Chapter 17: Wairau Aquifer

Introduction

The Wairau Aquifer is arguably the Wairau Plain's most valuable natural resource and is often taken for granted as a limitless supply of water. It is the predominant groundwater system underlying the Wairau Plain. It is the source of most irrigation water for this intensively farmed area, together with the bulk of drinking and stock water.

The Wairau Aquifer also supplies the municipal water requirements for Blenheim and its satellite towns of Renwick and Woodbourne. It is the most extensive and important groundwater resource in the region by far (Fig. 17.1).

Figure 17.1: Coastal Wairau Plain looking south

On a national scale it ranks alongside the groundwater resources beneath the Heretaunga Plain, Hutt Valley, Waimea Plain and the Canterbury Plains, as being the most significant in the country.

What makes the Wairau Aquifer such a superb natural water reservoir is a combination of its geology and a reliable source of recharge. The Wairau Aquifer is hosted by the highly permeable Rapaura Formation gravels. These gravels were deposited by the Wairau River and its ancient predecessors over thousands of years and these gravels are still being deposited and reworked to this day.

The Rapaura Formation represent the upper 30 or so metres of what is essentially a large pile of alluvial gravels filling the Wairau Valley from the Upper Wairau to Cloudy Bay.

The other factor which makes the Wairau Aquifer such a reliable source of water is its continuous and uninterrupted supply of recharge water from the nearby Wairau River. This natural process whereby river flow drains into the underlying gravels, occurs continuously all year round.

Extent & boundaries

The Wairau Aquifer underlies a land area of around 26,000 hectares (Fig. 17.2). It is defined as the area predominantly influenced by Wairau River recharge, and to a lesser extent formed of the highly permeable Rapaura Formation Gravels.

The Renwick Terrace is an obvious feature and forms the southern boundary of the Wairau Aquifer west of Renwick. It was created by the Wairau River and marks the southern extent of its meanderings over geological time. The terrace fades out further east near the north east corner of Renwick where the Omaka River joins Gibson Creek. From the base of the lower terrace across to the Wairau River the more permeable alluvium has been flushed of its fine material by the action of the Wairau River. By contrast the claybound material forming the terrace predominates in the Southern Valleys catchments to the south, and explains the low productivity of wells there.

The southern boundary of the Wairau Aquifer east of Renwick through to Blenheim, is less obvious and is based on geological differences which occur gradually and are likely to vary with depth. The location of the boundary has been deduced from drilling and field studies of groundwater flow patterns.

