

Wairau Plain Groundwater & Wairau River Interaction

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1. Introduction

Surfacewater-groundwater interaction has become an important issue over the last decade in New Zealand as water resources have come under increasing pressure for the summer irrigation of crops.

Recognition of the linkage between groundwater and surface water flows is reflected in the number of recent reports that deal with different aspects of the issue (PDP and Environment Canterbury, 2000; White et al., 2001; New Zealand Hydrological Society, 2004).

The purpose of this report is to provide background material for decisions on groundwater allocation as part of the 2011 review of the freshwater components of the district plan by Marlborough District Council.

The report focuses on the effect of groundwater pumping from the Wairau Aquifer on the Wairau River. In particular the reach of the Wairau River where it interacts most directly with the Wairau Aquifer which is from the Waihopai River confluence to the Tuamarina River confluence (Figure 1).

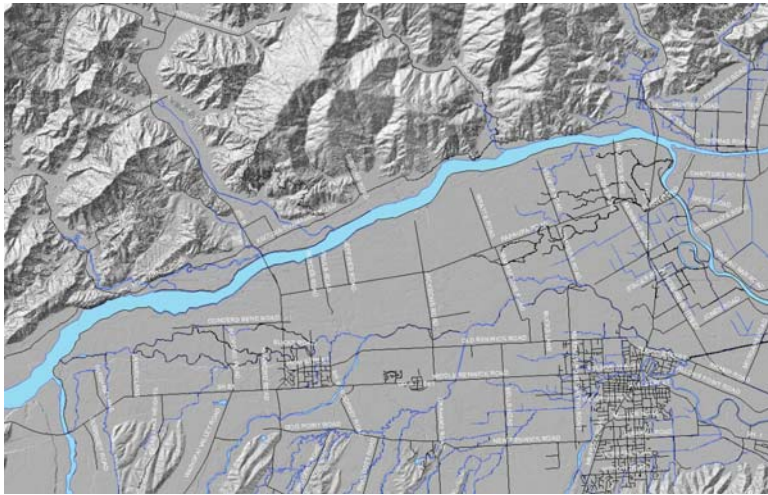


Figure 1. Wairau Aquifer Recharge Sector

This report has been updated from the original prepared in 2005 by Scott Wilson, a former Marlborough District Council hydrogeologist.

2. Hydrological setting

There are many examples of groundwater interaction with rivers or springs throughout Marlborough province. The most studied are the links between the mid Wairau Plain groundwater fed springs and pumping from the Wairau Aquifer (SKM 2006 & 2008).

Of potentially greater import is the effect of pumping from the Wairau Aquifer underlying the north-western Wairau Plain on Wairau River flows. Natural losses of water from the Wairau River channel provide most of the recharge for the Wairau Aquifer. This hydraulic connection is demonstrated by the rise in groundwater levels following Wairau River floods (Figure 2).

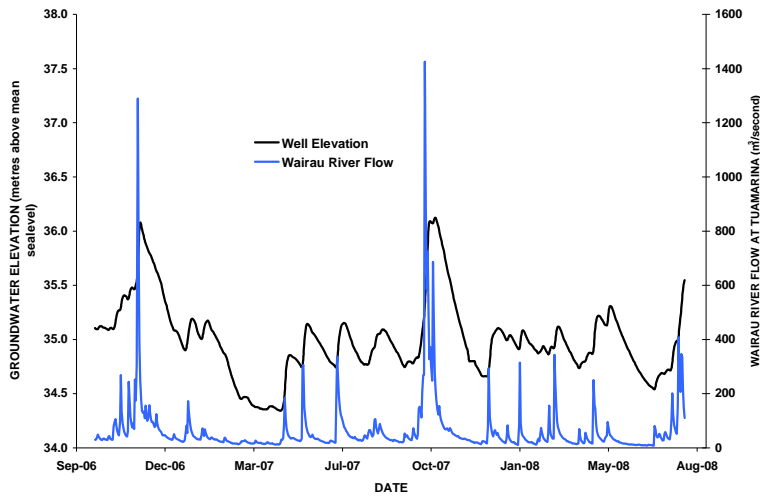


Figure 2. Wairau Aquifer Response To River Flows

The record in Figure 2 is from well 3821 located around 1.5 kilometres south-east of the Wairau River near the intersection of SH6 and Conders Bend Road. The response to floods at other MDC groundwater monitoring wells is just as compelling, but varies depending on the way in which local aquifer properties transmit the flood wave through the gravels.

This is illustrated by Figure 3 showing four wells representing varying degrees of aquifer confinement, versus the Wairau River flood peak in grey, measured at Barnetts Bank upstream of Tuamarina.

The blue line represents the same site (3821) as in Figure 2, where groundwater levels rise slowly due to the large storage of the unconfined aquifer west of Renwick that has to be filled by the water forming the river flood wave as it propagates inland.

The response at well 4577 in Selmes Road in red is far more rapid and reflects the lower storage of local gravels and the semi-confined nature of the aquifer. A quick rise also occurs at the coastal confined aquifer well (3667) shown in black. Groundwater levels at this site exhibit the trademark tidal variation.

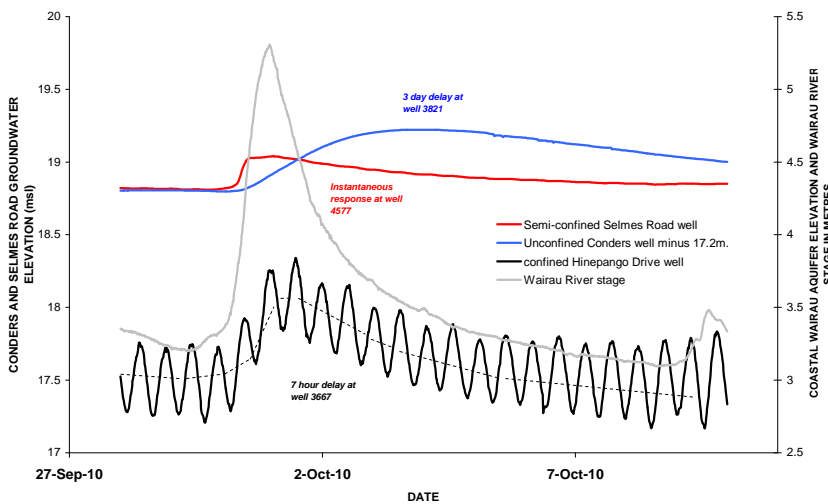


Figure 3. Wairau Aquifer Well Responses To A Wairau River Flood

The Wairau River is the dominant recharge source for the Wairau Aquifer. The direction of groundwater flow away from the river is shown by the straight black lines on the peizometric map in Figure 4.

