Review of the hydrology of the Tengawai River upstream of Cave and the impact of abstraction on river flows at the Cave Picnic Reserve recorder

Prepared for the Tengawai Water Users Group

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Summary

The hydrology and flow pattern of the Tengawai River upstream of Cave Picnic Reserve flow recorder has been reviewed. Below the Tengawai Downlands water supply intake, the river losses water into the underlying gravels. This is more pronounced during times of low flows. During extreme dry periods, the river can be dry upstream of (approximately) Mawaro. Downstream of Mawaro, the river gains flow from re-emerging groundwater.

Water meter data for the major irrigation abstraction upstream of Cave, plus the Downlands water supply intake, show that there is very little response in flow at Cave Picnic Reserve attributable to upstream abstractions. An analysis of each irrigation season since 2014 shows that deducting the irrigation and water supply abstractions in total from the Manahune flow data leads to an overestimation of the actual effect of upstream abstractions on the flow at Cave Picnic Reserve.

The most likely reason for the lack of response to upstream abstraction is the fact that the storage of water within the upstream gravels and the subsequent re-emergence of that water below Mawaro provides a buffering effect that reduces any immediate changes on downstream flow.

The analysis clearly shows that the present method used by Environment Canterbury of "naturalising" flow for the Tengawai River upstream of the Cave Picnic Reserve recorder does not reflect what actually happens. The method does not account for the buffering effect of the water stored and subsequently released into the river downstream of Mawaro and overstates the impact that abstractions have on the residual river flow.

The methodology to assess naturalised flows needs to be revised and amended to be able to account for the buffer storage of groundwater upstream of the Cave Picnic Reserve site.

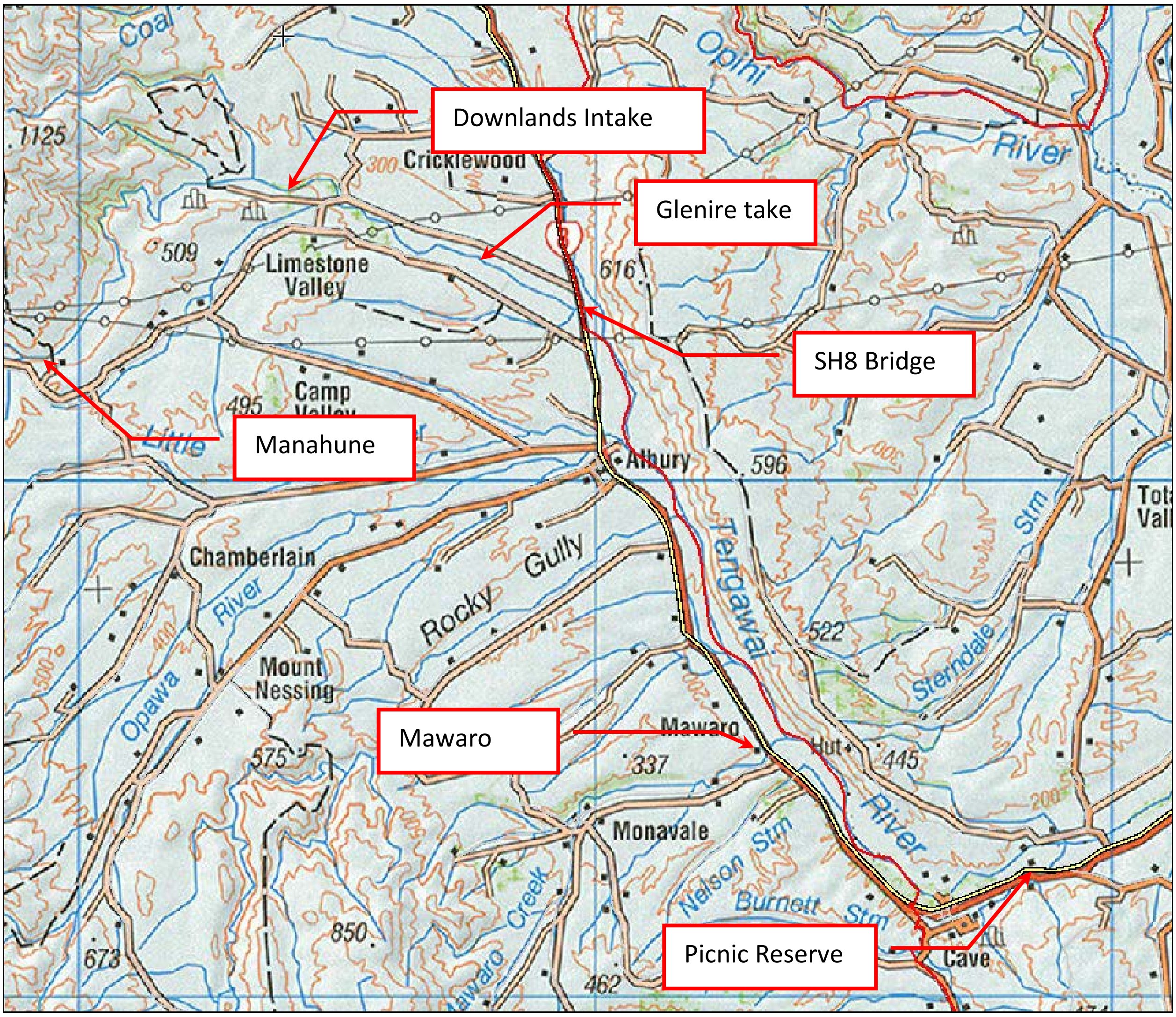
Contents

1) Introduction

This report has been prepared for the Tengawai Water Users Group. It summarises the knowledge of the hydrology of the Tengawai River between the present site of the Downlands intake (6.5km downstream of the Environment Canterbury flow recorder sited at Manahune) and the flow recorder sited at the Cave Picnic Reserve. The impact of upstream abstractions on the rate of flow recorded at the Cave Picnic Reserve is also investigated.