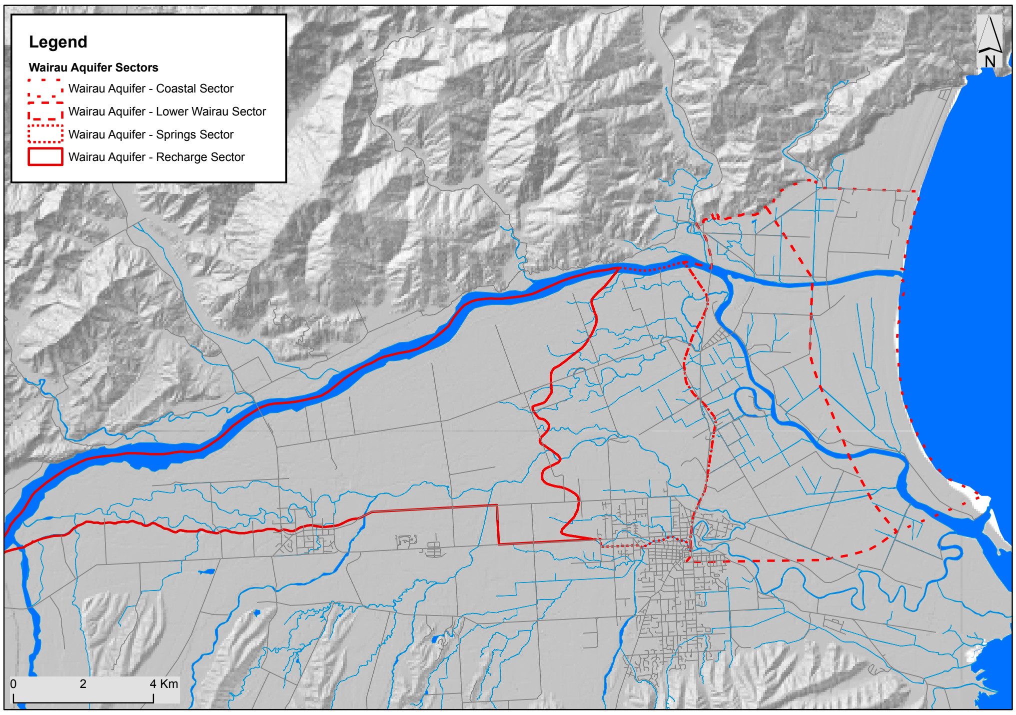


Figure 17.2: Wairau Aquifer boundary

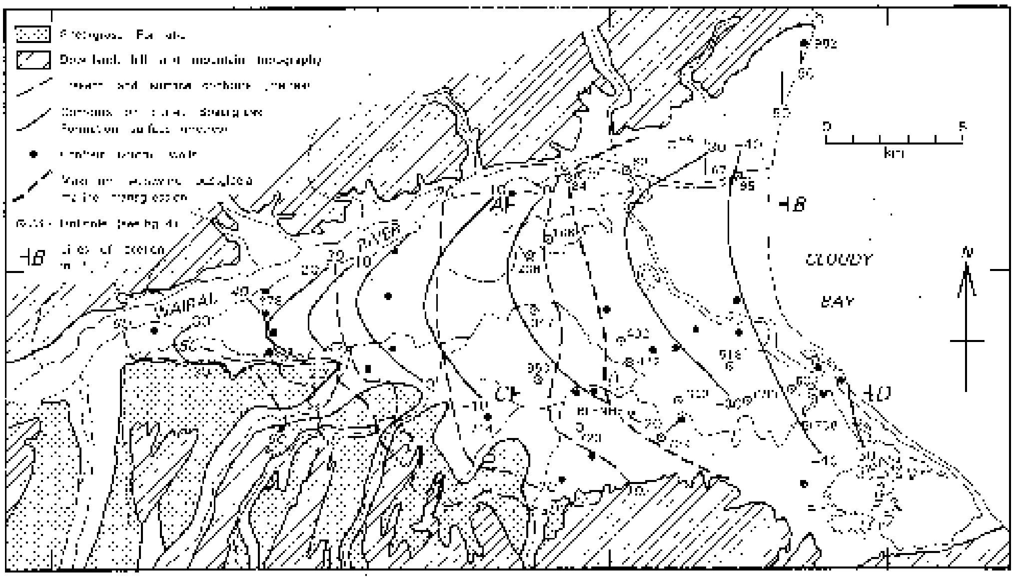


Figure 17.3: Contours of the buried Speargrass Formation surface relative to mean sea-level

At the Cloudy Bay coast, the northern boundary of the Wairau Aquifer coincides with Rarangi Road. A separate Wairau Aquifer Coastal Sector has been defined largely for managing the direct effects of consented water users. The coastal sector, especially at Rarangi and Riverlands, contains older, more evolved groundwater than further inland.

Wairau Aquifer groundwater from Blenheim east to the Wairau Lagoons is still dominated by Wairau River water sourced recharge, although a separate Riverlands Aquifer was designated by the MDC in 2008 to reflect distinctive local groundwater properties.

Experience in other coastal alluvial plain areas around New Zealand suggest that the gravel deposits that form the Wairau Aquifer will extend offshore. It is possible that wells drilled on a barge moored in Cloudy Bay could intercept Wairau Aquifer groundwater.

Based on our knowledge of groundwater chemistry patterns, the eastern boundary of the Wairau Aquifer is likely to be onshore near the northern and southern edges of Cloudy Bay, and possibly offshore towards the centre of the bay. The existence of the Wairau Aquifer beyond the present day Cloudy Bay coastline however, remains uncertain and may never be adequately defined.

The Wairau Aquifer serves a number of users located outside its geographical foot print. Water pumped from wells in the Wairau Aquifer is transported south for irrigation and industrial purposes where local water resources are naturally inadequate. Examples include the long-standing Pernod Ricard/Montana Wines pipeline which sources water from north of Middle Renwick Road at Woodbourne, for irrigating vineyards in the Fairhall-Brancott Valley. There are also a series of vineyards on the upper terrace in the Lower Waihopai Valley near the Delta Hill that are supplied from wells along the foot of the Renwick Terrace, again due to the lack of suitable wells locally.

Aquifer structure

The principal water bearing and transmitting components of the Wairau Aquifer are formed of gravels deposited by the Wairau River or its predecessors. It is likely that the overall thickness of the alluvial sequence forming the Wairau Plain is around 500 metres.

We know from drilling that the permeability of the aquifer forming gravels decreases with increasing depth due to natural processes such as cementing and