The dashed lines represent contours of groundwater elevation in metres above mean sea-level based on field observations made by the Marlborough Catchment and Regional Water Board during a survey in March 1978.

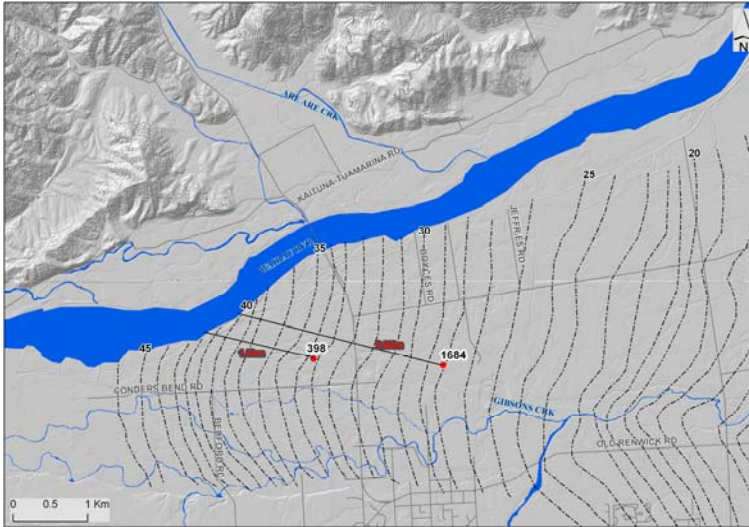


Figure 4. Wairau Aquifer Recharge Flow Direction

The interaction between Wairau River flow and groundwater along its south bank, in the reach between the Waihopai confluence and Tuamarina, is different to elsewhere in the Wairau catchment.

With the exception of small, localised losses of Wairau River flow to groundwater on the north-bank, the Wairau Plain south-bank is the only area of the catchment where a significant proportion of channel flow is lost to groundwater (Botting - 2010).

Elsewhere the Wairau River generally gains flow, mostly from surface runoff. This includes the Kaituna area on the north-bank of the Wairau River, where both groundwater and surface runoff is supplied from the Richmond Ranges and its tributary valleys (Taylor, 2004).

Wairau River low flows normally occur during the months of February to March, and coincide with the period of peak irrigation demand for water. At this time the Wairau River loses approximately 3-4 m³/second between Rock Ferry and the SH6 Bridge north of Renwick (Figure 1).

An additional 3-4 m³/second of channel flow is lost between the SH6 Bridge and about opposite Selmes Road. Relatively speaking the lowest channel flows are observed opposite Selmes Road, and downstream to Tuamarina, flows of 0.5-2 m³/s return to the river from groundwater. This reflects the appearance of the confining layer which forces groundwater to the surface and returns it to the Wairau River.

During higher flows the amount of recharge from the Wairau River into the aquifer is likely to be significantly greater than 7-8 m³/second. This is because river stage increases with flow, thereby increasing the wetted area of the riverbed. An increase in the wetted area allows a greater volume of river water to flow into the Wairau Aquifer. In addition, an increase in the relative difference between aquifer level and river stage increases the driving force for water to enter the aquifer.

3. Regulatory framework

The Wairau/Atawere Resource Management Plan (WARMP) specifies an 8 m³/second minimum flow below which surfacewater consents within the Wairau River catchment have to stop pumping.

The aim of the 8 m³/second limit is to protect instream ecological or natural character values, and maintain a minimum rate of recharge to the Wairau Aquifer from the Wairau River. The allocation

framework allows consent holders to take at a sum rate of 15 m³/second when river flow is above 30 m³/second at the Tuamarina recorder site. This allocation progressively reduces to zero when river flow reaches 8 m³/second.

The WARMP also signals the intention to establish a sustainable flow regime for groundwater abstractions along the same lines as that used for Marlborough’s larger river systems. To date no thresholds have been specified.

3.1. Wairau River low flows

Wairau River flow has been recorded near Tuamarina since 1960. The lowest recorded instantaneous flows were 2.5 m³/second in March 1973, and 2.6 m³/second in March 2001. Flow also fell below 5 m³/second in March 1972 and March 1978 (Figure 5).

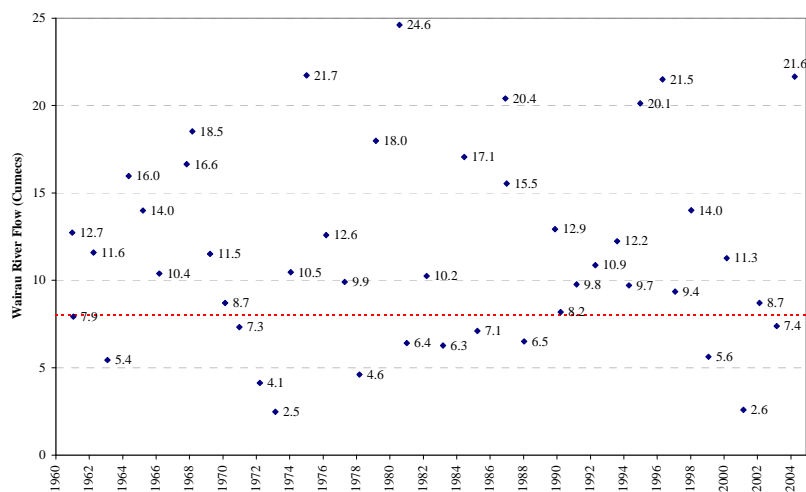


Figure 5. Annual Instantaneous Wairau River Low Flows At Tuamarina

The cut-off for class B surface water allocation is based on the mean daily low flow at Tuamarina of 8 m³/second. To give an indication of the relative reliability of this flow for water users, the annual low flows for each year from 1960 through to 2004 are shown by Figure 5 relative to the 8 m³/second threshold.

The Gumbel distribution gives a return period for a 3 m³/s low flow over a 3 day period at Tuamarina of 30 years. An instantaneous flow would occur a little more frequently and one lasting seven days, significantly less often.

4. Stream depletion principles

Stream depletion occurs when streamflow or groundwater that would otherwise end up contributing to channel flow, is removed by pumping wells. In many cases the effects are negligible and do not need to be considered further.