Relevant locations are shown in Figure 1

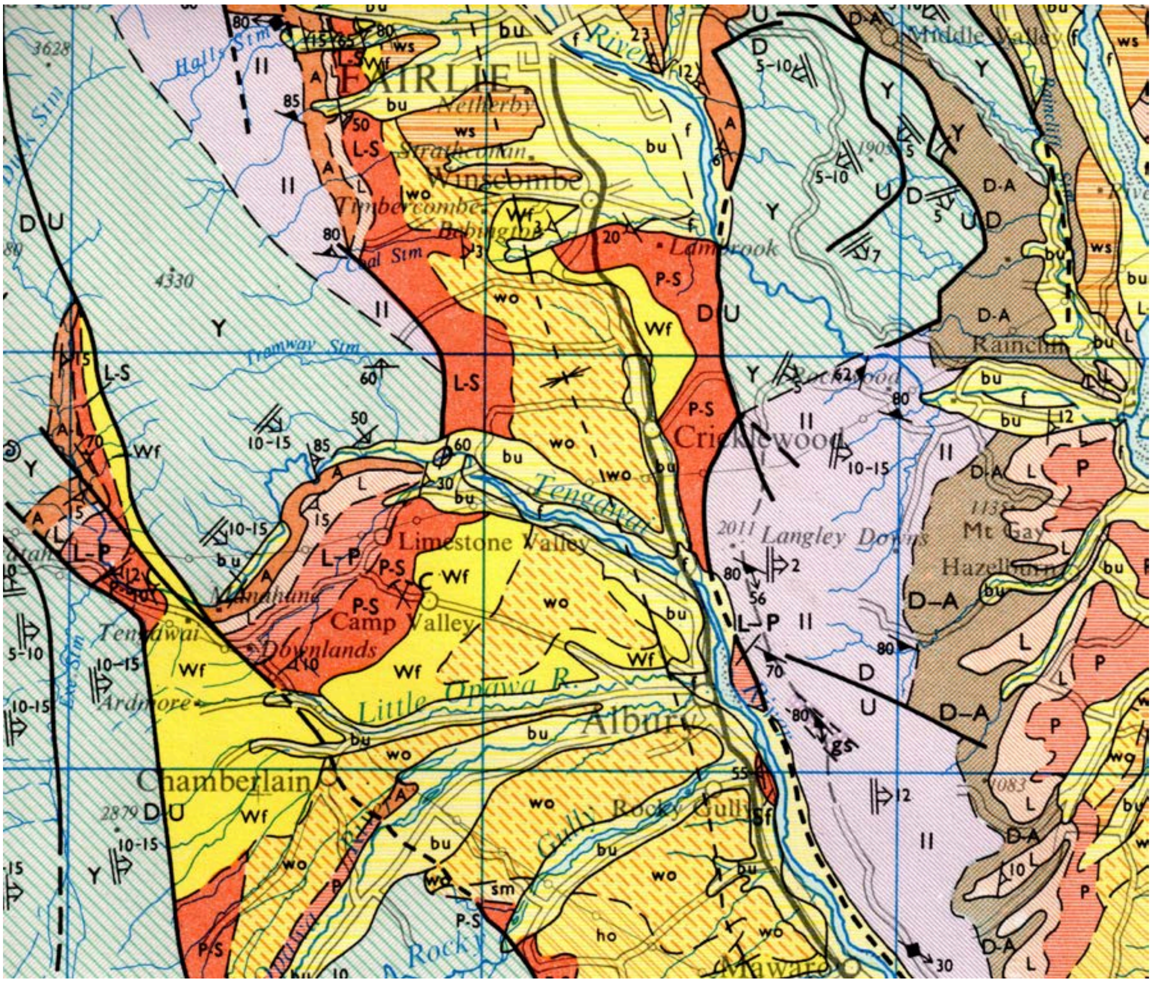
Figure 1 : Location of Tengawai sites referred to in this report



2) Geology

The broad scale geology of the Tengawai in the area of the existing Downlands water supply intake (see figure 2) has been mapped by Gair (1967), and indicates the presence of reworked outwash gravels (Burnham formation) within the river bed overlying Tertiary fine grained marine sediments (limestone, siltstone, mudstone). While the depth to the marine beds is unknown, the presence of Tertiary outcrops on the surrounding river valley sides indicates the gravels will be of a shallow nature.

Figure 2 : Geology (after Gair 1967)



The underlying geology significantly influences the rate of surface flow within the Tengawai River at various locations. Upstream of the Downlands intake, the river flows through a gorge underlain with greywacke basement rock and Tertiary fine grained marine sediments. The relatively impermeable nature of the strata ensures that the surface flow comprises virtually the total flow of the river. Below the Downlands intake, the marine beds dip to the east and the adjacent gravel deposits thicken. Surface flow disappears from the river into the permeable gravels to be held in storage. At Cave, the river once again flows over marine sediments and the surface flow of the river once again comprises the total flow. Eastward of Cave, the marine beds dip eastward and the surface flow again disappears into the adjacent river gravels.

3) Hydrology

The Tengawai River receives rainfall runoff from the Rollesby and Albury Ranges, and flows in a southerly direction towards Cave before flowing eastwards to join the Opihi River at Pleasant Point. Continuous flow records are available for the Tengawai River at the Cave Picnic Reserve (site 69635) from March 1982 to the present. Continuous flow record has also been recorded at the site known as Manahune (located at the upper end of the Tengawai River gorge at Topo50 NZTM BZ17:19073-02303) since 18th July 2014.

The Manahune recorder is located approximately 6.5km upstream of the Downlands water supply intake site. From the limited number of flow measurements carried out to date there appears to be little or no flow loss between the Manahune and Downlands Intake sites because the measured flow downstream of the Downlands Intake is equal to the sum of the flow at Manahune plus the flow being abstracted at the intake.

An estimation of the low to median flow range for the Tengawai River at the Downlands intake has previously been derived (Environmental Consultancy Services Ltd. 2001) using a correlation of 32 sets of concurrent flow gaugings carried out by the South Canterbury Catchment Board between 1965 and 1981. The correlation (Downlands = 0.5257 x Cave + 68, r^2 = 0.9796) was derived from flow rates in the range 199 l/s to 2700 l/s at Downlands, and is considered to provide a reasonable estimation of the low to median flow range.

A correlation has been calculated between the recorded flow at Manahune (upstream of any abstractions) and the Cave site during months when there is no irrigation occurring. For this purpose, regressions were obtained using data for the months of June to August for each overlapping data year (ie 2014, 2015, 2016). The regressions (see figures 3.1 and 3.2) account for the Downlands Water Supply (maximum take 79 l/s, but average take is 45 l/s). It is considered that this abstraction is continuous throughout the year and as it is an essential use it should not be included as an abstraction for "naturalised flow purposes.