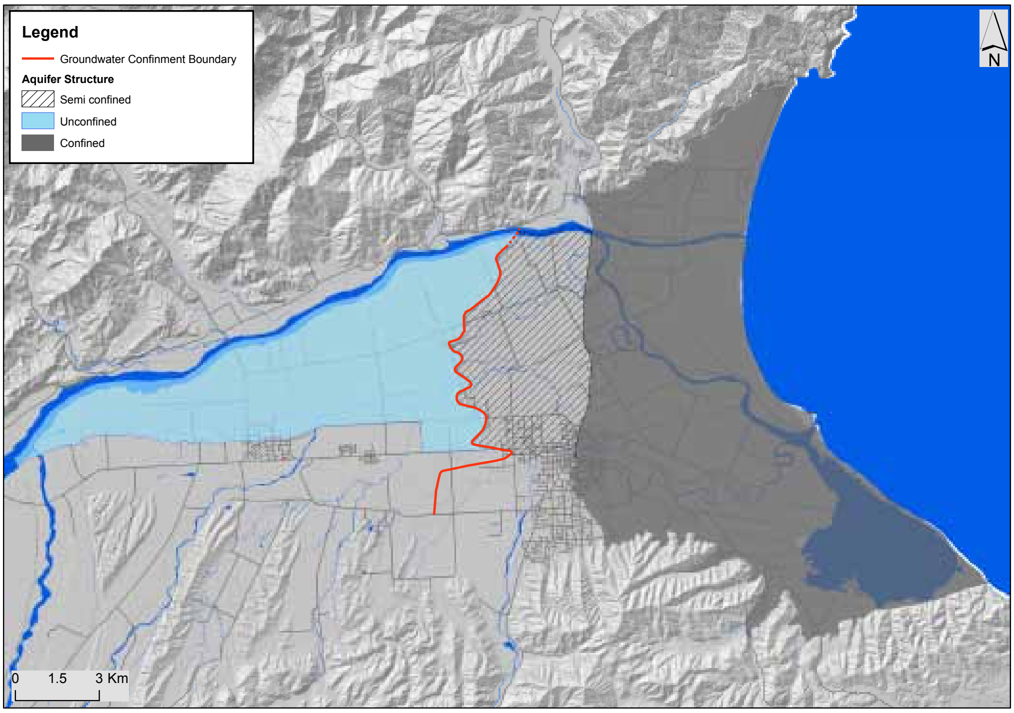


Figure 17.4: Nature of Wairau Plain surface deposits (Brown - 1981)

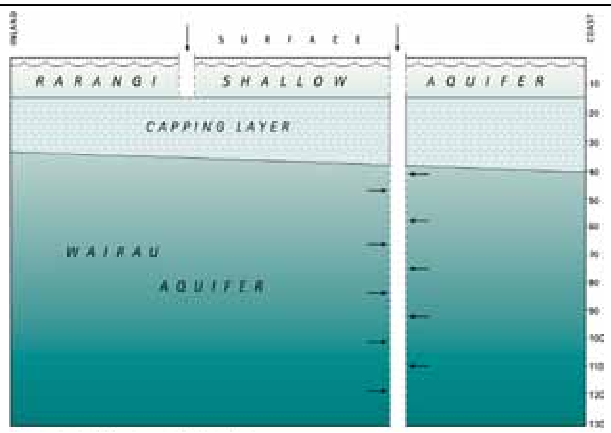


Figure 17.5: Wairau Aquifer structure

compaction. In most places the upper veneer of gravels provides sufficient groundwater to meet current demand without the need to drill deeper. This is reflected in the fact that only the upper 30 metre band of gravels closest to the surface is currently tapped by wells.

The base of the permeable gravels is marked by the appearance of the Speargrass Formation which consists of gravels with a higher proportion of finer grained silts, sands and clays than that of the overlying Rapaura Formation. The Speargrass Formation is commonly referred to as clay-bound gravels in drillers' records.

The Speargrass Formation lies at depths of 20 metres inland near Renwick, to more than 50 metres near the Cloudy Bay coast and has a steeper slope compared to the land surface (Fig. 17.3).

Interspersed within the water bearing gravels forming the Wairau Aquifer are finer grained sediments of marine or terrestrial origin which are naturally less permeable. They form barriers of varying degrees to groundwater flow. In some cases the material is so impermeable they act as so called confining layers (aquitards) (Fig. 17.4). Material located between Cravens Road and SH1 is predominantly land derived and was deposited when the Wairau Plain was covered with swamps. East of SH1 the confining layer is made up of clays of marine origin.

Figure 17.6: Highly weathered molluscs excavated from a well

The marine clays were deposited following the last glaciation when sea-levels rose and the sea invaded the land as far westward as SH1. The confining layer of marine clays thickens in the direction of the coast and forms a wedge shaped structure underlying the lower Wairau Plain (Fig. 17.5). The marine deposited sediments are a distinctive grey or blue colour and commonly contain fossil shells (Fig. 17.6). The extent of the marine beds has been mapped based on the distribution of fossil shells recorded by drilling (Fig. 17.7).

Local differences exist in the nature of the confining layer clays with material deposited in low energy areas, such as estuaries, being finer grained. Higher energy open coastal areas such as Rarangi have coarser material with fewer intact fossil shells.

Confining layer

One of the risks associated with drilling water wells into the confined Wairau Aquifer is the potential for uncontrolled leakage. While wells are regularly drilled into the confined layer, if they aren't properly constructed with a tight seal, groundwater can leak up the outside of the casing (Fig. 17.8). Fortunately this is

Figure 17.7: Extent of marine deposits (GNS Science - 2009)