It is useful to describe the way in which stream depletion develops, and the well, aquifer or river parameters that determine its effects. Stream depletion develops via two main mechanisms. Either through the direct effects of a pumping well close to a stream or river, or through the indirect influence of many wells pumping a long distance away.

4.1. Direct effects

Direct stream depletion effects occur when the drawdown cone of a pumping well intersects the surface water body. The amount of water drawn from the stream into the well is largely determined by the degree of hydraulic connection with the surface water body.

Direct stream depletion can be measured by the change in flow of a river, by aquifer tests, or calculated using equations that have been developed over the past decade. In practice there may be several pumping wells operating at any one time.

In this situation it is difficult to attribute the effects to a single well. The effect on the surface water body is compounded when multiple wells are pumping and the cumulative stream depletion effect can be calculated by summing the individual direct effects.

4.2. Regional drawdown effect

Unlike direct stream depletion effects, the regional effect cannot be traced to any individual user or group of users. Regional stream depletion effects are caused when the water table is lowered over a large area in the vicinity of the surface waterbody.

In this case, drawdown resulting from a loss of groundwater is the most significant factor. Regional stream depletion effects will occur where the cumulative abstraction across an aquifer is sufficient to steepen the hydraulic gradient away from the Wairau River, and consequently, to induce more water out of the river than would naturally be the case.

The stream depletion effect resulting from regional drawdown is limited by the conductance of the streambed as the difference between the river level and aquifer water table increases. Leakage from the river increases as the hydraulic gradient increases and approaches the streambed conductance value when the river eventually becomes "perched".

The transmissivity of the Wairau Aquifer is very high meaning wells will readily establish a hydraulic linkage with neighbouring rivers or springs, even over large distances. Consequently, the lowering of groundwater levels caused by pumping in the unconfined aquifer north of Rapaura Road will be limited due to the presence of the river. In other words, drawdowns will extend outwards to intercept the channel and will then be buffered by the effect of the river acting as a recharge boundary.

4.3. Methods of determining stream depletion rates

4.3.1. Direct measurement

In streams with small flows, stream depletion effects can be measured by the difference between flow at two points in the channel. However, large flowing braided rivers such as the Wairau River are notoriously difficult to gauge accurately. Concurrent gaugings have also been used successfully in streams with smaller flows such as the Tuamarina River, Ganes Creek, Doctors Creek, Fultons Creek, Murphys Creek and Drain N.

Wairau River channel losses due to pumping from an individual bore are small relative to the total flow. As a result, any measured depletion will be within the error limits of the gauging method.

4.3.2. Analytical equations

Individual stream depletion effects are commonly estimated using mathematical equations representing a particular aquifer type and boundary conditions. These mathematical representations of the real world have been developed relatively recently as interest in and recognition of stream depletion has developed (Hunt, 1999; Hunt, 2003; Environment Canterbury, 2000).

The results of calculations are specified in terms of actual stream loss to the well, or as a percentage of the pumping rate. An example of an assessment in an unconfined aquifer is shown in Figure 6.

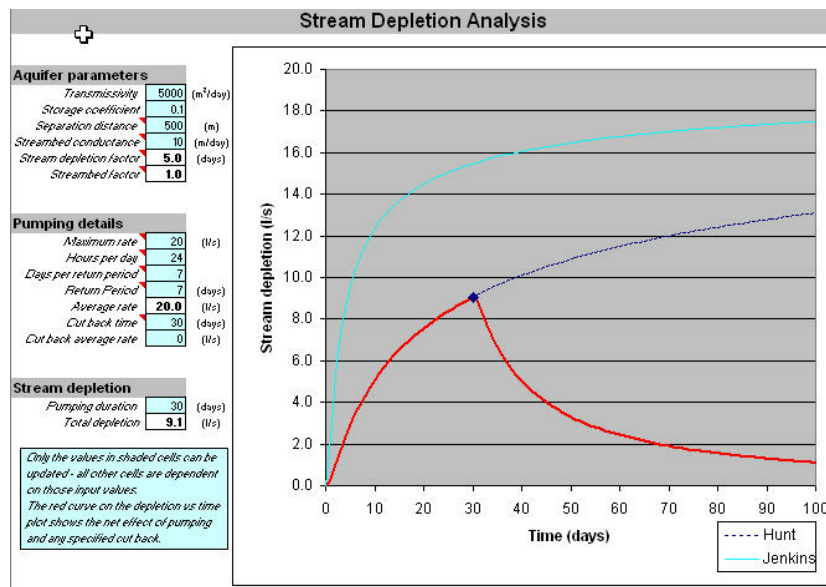


Figure 6. Example Of A Stream Depletion Assessment For An Individual Abstraction (courtesy of Environment Canterbury)

The graph shows an assessment using two different analytical methods. The Jenkins method (light blue curve) does not take into account streambed conductance and is invalid for streams where there is a significant silt layer, whereas the Hunt method (red curve) does.

The latter approach also incorporates a response to the pump being turned off, in this case after 30 days duration. Because Wairau Plain springs don't generally have well developed, thick stream bed clogging layers, the Jenkins equation provides a good estimate of the stream depletion effect.

Stream depletion effects can also be detected in aquifer test observations based on graphs of well drawdown over time. A distinctive flattening of the slope often accompanies the onset of stream depletion effects, reflecting the interception of a recharge source by the cone of depression generated by a pumping well.

Care does need to be taken with interpreting drawdown curves as changes in slope may also represent other effects such as leakage of water from an aquitard, or delayed yield in an unconfined aquifer.

Aquifer tests can also be used to solve the stream depletion equations, and derive indicators of stream depletion such as the stream bed clogging parameter Lambda. However this approach isn't as certain as direct measurement if there are multiple unknown parameters. The availability of nearby aquifer test results gives much greater confidence when estimating stream depletion effects.

Another analytical technique to determine the regional effect of stream depletion is the river coefficient method (Rushton, 2003). This approach uses observations of concurrent flow (Q_r) and the water level in the river versus the aquifer to derive a river coefficient called RC.

$$Q_r = RC (H_{\text{groundwater}} - H_{\text{river}})$$

This empirical method can give an approximation of stream loss due to a reduction in groundwater level caused by pumping. Its accuracy relies on a large number of concurrent flow and riverbed versus aquifer level observations to define the value of the river coefficient.

4.3.3. Numerical modelling

Numerical models are useful for assessing regional stream depletion effects because they have the computational power to incorporate the many hydraulic and physical properties of an aquifer which drive stream depletion. For example they can simulate the complex nature of the Wairau River braided river pattern and predict how daily changes influence the rate of aquifer recharge.