While it is obvious that there is a time lag for the measured flow at Manahune to reach the Cave recorder site, the best flow correlation at times of low flow (and at periods of stable flow) is achieved by using the instant flow data at both sites. Figure 3.2 shows that the correlation with a 1 day time lag results in a slightly lower correlation.

Figure 3.1 – Manahune Cave Correlation with no lag

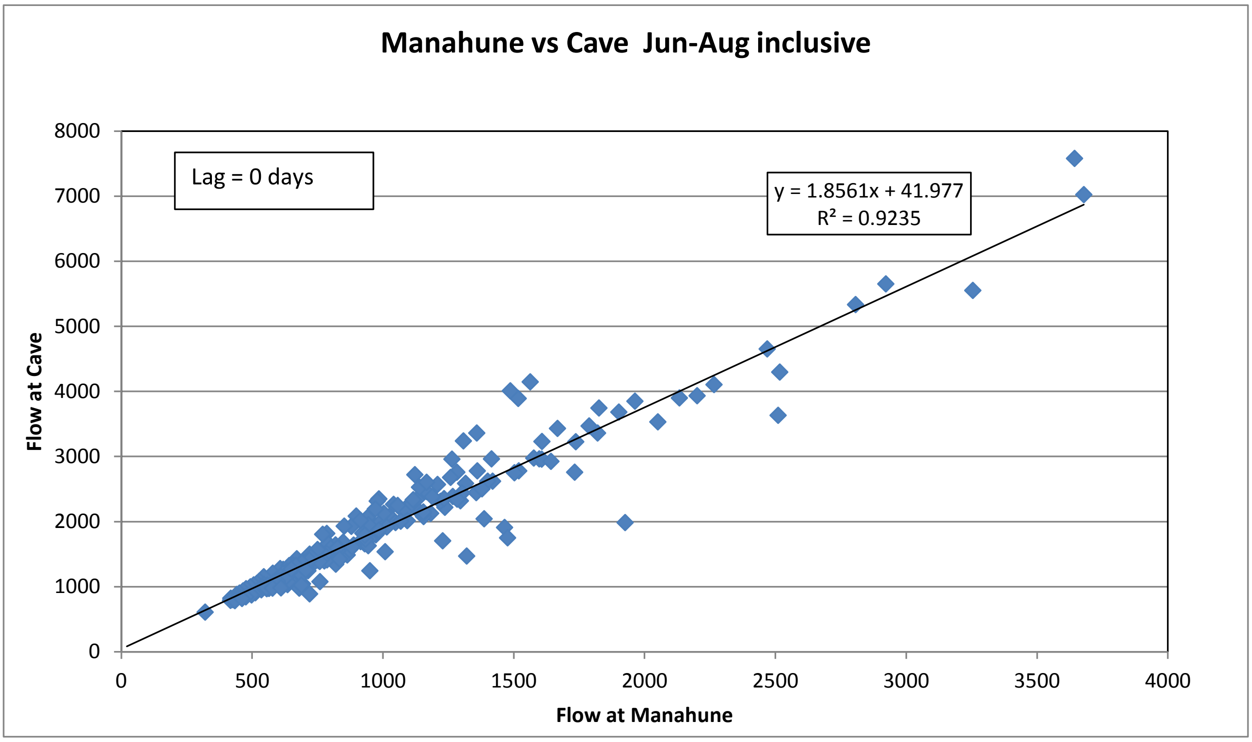
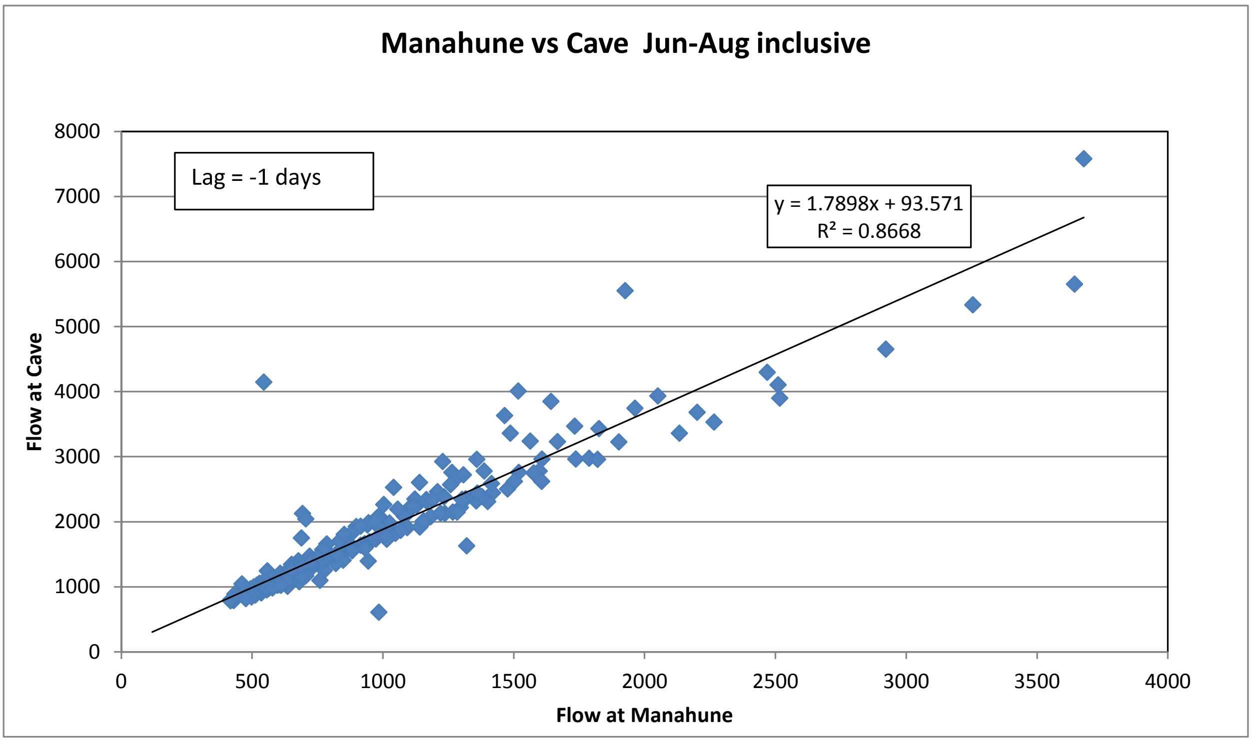


Figure 3.2 – Correlation with Manahune lagged by 1 day



4) Flow Pattern - Downlands intake to Cave

Visual observations made by South Canterbury Catchment Board staff showed that the Tengawai River loses surface flow to the underlying gravels from below the existing Downlands Tengawai Intake to Cave. The river was observed to be dry in some reaches during droughts in the early 1970's, and during the 1980's and 1990's.