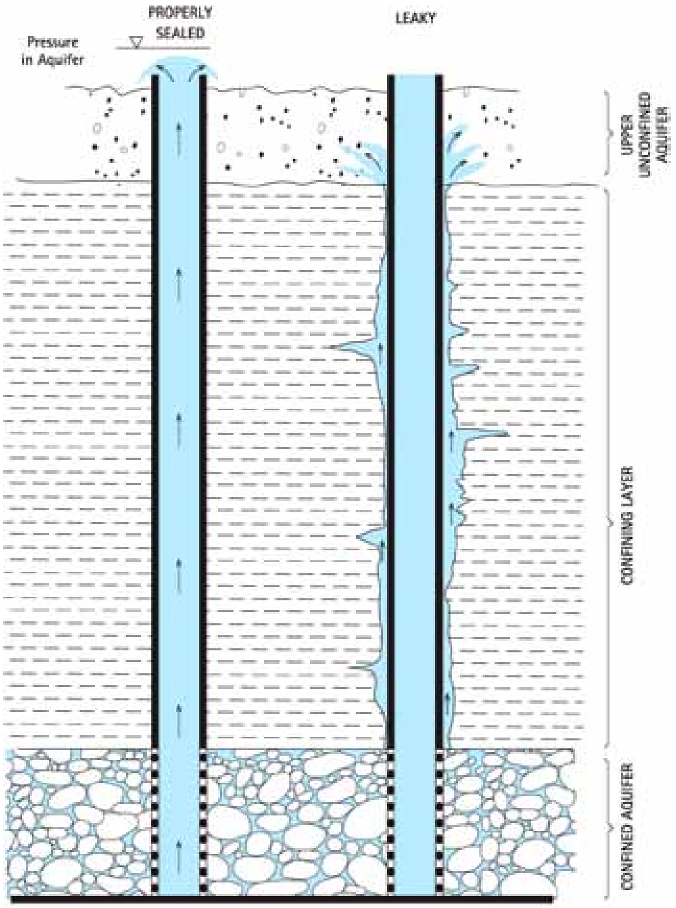


Figure 17.8: Confined aquifer leakage

a rare occurrence because of the skill of local drillers. It has however happened as part of the construction of the Ferry bridge over the Wairau River near Spring Creek in the early 1990s. The piers closest to the right bank breached the confining layer and continue to leak a small volume of groundwater to the Wairau River to this day.

Aquifer thickness and well depth

Over the past 25 years there has been a refinement of aquifer boundary definitions as more information comes to hand. The biggest advances in knowledge are associated with the aquifer lateral extent although there are still too few deep wells to fully define the vertical extent of the Wairau Aquifer.

The depth of Wairau Aquifer wells are dictated by their location and use. Wells in the unconfined western section of the aquifer vary significantly in depth with some as shallow as 5 metres, while most are around 15 to 20 metres deep.

Wells are shallow because productive water bearing layers naturally occur close the surface. The shallower material is more permeable because it has been reworked by the fluvial processes associated with the Wairau River during recent geological time.

Shallower wells generally provide water for stock and domestic purposes as they require lower volumes and generate smaller drawdowns. Deeper wells are needed for irrigation, municipal or industrial supply which have higher pumping rates. Deeper wells also require larger diameter well casings to accommodate bigger pumps.

The depth to the water table is significantly greater over summer in the west and south of the Wairau Aquifer where rainfall or river recharge is lowest in relation to abstraction and natural drainage. As a consequence wells are deeper in these areas.

There has been a trend towards drilling deeper wells in the unconfined area of the Wairau Aquifer in recent years. This trend is a response to droughts, increased cumulative demand and larger irrigated blocks needing more water from a single well.

In the confined section of the Wairau Aquifer the natural structure of the sub-surface strata requires that wells be drilled through the confining layer and means all wells in a certain area have similar depths. The minimum depth to penetrate the confining layer or aquitard formed by the Dillons Point Formation varies from between 22 metres around the SH1 area, to some 40-60 metres near the present day coastline and the Riverlands area.

Aquifer base

A small number of deeper wells have been drilled in the area west of Renwick since 2000. The main aim of drilling deeper wells has been to minimise the interference effects between wells. The maximum well yield can also be obtained by setting pumps as low as possible relative to the groundwater table. Although it is not conclusive, the evidence from these and earlier exploratory deep wells suggests there is little likelihood of finding new high yielding water bearing layers beneath the upper 30 metres of permeable gravels known as the Rapaura Formation.

	pH	Chloride (g/m^3)	Conductivity (mS/m)	Nitrate-Nitrogen (g/m^3)
Wairau River at SH6 bridge	7.3	3.4	6	0.1
Shallow layer groundwater from well 2651	6.3	4.5	14.5	6.7
Shallow layer groundwater from MDC shallow well 398	6.6	4.8	6.5	0.3
Medium depth well 4025*	6.7	2	8	0.68

** Single sample only*

Table 17.1: Shallow versus deep groundwater chemistry

Deeper wells provide added security where water quality is paramount such as for municipal or domestic supplies. Deeper screens provide greater isolation from surface contamination and allow longer times for microbe die-off, or turbidity caused by floods. Conversely deeper groundwater may have a naturally poorer quality water due to the increased contact time with local rocks and lower oxygen levels which leads to greater concentrations of dissolved minerals.

Two deeper wells occur near the intersection of Lanark Lane and Gibson Creek (wells 4025 and 2914), approximately four kilometres west of Renwick. Both wells are screened at depths of more than 45 metres. These wells are low yielding compared to nearby wells of conventional depth. While there is a significant difference in the yield between the upper and lower layers of the Wairau Aquifer, the groundwater chemistry from well 4025 is very similar to that of shallow groundwater and Wairau River water (Table 17.1).

A three day aquifer test conducted on the deeper wells 4025 and 2914 showed they were hydraulically linked, but there was no response to pumping at a shallower well 2651 nearby, implying separate aquifers (PDP - 2003). The rate of drawdown in both deeper wells flattened over time, suggesting some downward leakage of groundwater from above. The early time transmissivity of the deeper layer was 98 m^2/day, considerably lower than for the upper layer. Static levels in the deeper layer well 4025 were artesian whereas the level in the second deep well 2914 and the shallow well 2651 were 1.4 and 3.9 metres lower. The PDP (2003) report concluded that: "*well 4025 abstracts from a confined gravel aquifer with an artesian pressure that indicates it is quite separate from the shallow strata used by most neighbouring wells*".