A numerical model is a mathematical approximation of reality and are extremely useful for forecasting. For example, how would pumping an extra 1 m³/second of groundwater from the Wairau Aquifer in the Rapaura area affect Spring Creek flow. The river coefficient equation outlined above is built into the model to describe the relationship between groundwater and surface water.

The accuracy of any model requires a good conceptual understanding of the aquifer being assessed and sufficient observations to calibrate it. MDC first developed a model of the Wairau Aquifer to set sustainable limits on abstraction in the early to mid 1990s.

More recently PDP Ltd and Aqualinc Research Ltd have been commissioned by MDC to develop more comprehensive models to refine these limits, and these have been used to predict stream depletion effects on springs due to groundwater pumping.

4.4. Assessment considerations

The effect that any groundwater abstraction will have on a stream is dependant on many factors:

Well and screen location: Stream depletion is strongly influenced by the proximity of the well to the surface waterbody. The closer a well is to the waterway the larger the potential effect. Also, wells with deeper screens will tend to have a lesser effect than those with shallow screens that are closer to the stream channel.

Aquifer hydraulic properties: Stream depletion effects are greater when an aquifer has low storage (S), and transmits water well meaning it has a high transmissivity value (T). Aquifer properties are often used to describe the stream depletion effect in terms of the stream depletion factor (SDF):

$$SDF = (d^2 S) / T$$

Where d is distance from the surface waterway. The stream depletion factor is reported in terms of days, with a low SDF indicating a high effect, and a high SDF (e.g. 100 days) indicating a negligible effect. Note that the SDF will give an indication only, as the actual stream depletion will be influenced by many other factors, as outlined below.

Pumping rate and duration: The larger the pumping rate, the greater the aquifer drawdown and ability to establish a hydraulic connection. Stream depletion effects increase over time as pumping is continued.

Degree of confinement: Aquifer structure and in particular the presence of a confining layer creates a physical barrier separating the surface waterbody from the aquifer, thereby reducing the stream depletion effect. However, full confinement can also increase the rate of stream depletion due to the low storage it imparts on the aquifer through its structure.

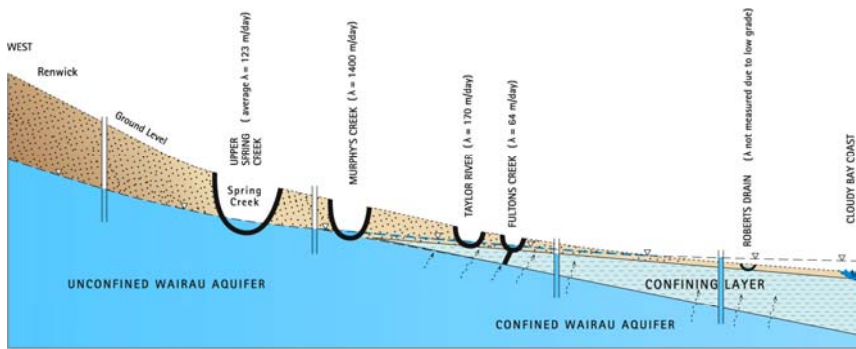
Streambed conductance (λ or λ): Streambeds can contain either coarse or fine sediments. Increasing the proportion of fine clays or silts forms a barrier that reduces the vertical flow of groundwater from the aquifer to the stream or vice versa.

Some streams may be so full of fines that they are effectively sealed. An example of this is Gibson Creek near Renwick which had silted up prior to the introduction of the Southern Valleys Irrigation Scheme (SVIS) in 2004 and its associated channel works which restored the previously leaky channel regime.

The streambed conductance of the Wairau River will change from reach to reach and over time. Generally speaking the average value is likely to be high; otherwise water wouldn't move as freely as it does to and from the aquifer.

During periods when there are fewer flood flows, it is likely that silts accumulate and reduce the rate of groundwater recharge, but there are few measurements to confirm the variability. The analysis of aquifer test results indicates a Wairau River bed conductance of 150 m²/day to 1500 m²/day, indicating a close connection with groundwater (PDP, 2004).

Most of the groundwater fed springs that rise through the centre of the Wairau Plain have high stream bed conductance values. This means groundwater and spring channel flows form a single water body, especially in their upper reaches before the confining layer thickens (Figure 7). For example values as high as 1,400 m²/day have been measured for Murphys Creek.



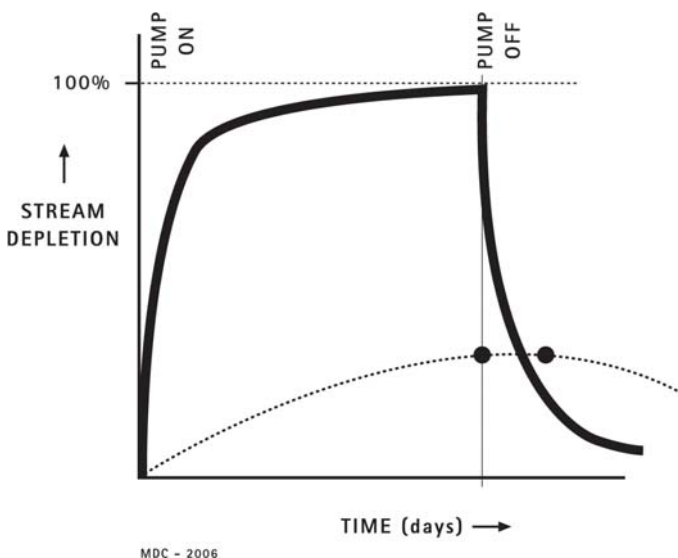
SPRING INTERACTION WITH GROUNDWATER

MDC - 2008

Figure 7. Longitudinal Variation in Aquifer Confinement And Spring Bed Conductance

Delayed response: The combination of the above factors will contribute to varying degrees of delay in the magnitude and timing of the stream response to pumping. Conversely there is also a delay in stream depletion response to the turning off of a well (Figure 8).

The heavy line in Figure 8 represents the pumping rate. Under some conditions, a stream depletion effect can continue to increase slightly after a well is turned off before the effect starts to subside as Figure 8 illustrates conceptually.



MDC - 2006

Figure 8. Delayed Stream Depletion Response

Percentage of flow: A stream depletion effect of 10 l/s from a single well on a small stream, for example Doctors Creek, could reduce flow by up to 10% during periods of low flow, even in its lower reaches where flow is perennial. The same depletion effect on the Wairau River would be insignificant compared to the typical summer flows of around 20 m³/second at Tuamarina.