A series of three sets of concurrent flow gauging were carried out at sites between Downlands intake and SH8 during 2015/16. The results, together with some historical flow measurements previously carried out at the Downlands intake and at SH8 are shown in table 1.

Table 1 : Flow losses, Downlands Intake to SH8 Bridge

	Manahune	Below Downlands Intake	Cricklewood Rd Bridge	O'Sullivan's Below Pylon	State Highway 8 Bridge
28/10/2015	552	522	460	468	430
24/11/2015	350	298	234	203	152
29/02/2016	270	235	213	182	128
30/01/1998		192			76
28/10/1998		1450			1389
05/02/1999		756			742
13/05/1999		932			840
06/12/1999		2704			2665

The gaugings show that the greatest flow loss is on the section between the Downlands Intake and the Cricklewood Road Bridge. Flow losses continue to occur between the latter site and SH8.

A limited series of flow measurements (Table 2) have been taken at locations between the Downlands intake and Cave, and these confirm the observed flow pattern within the river. Flow measurements undertaken on 6 December 1999 (at a time of approximately average flow) showed that surface flow loss is approximately 22.3 l/s/km in the reach between Cricklewood Bridge and upstream Rocky gully confluence. Downstream of that reach, flow losses (after allowing for the inflow from Rocky Gully) reduce to approximately 11.18 l/s/km. These losses are reduced by inflows from Rocky Gully Stream and Mawaro Creek. A flow rate of 76 l/s was measured at the SH8 Bridge on 30 January 1998. That flow, which was measured during severe drought conditions, reduced to 40 l/s in the Tengawai River immediately above the Rocky Gully confluence on 30 January 1998. It is suspected that the Tengawai River would have been dry in reaches downstream of that point because the flow rate at the Cave recorder site was only 199 l/s.

Table 2 : Tengawai Flows Downlands to Cave

Site	Distance from Old Weir	30/01/1998	28/10/1998	5/02/1999	13/05/1999	2/12/1999	6/12/1999
Tengawai above Downlands W/S	2.2	192	1450	756	932	2704	2704
Tengawai @ Cricklewood Br	4					2571	2571
Tengawai @ S.H. 8	9	76	1389	742	840	2665	2665
Tengawai above Rocky Gully Stream	13.8	40					2464
Tengawai below Rocky Gully	13.9		1958	1155	1341		2739
Tengawai above Mawaro Stream	19	92			1399		2514
Tengawai below Mawaro	19.2						2549
Tengawai at Picnic Reserve	26	199	2175	1405	1507		2380

Flow measurements undertaken show that during times of low flow, surface flow continues to be lost into the underlying gravels until above Mawaro. The author personally noted that during the 1986 drought the river was dry in this reach.

Below Mawaro, the river gravels start to thin out until the underlying marine beds become exposed again upstream of the Belmont Bridge. River flow increases from downstream of Mawaro as groundwater re-emerges from the gravels.

The re-emergence of groundwater recharge into the river downstream of Mawaro is an important factor which dominates the flow pattern at Cave. This is particularly more significant during periods of relatively stable low flows.

5) Naturalised river flows

"Naturalising" river flows is an attempt to recreate the flow record at a specific location if there were no upstream abstraction of water. The method used is described by Dodson & Steel (2016). That document is still in draft form until all the relevant data (especially water usage and resource consent details) has been checked. For the Tengawai River at Cave, the naturalised flow has been estimated to be 611 l/s.

The "naturalising" method is based on the primary assumption that the flow of water at a downstream site will be the sum of the actual flow plus any upstream abstractions. This assumption is reasonable in rivers where there are no significant gains or losses between the relevant sites. For example, there is negligible change in flow rate between the Manahune recorder site and the Downlands Tengawai intake site[1]. Measurements carried out for the Downland Water Supply Committee in 2015-16 show that the measured flow rate in the Tengawai immediately downstream of the present day intake site equalled the sum of the measured flow at Manahune less the Downlands intake flow.

However, there can be a significant volume of water stored within the river gravels of a river. In reaches where water is being lost to (or gained from) groundwater, there is a significant buffering effect on downstream flows. The previous section of this report shows that there are significant losses of surface flow to groundwater in the mid-upper section of the Tengawai River, with re-emerging groundwater entering the river upstream of the Cave recorder site.

The method used by Environment Canterbury to predict "naturalised" flows has been assessed using two methods.