Degree of confinement

The PDP (2003) report confirms the thickness of the Wairau Aquifer at no more than about 30 metres beneath the surface in the Rapaura and Renwick areas. Another feature of these deeper Wairau Aquifer strata is their apparent confinement, which contrasts with the unconfined structure and free-draining nature of the overlying gravels. This was discovered during the replacement of the long-time MDC monitoring well 0398 by well 3821 in 2001. These wells are located about 1.5 kilometres south of the Wairau River channel in the vineyard near the intersection of SH6 with Conders Bend Road. The gravelly nature of the adjacent vineyard clearly shows the area is formed of recently deposited Wairau River material (Fig. 17.9).

Figure 17.9: MDC Wairau Aquifer monitoring well 3821

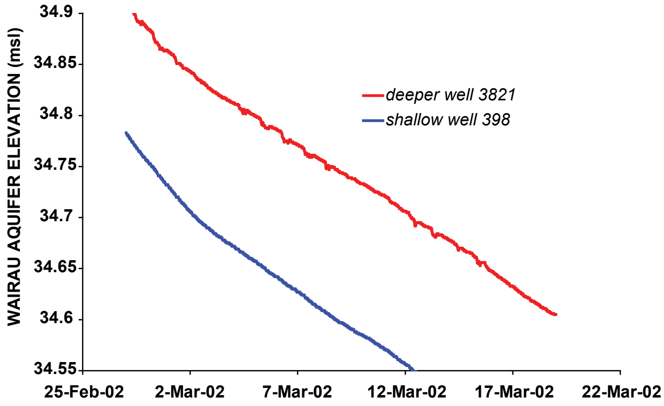


Figure 17.10: Well response and level versus well depth

Well 0398 is a six metre deep excavated well dating from the early 1970s and was replaced by a screened well 22 metres in depth (3821). During the period of overlap the water level in both wells, which are within metres of each other, was monitored. These two records behaved slightly differently. Firstly, groundwater was around 150 millimetres higher in the deeper well suggesting a degree of confinement (Fig. 17.10). Secondly, there were small variations of around 10 millimetres in groundwater level in the deeper well, which didn't occur at the same time in the shallower well. Similar fluctuations were observed in 2005 and corresponded with abstraction from the nearby Montana Wines irrigation well 3758 located 1,400 metres to the west (Fig. 17.11). To account for this response it would require an aquifer storativity in the order of 10^{-4}. This is several orders of magnitude lower than the 0.1 normally attributed to the shallower layers of the unconfined Wairau Aquifer.