However, the significance of the effect on the Wairau River will be greatly increased when considering the cumulative impact of 100 wells each pumping at 10 l/s, or during very low flows (Figure 9). At the lowest flows observed in the Wairau River at Tuamarina of around 3 m³/second, the predicted potential stream depletion effect generated by several hundreds of irrigation consents of around 0.5 m³/second, becomes significant as Figure 9 shows.

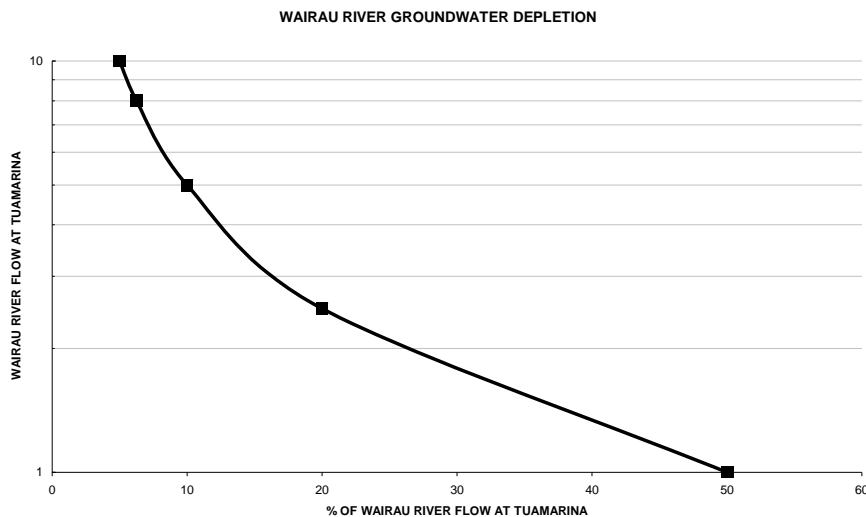


Figure 9. Stream Depletion As Percentage Of Wairau River Drought Flows

Interpretation: The effect of any abstraction can be assessed in different ways depending on whether the percentage of surface water contributing to well abstraction is important, or the actual stream depletion rate. These two different approaches correspond to two different philosophies regarding resource allocation.

A percentage of surface water, or degree of hydraulic connection, indicates the proportion of the abstraction that can be regarded as surface water versus groundwater. The calculation of actual loss to the stream is an effects-based approach, and does not necessarily distinguish between surface water and groundwater for allocation purposes.

5. Effects of groundwater abstraction on Wairau River flow

Current levels of consented demand can potentially reduce Wairau River channel flows. Because the effects are quite different depending on whether wells are situated on the north or south of the Wairau River, the effects are assessed separately.

The reasons for the differing effects are primarily geological. The south-bank of the Wairau River is more characteristic of the narrow, Wairau Valley further west. Whereas the south-bank is hydraulically linked to the much larger alluvial Wairau Plain. Some of the distinguishing characteristics of the two areas are:

- *North-bank streams and groundwater flow towards the Wairau River and contribute to the total catchment runoff measured at the Tuamarina flow recorder. The reverse occurs on the south-bank, with Wairau River water being lost to the Wairau Aquifer in the Rapaura area. Both of these phenomena are natural processes.*

- Any take from north-bank streams intercepts water that would otherwise join the Wairau River. Groundwater abstractions generally have a lesser, indirect effect on Wairau River channel flow. This reflects the buffering effect of aquifers, meaning water pumped to the surface will be taken from storage during the initial stages of pumping, rather than active throughflow to the river.
- The important factor to consider here is the effect of delay, which is a measure of the aquifer’s ability to offset the loss in river flow caused by pumping from wells. The degree is largely dependant on the quantum of aquifer storage and the distance of the well from the Wairau River channel.
- Another major difference in aquifer processes is the smaller size of the gravel deposits forming the north-bank aquifers. They store less groundwater than the south-bank, which is a very large natural reservoir by comparison.
- North-bank gravels also have both lower permeability and nearby rock boundaries which limit the volume of groundwater available to abstract, and compounds the magnitude of drawdown generated by a pumping well, all other factors being equal.
- Due to its smaller volume, the north-bank groundwater resource is more sensitive to natural recharge patterns. Levels are likely to change considerably throughout the year in response to ephemeral Wairau River tributary flows such as the Onamalutu or Waikakaho Rivers. Notwithstanding this rainfall on the north-bank is higher and at least 1 metre per year.
- There are several surface water abstractions on north-bank streams. There are very few instances of direct takes on the Wairau south-bank downstream of the Waihopai confluence because of the accessibility of groundwater everywhere.

Details of water consents along the margins of the Wairau River are listed in Table 1.

Category	South-bank	North-bank
Number of consents	128	25
Total abstraction	83,642 (m ³ /day)	20,214 (m ³ /day)

Table 1. Water Permit Details

The location of these water permits is shown by the map in Figure 10.