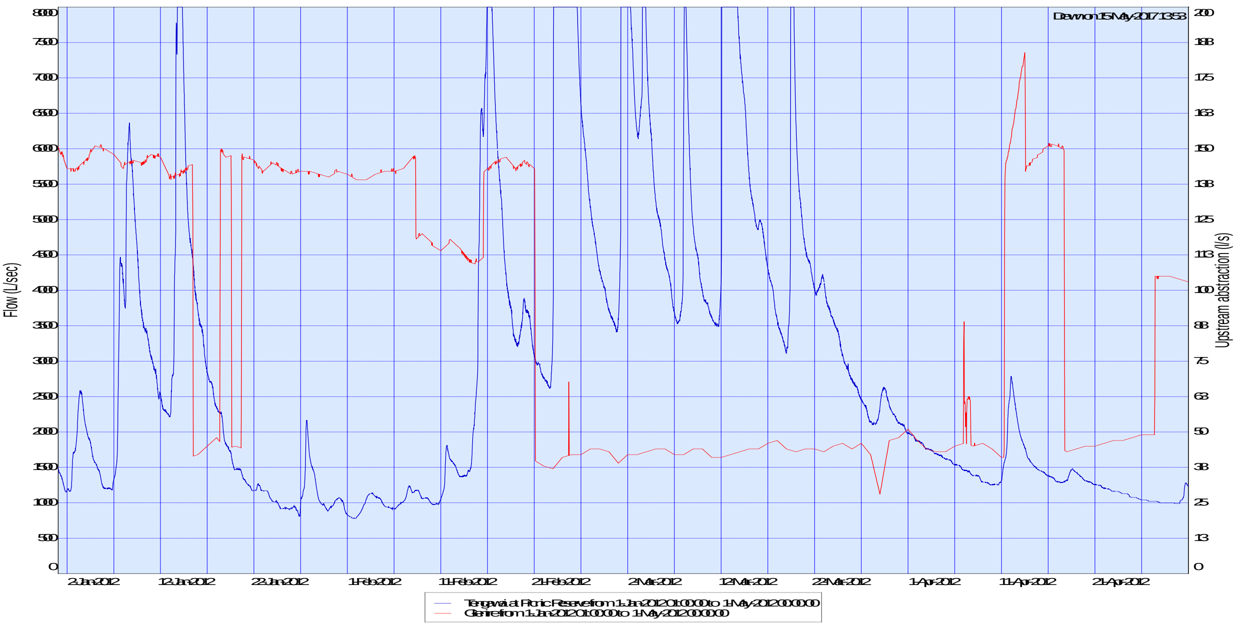
6) Method one – Variation of measured flow rates and recorder upstream abstractions.

The first method is to simply compare the variations in rates of measured flow at the Cave Picnic Reserve with the known variation in upstream flow abstractions. In this case, the major abstractions of water upstream of the Cave recorder site are the Downlands water supply intake (CRC012184, maximum take of 79 l/s) and the irrigation takes of Glenire (CRC992792.3, CRC171708 – total take 103 l/s). These takes are located in the upper section of the losing reach upstream of Mawaro.

Water usage data is available for the above consents since at least 2010. The following graphs show the recorded river flows (Manahune and Cave) and the recorded total abstraction from the consented takes upstream of Cave for the months of January to April inclusive for the last five years. The scale for the water usage data has been expanded to allow a better view of the data.

Figures 4 to 8 show the total abstraction of Irrigation plus Downlands Water supply. Figure 9 shows the abstraction of irrigation water only. This is because the Downlands supply is a relatively constant (and year round) abstraction.

Figure 4 : Tengawai River flow and recorded upstream abstraction 2012



[1] Gaugings between the old Downlands dam site and the present day intake site in 1998 and 1999 show there is no flow loss within this section