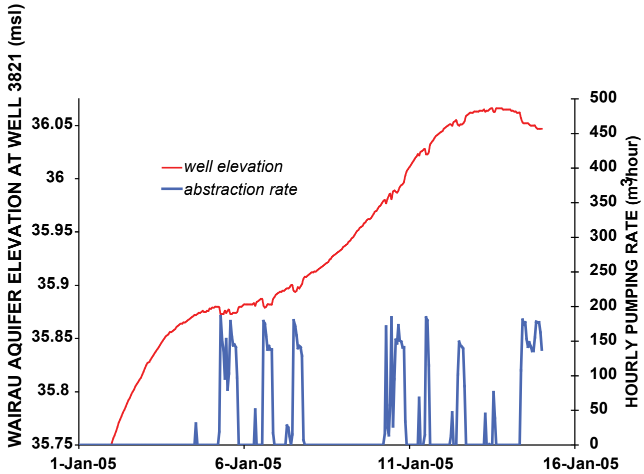


Figure 17.11: Pumping induced changes in well 3821 level

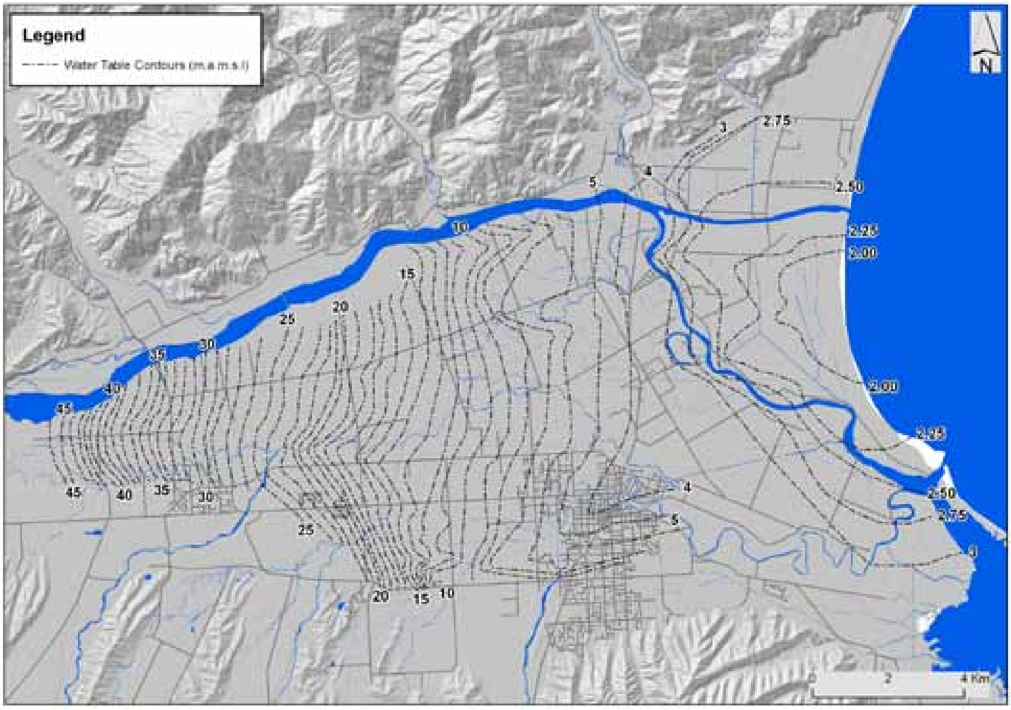


Figure 17.12: 1978 Wairau Aquifer water level contours

Recharge and flow patterns

Northern Wairau Plain regional flow

Water flows from the Wairau River into the unconfined part of the Wairau Aquifer because the gravels are permeable and the Wairau Plain surface slopes away towards the sea providing a down hill gradient. In general terms groundwater flows from west to east, downhill towards the sea under the force of gravity.

Groundwater elevation measurements were taken from over 150 wells across the Wairau Plain between the 4th and 6th March 1978. This information has been mapped to produce contour lines of groundwater elevation across the Wairau Plain (Fig. 17.12). Records show that March 1978 was part of a relatively dry summer season. Groundwater flows at right angles to the contours of water table elevation, and at a regional scale the general pattern of groundwater flow is from the recharge area near the SH6 bridge, towards Blenheim and the Cloudy Bay coast. The contours are more closely spaced inland meaning the water table or hydraulic gradient is steeper in up-plain areas such as Conders and Rapaura than in more easterly areas such as the Lower Wairau. The distorted shape of the contours in the mid plains

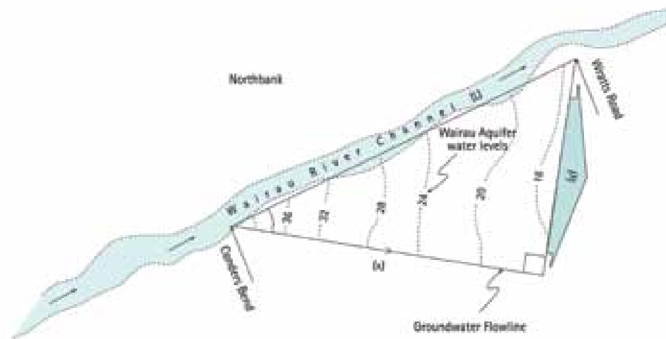


Figure 17.13: Water table contours in recharge area May 1988

area around Hammerichs and O'Dwyers Roads is as a result of groundwater leaving the aquifer as flow from Spring Creek. Convergence of the contours indicates losses, while divergence means the aquifer is gaining water. The groundwater level near the Cloudy Bay coast is around two metres above mean sea level. Derivation of contours in this area involved making corrections for tidal influences. The shape of the contours in the Lower Wairau area implies that groundwater flow in the confined aquifer near the coast is focused upwards or on some point offshore. The slight curvature of the northern tips of the contours in the recharge area from the Waihopai River confluence to Wratts Road show that Wairau River flow is being lost to the aquifer within this reach (Fig. 17.13).

Structural and topographic influences

Geological structure and the slope of the land surface relative to the Wairau Aquifer water table has a big influence on regional groundwater patterns. The appearance of the confining layer beneath the mid-Wairau Plain partitions the Wairau Aquifer flow, with most groundwater taking the path of least resistance and coming to the surface to form springs. This divergence of groundwater flow is also a function of the natural flattening of the land surface relative to the water table. This causes the water table to intercept the ground level in low lying areas.

Topography is the controlling influence on spring flow in western parts of the Wairau Aquifer with the structure of the confining layer dominating in eastern areas (Fig. 17.14 and Fig. 17.15).

Only a small proportion of groundwater flow enters the confined Wairau Aquifer, and once there it moves slowly due to the lower gradient driving it and the increased friction effects of the confining layer.