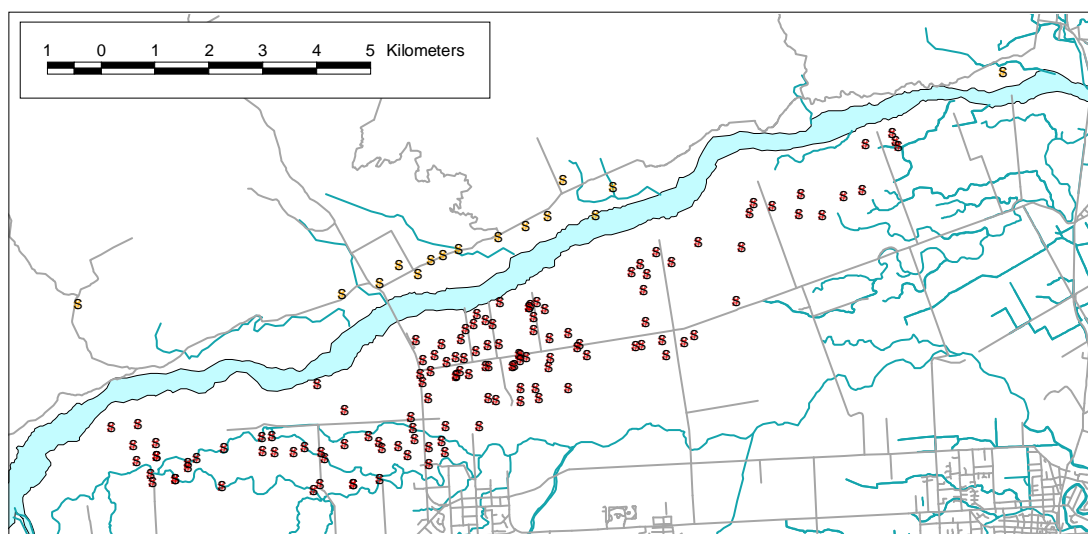


Figure 10. Underground Water Permits Bordering The Wairau River

5.1. South-bank stream depletion effects

5.1.1. Individual effects

Three aquifer tests in the Conders area, south-west of the SH6 bridge over the Wairau River have been analysed to determine the stream depletion effects generated by pumping wells (PDP, 2004). Of the three tests analysed, one result showed a clear river recharge effect (well 3758), one was probable (well 4163), and the other was not proven (well 4025). While there are uncertainties over the hydraulic linkage for two of these wells, it is likely that their pumping has at least some effect on Wairau River channel flows.

The reason for this is that the Wairau Aquifer is very transmissive in the Conders-Rapaura area. Where transmissivity is high, the radius of influence caused by a pumping well is also large. If the radius of influence of a well intersects the river channel, it can generally be assumed that some stream depletion will occur. The radius of influence is determined from a distance-drawdown plot.

5.1.2. Cumulative effects

The cumulative stream depletion effect of pumping on the Wairau River can be estimated by summing the individual drawdowns generated by each well. This is the approach taken by Environment Canterbury in the development of their Natural Resources Regional Plan Section 32 report (Scott, 2003). This method has here been applied to estimate the cumulative south-bank pumping effect over a dry irrigation season on Wairau River flow.

Knowledge of aquifer properties are needed to calculate the effects. These are measured by aquifer tests, but are few and far between near the river. Consequently, representative values for aquifer properties were used for the simulation of: transmissivity = 2500 m²/day, storage = 0.1, lambda = 50 m/day. The simulation was tailored for an extreme situation, or drought year, where an abstraction of 75% of the consented allocation continues for a 100-day period.

The results of the south-bank simulation are graphed in Figure 11 as a distribution of the individual effects. The river depletion effects have been ranked and classed according to the same system used by Environment Canterbury (Scott, 2003). The criteria for distinguishing between the categories of effect are as follows:

- High-moderate threshold: stream depletion effect after 7 days = 90% of pumping rate
- Moderate-low threshold: stream depletion effect after 150 days = 60% of pumping rate
- Low-insignificant threshold: stream depletion effect after 150 days = 40% of pumping rate

None of the abstractions in the simulation can be considered as having a high effect based on the Environment Canterbury framework. The results show that the stream depletion effects are fairly evenly proportioned between a moderate, low and insignificant effect.

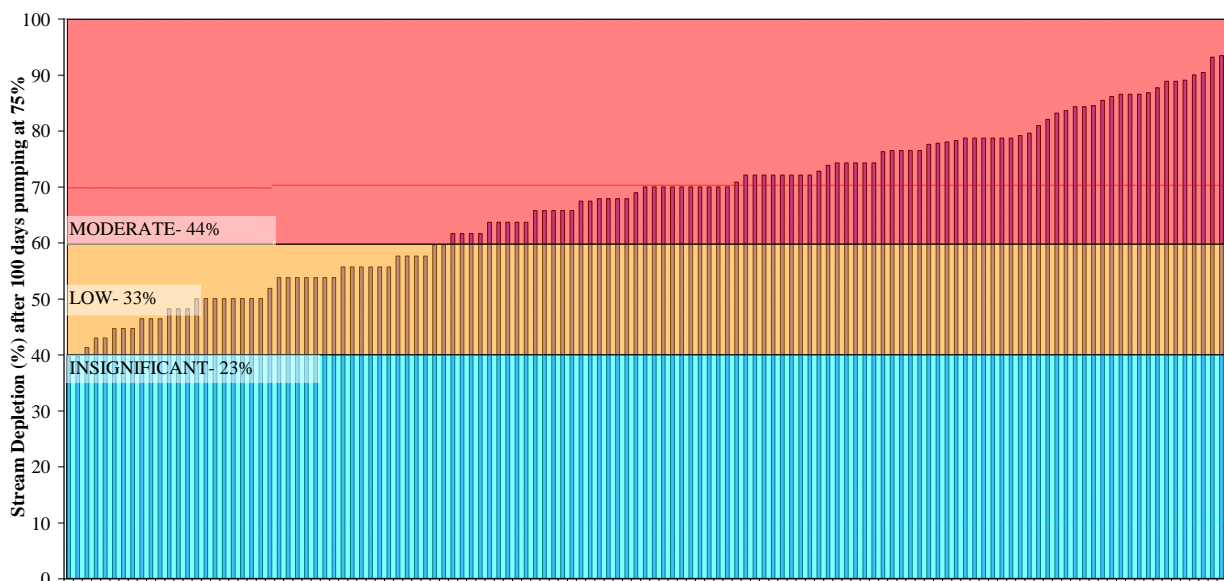


Figure 11. Distribution Of Stream Depletion Effects For Consented Abstractions Within 3km of Wairau River South-bank

The simulation results are highly dependant on the values of parameters used. For estimating effects on the Wairau River, the equation is most sensitive to aquifer storage and to a lesser extent transmissivity. Streambed conductance has little bearing on the result as this value is expected to be high (at least 50 m/day), so its potential to limit stream depletion is low.

The potential upper limit of stream depletion effects is 650 l/s, with an expected range of 350-500 l/s. It should be noted that total stream depletion may be slightly higher than this value depending on the amount of regional drawdown caused by loss of groundwater storage during pumping.

5.2. North-bank stream depletion effects

5.2.1. Individual effects

Five pumping tests in the Kaituna area have been assessed for stream depletion effects (PDP, 2004). Several of the tests such as the pumping of well 4132 indicated hydraulic connections with Are Are Creek, however not all were this definitive.

A unique aspect of north-bank streams and aquifers is the contribution they make to Wairau River channel flow. This doesn't occur to the same extent on the south-bank, except for the reach from opposite Selmes Road downstream to Tuamarina.

Any abstraction along the north-bank intercepts water that would otherwise contribute to Wairau River flow. However, the loss of Wairau channel flow from a well located away from the Wairau River will not be instantaneous, and in some cases there may be considerable delay before a reduction in flow in the main stem takes place. This will especially be the case if the well is pumped at a low rate.