Figure 5 : Tengawai River flow and recorded upstream abstraction 2013

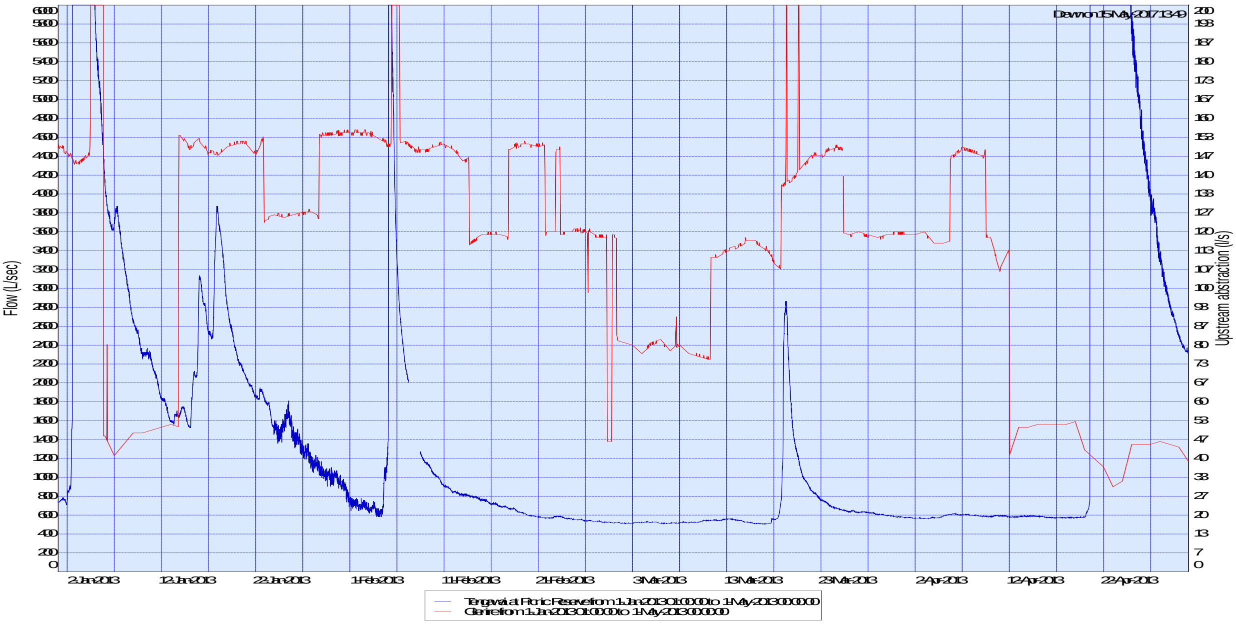


Figure 6 : Tengawai River flow and recorded upstream abstraction 2014

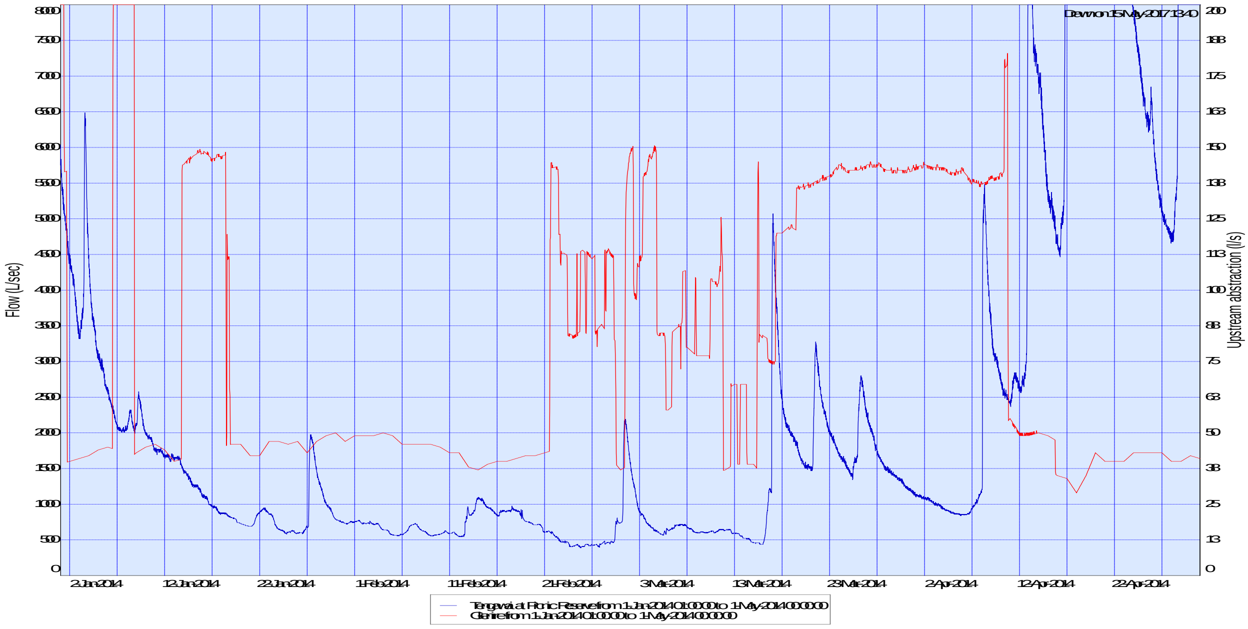


Figure 7 : Tengawai River flow and recorded upstream abstraction 2015

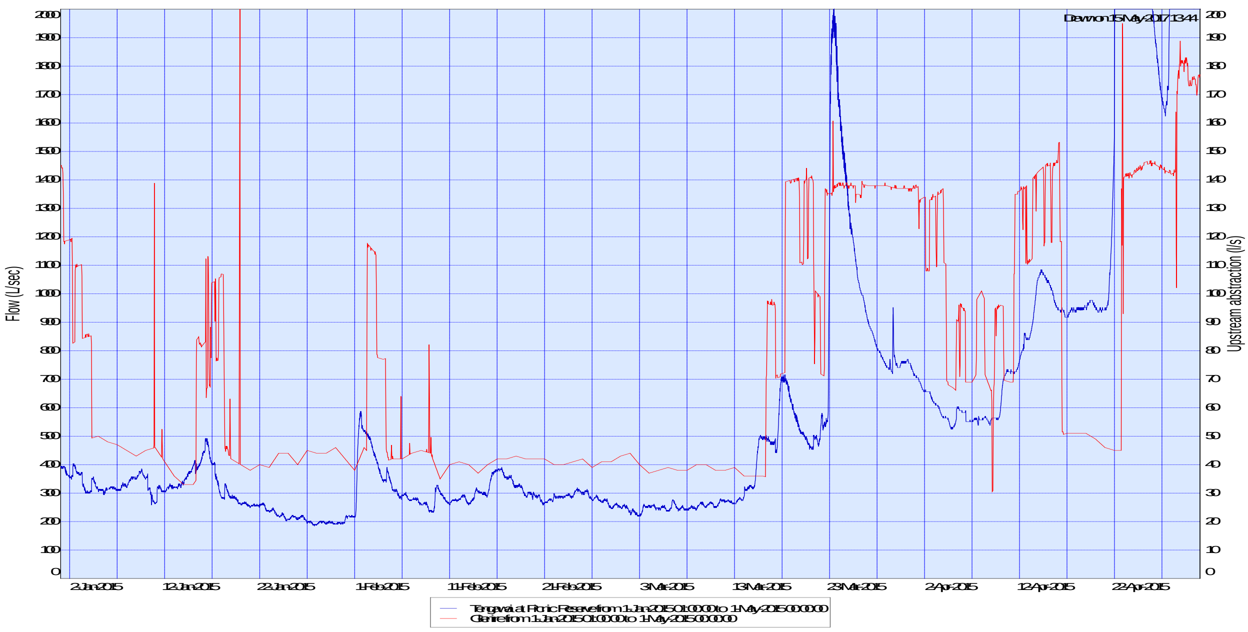


Figure 8 : Tengawai River flow and recorded upstream abstraction 2015

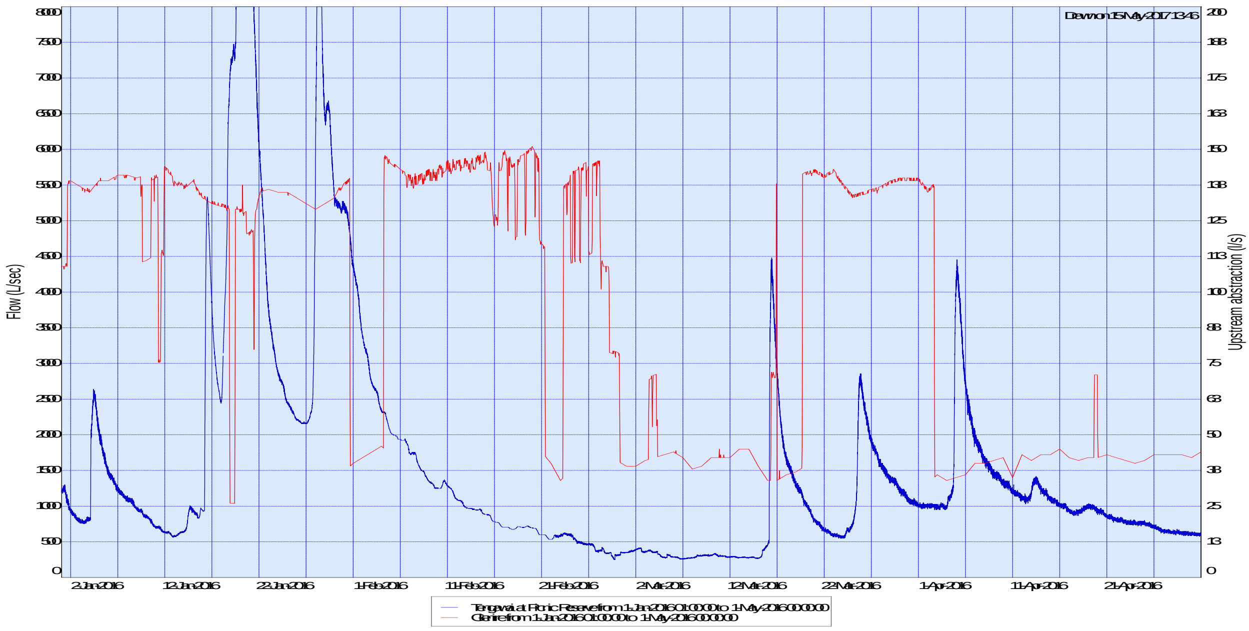
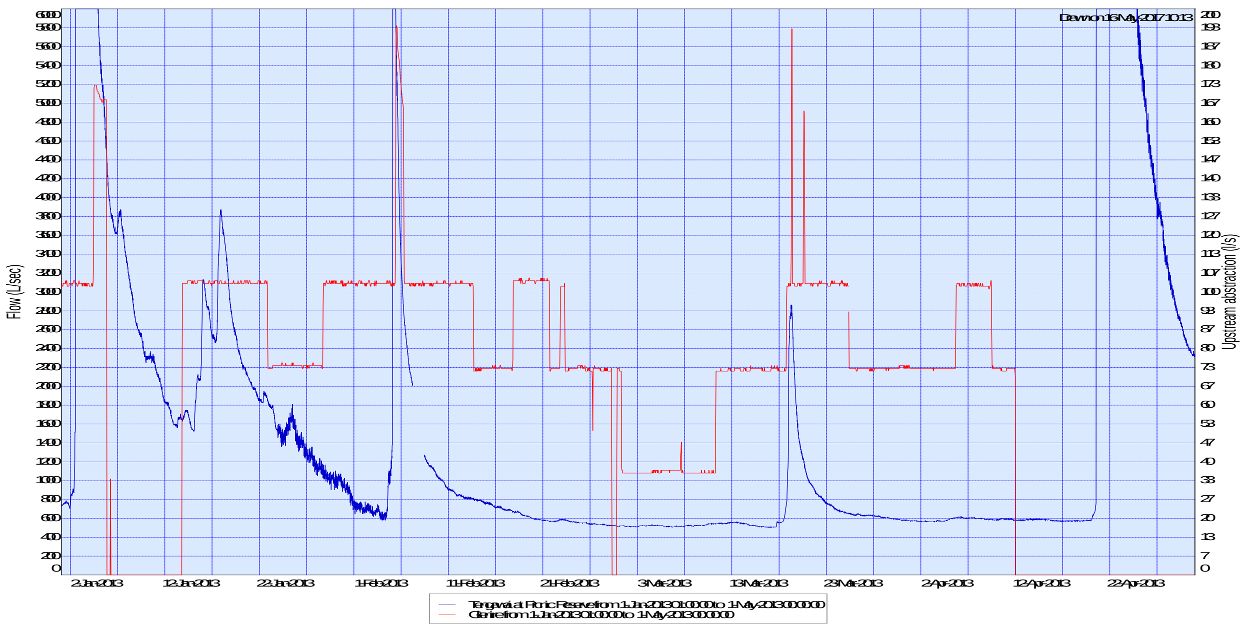


Figure 9 : Tengawai River flow and recorded upstream irrigation abstraction 2013



7) Method two - Flow regression Manahune minus abstraction and Cave Picnic Reserve

This method investigates the theory that the downstream flow is equal to the upstream flow (in this case Manahune) minus the abstractions.

A regression has been calculated using the measured flow at Manahune minus the abstractions of Glenire and Downlands Water supply, and Tengawai at cave Picnic Reserve. The regression used daily data for the irrigation season months October to April inclusive for the period from 2014 to 2017.

The regression is shown graphically in figure 10. Although the correlation co-efficient of 0.9265 suggest a very good fit, it can be seen that there is considerable scatter of individual points (which is in contrast to the lesser scatter of data points obtained for the non-irrigation season months shown in figure 3.1 and 3.2). The salient point here is that IF the flow at Cave WAS simply the flow at Manahune minus the abstractions upstream of Cave then it would be expected that there would be a very good correlation between the flow sites. Figure 11 provides a graph of the actual and predicted flow for Tengawai at Cave Picnic Reserve.

