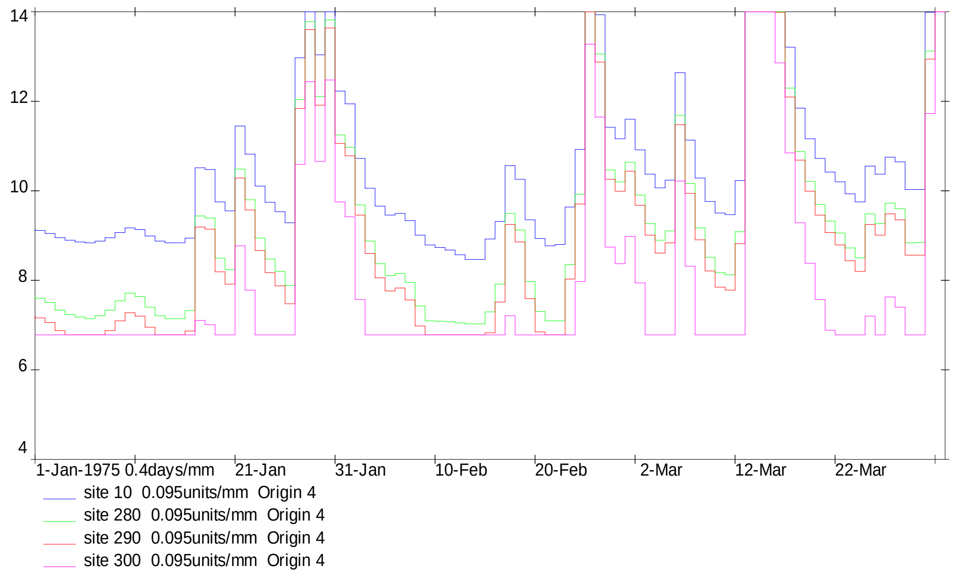

Figure 16. Waimakariri River estimated channel cross sectional area between Coutts Island and Courtenay (million m^2) for 1 Jan 1975 to 1 April 1975 (near-average flows for months): 'unmodified' daily average flow (blue), De Joux (pers. comm.); 'before NPTL' (green), 'after NPTL and before CPWES' (red) and 'after CPWES' (pink).

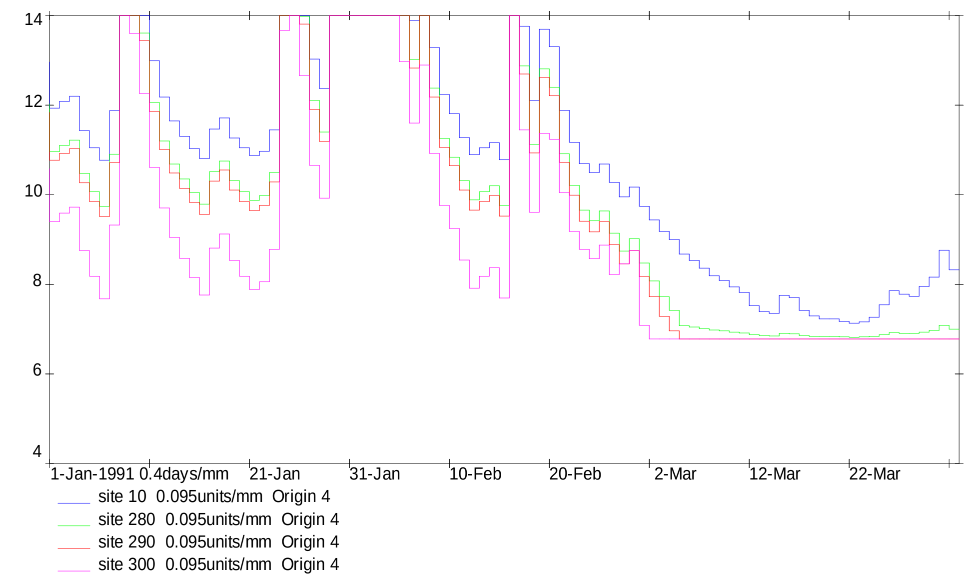

Figure 17. Waimakariri River estimated channel cross sectional area between Coutts Island and Courtenay (million m^2) for 1 Jan 1991 to 1 April 1991 (high flows for months): 'unmodified' daily average flow (blue), De Joux (pers. comm.); 'before NPTL' (green), 'after NPTL and before CPWES' (red) and 'after CPWES' (pink).

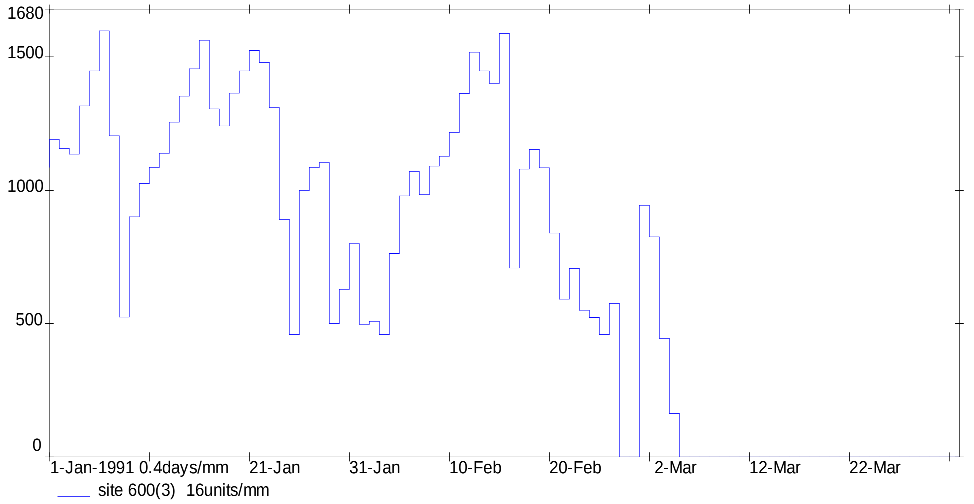

Figure 18. Waimakariri River estimated difference in groundwater discharge between Coutts Island and Courtenay (L/s) for 1 Jan 1991 to 1 April 1991 (high flows for months) with CPWES irrigation: i.e. groundwater discharge 'after NPTL and before CPWES' minus groundwater discharge 'after CPWES'.