This is particularly true of abstractions located at considerable distance up the side valleys, for instance the ephemeral Waikakaho River or Onamalutu River. Under these circumstances, there will be no direct effect on Wairau low flow as abstractions will draw entirely on groundwater storage while the streams are not flowing. When a rainfall event occurs after a dry period, water that would otherwise flow down the stream is lost to gravels in the vicinity of the well. The stream will not flow past the area of abstraction until groundwater storage is replenished.

Consequently the ephemeral streams are dry for longer periods of time, but much depends on the scale of pumping. So, while abstractions at some distance from the river can appear to be hydrologically isolated, they will potentially have a large effect during the critical period of flow recovery.

5.2.2. Cumulative effects

The cumulative stream depletion effect has been assessed using the same approach as for the south-bank of the Wairau River. A pumping schedule of 75% of the consented allocation over a 100 day period has been used.

Where appropriate, boundary effects have been included in the calculation to improve the accuracy of the forecast. The method used to calculate impervious boundary effects is outlined in Miller and Durnford (2005). There is greater confidence in the stream depletion predictions here because more aquifer test information is available for the Kaituna area than the riparian margins along the south-bank.

A summary of the predictions are shown in Table 2 and graphically in Figure 12. The surface abstractions in most cases can be considered as direct abstractions from the Wairau River. One exception to this rule applies to direct takes and groundwater abstractions from the Waikakaho or Onamalutu Rivers, where there are reaches which dry up.

Stream depletion (l/s)	Abstraction (l/s)	7 days	30 days	60 days	100 days
Wells without boundary effects	12.3	0.6	3	4.4	5.3
Wells with boundary effects	116.6	35.9	53.5	60.8	65.6
Surface Abstractions	90	90	90	90	90
Total	218.9	126.5	146.3	155.2	160.9

Table 2. Predicted North-bank Wairau River Stream Depletion

Consequently, there may not be continuous flow between the point of abstraction in the tributary and the Wairau River. A Wairau River depletion assessment for these abstractions involves a catchment simulation for the two tributaries, which is beyond the scope of this report. For ease of assessment, a continuous link with the Wairau River is assumed as the effect of these abstractions is most pronounced during the critical period of catchment recovery.

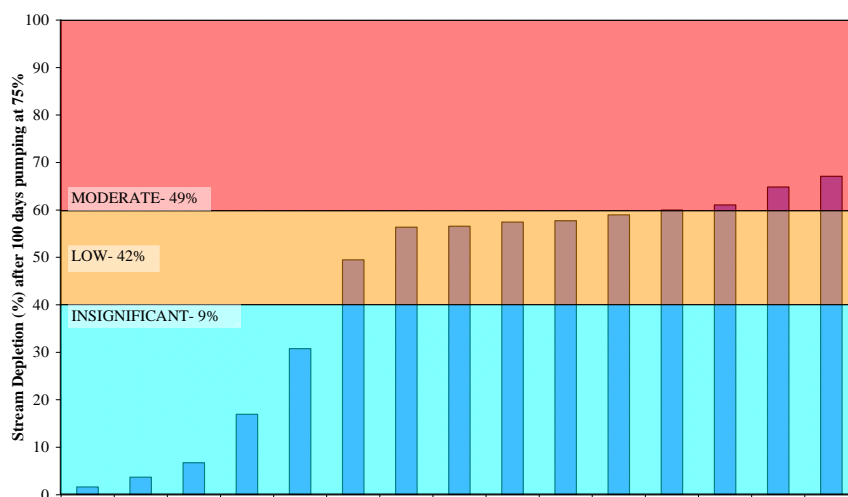


Figure 12. Distribution of Stream Depletion Effects For Consented Abstractions North of the Wairau River

6. Sensitivity of Wairau River flows to pumping and recovery

This section evaluates the significance of the stream depletion effect compared to river flow. When assessing stream depletion effects it is important to determine the value of turning irrigators off in terms of flow recovery. Enforcing restrictions is a time consuming exercise and there is no point in restricting irrigators if there is little benefit to the river.

Stream depletion effects will continue after abstractions have ceased, particularly as many wells are located a large distance from the Wairau River. In the case where Wairau River depletion after 100 days of irrigation is 500 l/s, there will still be 350 l/s of depletion a week after well pumping has ceased. In order to determine whether pumping restrictions will benefit river flow, we need to also consider the natural flow recession of the river.

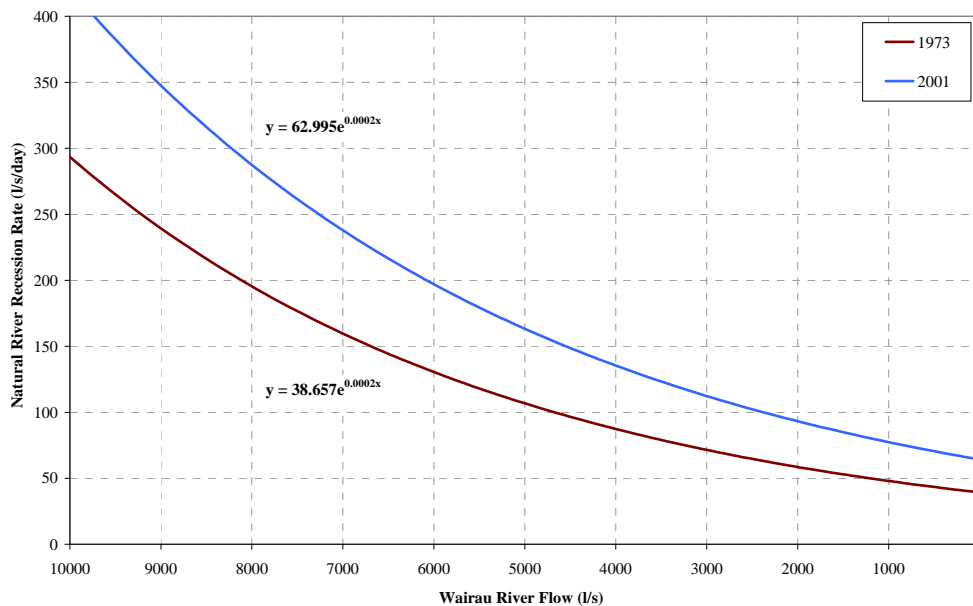


Figure 13. Wairau River Baseflow Recession Rates for the 1972-1973 and 2000-2001 Droughts

The lowest flows experienced by the Wairau River in recent times coincided with the 1973 and 2001 droughts. The baseflow recessions for these events are shown by Figure 13. For a low flow of 5 m³/second, the natural river baseflow recession is somewhere between 105 and 170 l/s per day. As a rule of thumb, river baseflow will halve every 14 days.