Water table slope

The slope of the aquifer water table , along with the nature of the gravels, determine the speed at which groundwater travels. The Wairau Aquifer water table reaches its maximum slope of around five metres per

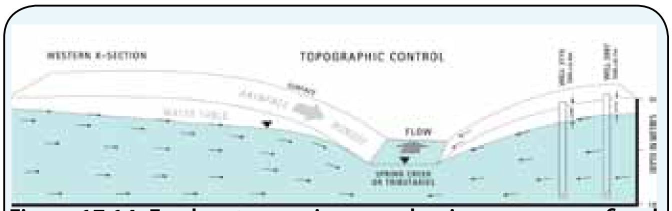


Figure 17.14: Freshwater spring mechanisms - unconfined aquifer. Topographic control dominates interaction between groundwater and spring flow

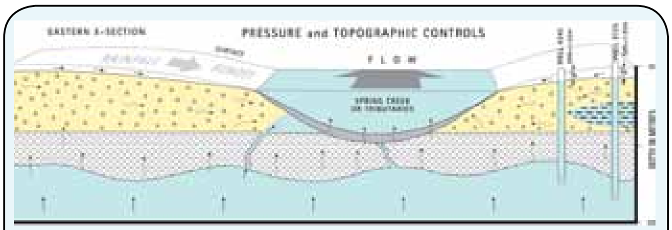


Figure 17.15: Freshwater spring mechanisms - confined aquifer. The extensive and relatively thick confining layer generates higher well pressures by trapping groundwater that entered at a higher elevation.

kilometre in western areas of the Wairau Plain near Renwick. The slope reduces to less than one metre per kilometre near the Cloudy Bay coast (Fig. 17.16). The steeper the slope the faster groundwater will flow through the aquifer. The influence of the water table slope lessens in the coastal confined aquifer where the vertical flow component dominates the horizontal driving force. One symptom of this is artesian flows in some wells in low lowing areas such as Riverlands and near the Cloudy Bay coast. The natural flattening of the aquifer water table is mimicked by that of the land surface in an easterly direction. This reflects the reducing energy of the Wairau River over geological time as it approaches the coast and results in a finer grade alluvium there versus coarser materials inland.

Regional water balance

Wells are windows into our aquifers. Well water level at any particular instant in time reflects the net balance of aquifer water inputs minus outputs. Recharge in the form of rainfall or river losses will cause groundwater levels to rise, while natural drainage or well pumping will make them fall.

A water balance is a common way of evaluating the quantum of water in the Wairau Aquifer and quantifying its components volumetrically (Fig. 17.17). When the aquifer is in equilibrium and inputs match outputs the aquifer is deemed to be in a steady state condition.

The water balance for the Wairau aquifer was derived in 1994 but is still valid today. Many of the values have been estimated because it is not possible to measure them directly on a regional scale. They represent average flow rates that would exist when the Wairau Aquifer had reached a natural balance in the absence of significant pumping or recharge events such as floods. These conditions would normally occur in a typical winter.

It is apparent from the Wairau Aquifer water balance that the rates of flow throughout the Wairau Aquifer are very large indeed, as are the volumes of water stored in its gravels. However, it is important to realise that rates of recharge are almost exactly balanced by natural losses. This means that pumping from wells relies on removing groundwater from storage. One of the natural assets of the Wairau Aquifer is its ability to recover quickly from a drought through recharge from the nearby Wairau River.

Typically during late summer there is significant abstraction from wells for vineyard irrigation and public water supply due to extended periods of dry weather. As a result the Wairau Aquifer is in a non-equilibrium

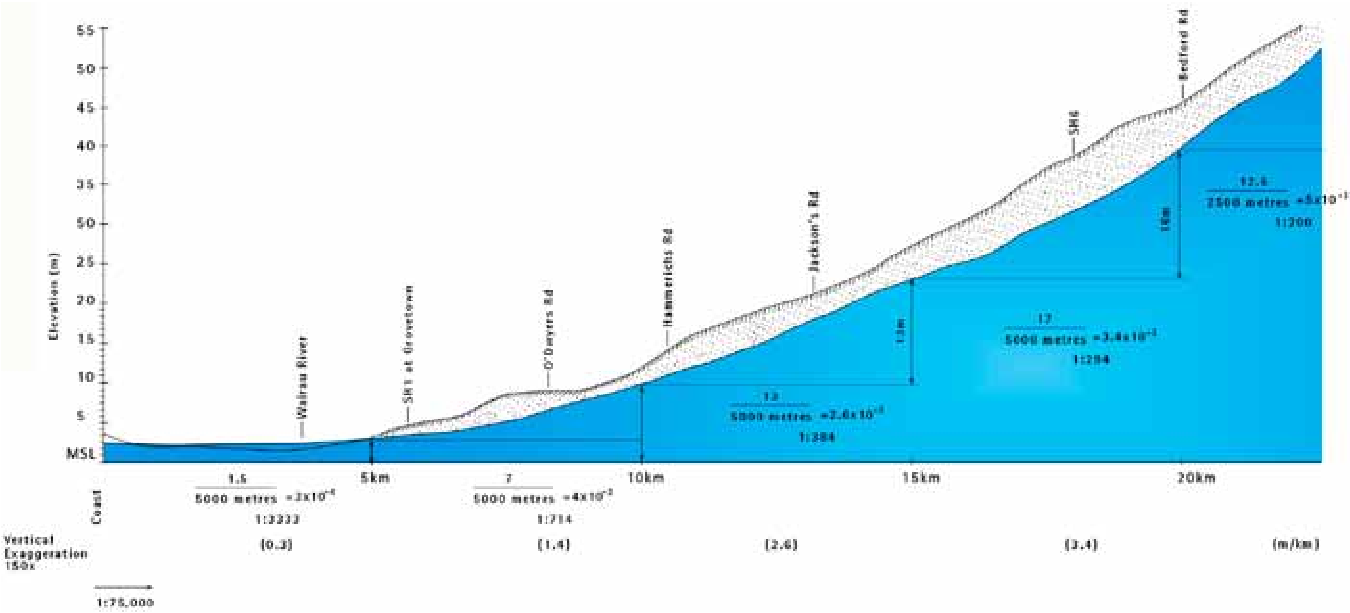
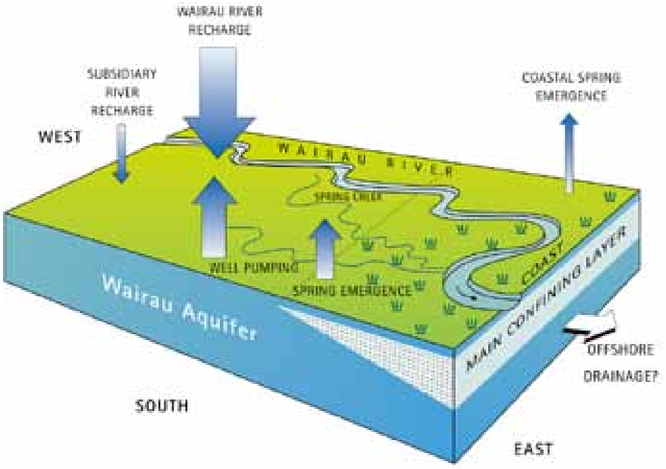