Figure 10 : Correlation Manahune minus abstraction vs Cave Picnic Reserve

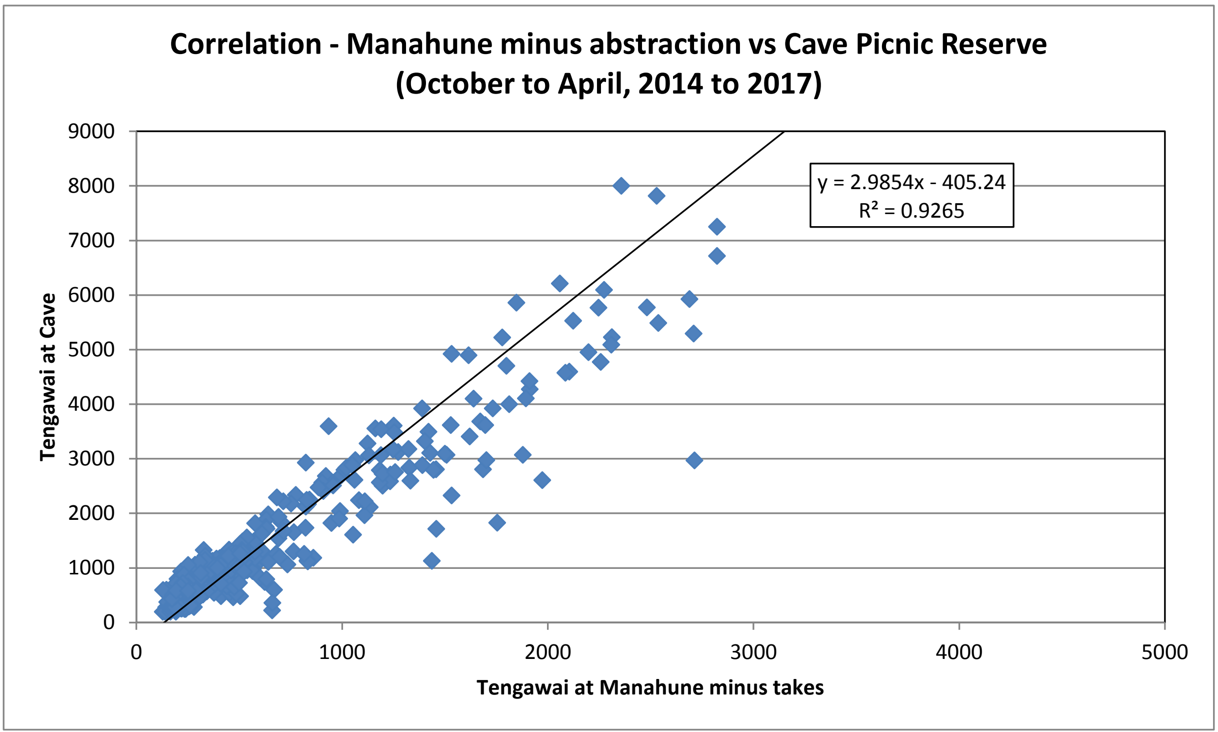


Figure 11 : Actual and predicted Irrigation season flow at Cave Picnic Reserve 2014 to 2017

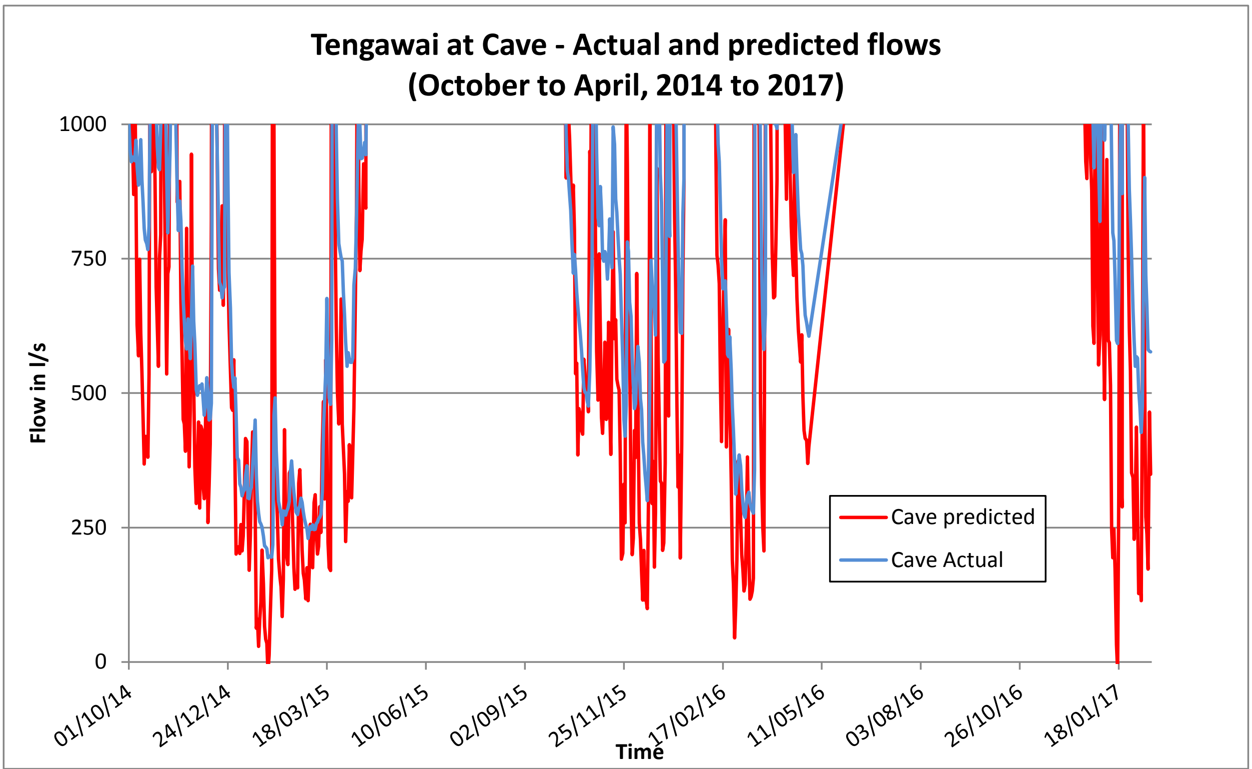


Figure 11 shows that deducting the upstream abstractions from the Manahune flow leads to an underestimation of the actual flow recorded at Cave Picnic Reserve. In other words, the assumption leads to an overestimation of the effects of upstream abstraction.

8) Discussion

Graphs 4 to 9 show that there is very little response in flow at Cave Picnic Reserve that can be immediately attributable to upstream abstractions. This is clearly demonstrated in the period of relatively stable flows in early 2013 (figures 5 and 9). Abrupt changes in upstream abstraction of 30 l/s do not show any noticeable change in river flows at Cave Picnic Reserve. The complete shutdown of irrigation abstraction (figure 9) on 12th April caused no change in flow at Cave Picnic Reserve prior to a fresh event on 20th April.

Graph 11 shows that for each irrigation season since 2014, deducting the irrigation and water supply abstractions in total from the Manahune flow data leads to an overestimation of the actual effect on the flow at Cave Picnic Reserve.

The most likely reason for the lack of response to upstream abstraction and the subsequent overestimation of effects of upstream abstraction, is the fact that the storage of water within the upstream gravels and the subsequent re-emergence of that water below Mawaro provides a buffering effect that reduces any immediate changes on downstream flow.

9) Conclusion

The graphs clearly show that the present method used by Environment Canterbury of "naturalising" flow for the Tengawai River does not reflect what actually happens. The method does not account for the buffering effect of the water stored and subsequently released into the river downstream of Mawaro and overstates the impact that abstractions have on the residual river flow.

The methodology to assess naturalised flows needs to be revised and amended to be able to account for the buffer storage of groundwater upstream of the Cave Picnic Reserve site.

References

Dodson, J; Steel, K: *Current state of surface water hydrology in the Opihi and Temuka catchments*. Environment Canterbury Report R16/16 (Draft). November 2016

Gair, H S; 1967: *Geological Map of New Zealand, Sheet 20 Mt Cook*. N Z Geological Survey Department of Scientific and Industrial Research