To significantly improve river flow at low flow, the benefits of restricting irrigators would need to be greater than the natural recession of the river. Figure 14 shows that if restrictions were applied to all abstractions at a flow of 5 m³/second, an improvement in river flow would not be noticed for at least seven days. For the first week after restrictions, the rate of natural river recession is greater than the rate of recovery from pumping.

During this period the river had continued to lose around 150 l/s per day through natural baseflow recession. It follows that the trigger level for restrictions would need to be set at a higher flow to meet a 5 m³/second target. Pumping would need to have ceased 8 days earlier when the flow was about 6.2 m³/second.

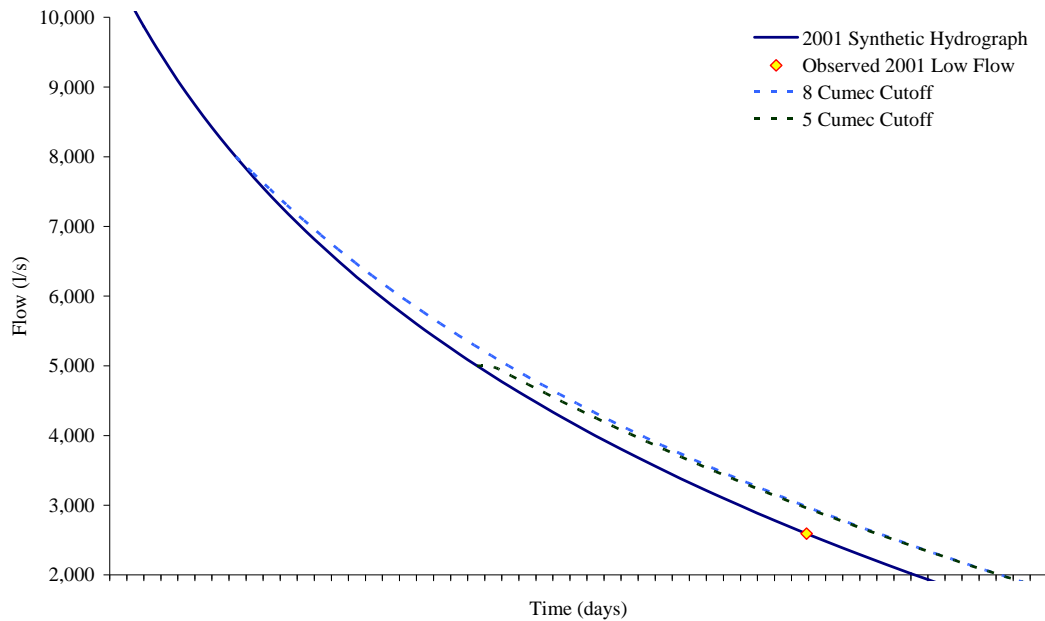


Figure 14. Synthetic Wairau River Recession Curve For 2001 Drought

The dashed lines represent the river response to a restriction of all simulated groundwater takes on the north and south banks.

7. Wairau River low flow management

The Environment Canterbury stream depletion framework is effective in circumstances where the abstraction volume of each well is approximately equivalent. Inequalities can occur in situations where there is a wide range in abstraction volume between individual consent holders. This is because the Environment Canterbury framework expresses stream depletion depending on the proportion of surfacewater to groundwater.

Consequently, the results do not indicate the actual pumping rate of the well, and therefore the net stream depletion effect. This can be accounted for by setting a threshold on the volume of abstraction to which the method is applied. Another approach is to assess the actual depletion effect in terms of the volume loss from the river.

Thresholds can be selected to avoid certain issues from developing, or to maintain the function of a waterway. As an example, an individual flow depletion effect of less than 2 l/s is generally considered to be insignificant relative to Doctors Creek low flows.

The threshold value is determined by comparing the cumulative depletion effect with its impacts on the flow regime in the critical reach ecologically, and to downstream rivers such as the Taylor River.

For the Wairau River where a large range exists in well pumping rates, stream depletion may be better defined in terms of the actual effect on river channel flow. What's more, about half of the predicted cumulative effect is generated by a dozen wells.

An alternative management strategy is to use thresholds or buffers strips along the length of the river where restrictions may apply. Table 3 shows the stream depletion effects on the south-bank for two arbitrary buffer distances.

Buffer distances can be refined by applying the stream depletion factor if there is sufficient knowledge of the variation in aquifer properties along the length of the river. A buffer management system is easy

to apply, but is not necessarily equitable. There may be wells within the buffer that have negligible depletion effect, and conversely wells outside the buffer may have a large effect.

It is of note that a 1000 metre buffer would encompass 44 consents. Comparatively if all abstractions in the study area with a stream depletion effect of 10 l/s or greater were targeted, there would be eleven consents with a total depletion of 245 l/s.

Buffer Zone	Total abstraction (m ³ /day)	Number of consents	Stream depletion (l/s)
less than 1000m	25646	44	186
less than 2000m	70949	105	436

Table 3. Predicted Stream Depletion for A Buffer Zone Along The South-bank

8. Conclusions

- During dry conditions Wairau River flows are predicted to be depleted by the order of 500 l/s due to the combined pumping effect of existing consented groundwater takes.
- This ball park estimate depends on a number of assumptions and factors such as the duration of pumping. Nevertheless it indicates the magnitude of the likely effects for planning purposes.
- Stream depletion effects are normally a small proportion of channel flow except under very low flow conditions.
- There are a number of ways of managing stream depletion effects generated by consented water users and each has its merits and disadvantages. Most involve defining an area where consented takes are managed in some way. For example buffer zones along the margins of the Wairau River or controlling groundwater takes which generate a high actual stream depletion effect, or induce a high proportion of river flow versus groundwater.
- The acceptable level of stream depletion caused by groundwater pumping is a community decision and there is no right answer. A comparison of the benefits of restricting access to water users for crop irrigation needs to be weighed against the ecological and community values associated with lower river flows for longer.
- At least half of current river depletion is the result of a small number of large abstractions.
- The benefits of restricting consented use is fairly slow acting based on simulations.

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