Figure 17.16: Wairau Aquifer water table slope



	PROCESS	FLOW m³/sec
IN	Wairau River Leakage	7
	Other Rivers	1.85
	Total Recharge	8.85
OUT	Spring Emergence	6.75
	Coastal Spring Emergence	0.5
	Well Pumping	0.54
	Total Losses	8.85

Figure 17.17: Steady state Wairau Aquifer water balance

state with outputs of groundwater due to pumping likely to be exceeding inputs (Fig. 17.18).

Even under low flow conditions the overall rate of spring discharge is similar to winter conditions despite there being significant pumping. Summer rainfall recharge is negligible compared to evapotranspiration and the rate of coastal spring flow is estimated at 0.5 m^3/s. The rate of abstraction is not precisely known without universal metering, but is likely to be of the order of 2-4 m^3/s, much of which will be originating from groundwater stored in the gravels causing well levels to fall. The rate of change in groundwater storage can be expressed as:

Change in Groundwater Storage = River recharge + Tributary recharge – Well pumping - Natural drainage.

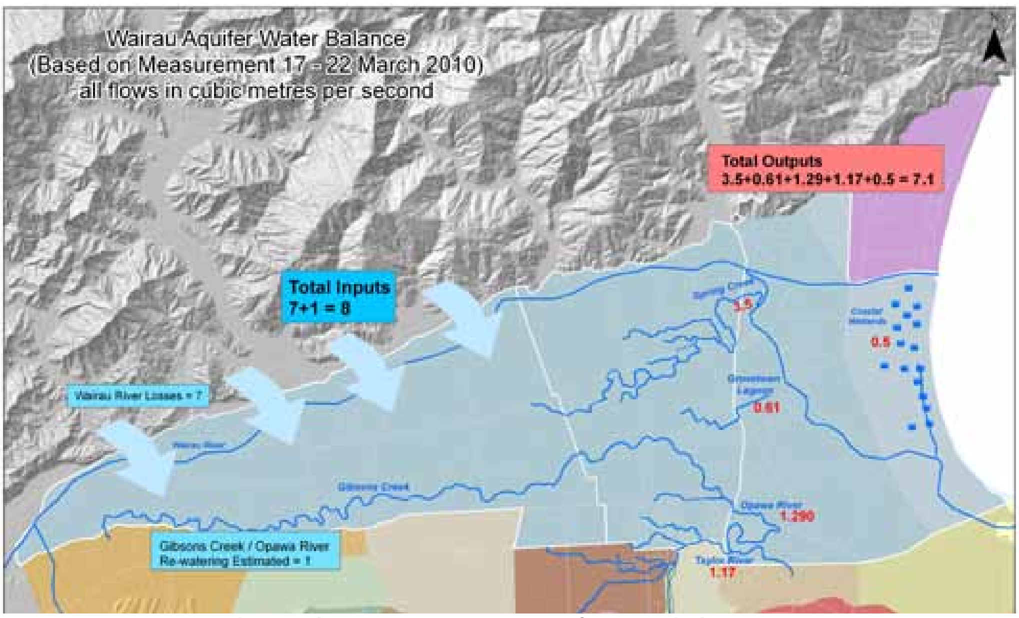


Figure 17.18: Non-steady state late summer Wairau Aquifer water balance

Recharge

The Wairau Aquifer gains at the expense of the Wairau River. A lesser volume of recharge is sourced from rainfall, or tributary rivers such as the Waihopai River, Gibsons Creek, or those draining the Southern Valleys Catchments. The latter sources become more important with increasing distance from the Wairau River and especially during the higher rainfall months. Isotope studies have also shown that rainfall contributes a higher proportion than first estimated (Stewart - 2006).

The Omaka, Taylor and Fairhall Rivers contribute water along the south-western fringes during winter or spring. Over summer these rivers are ephemeral and the amount of recharge is negligible by comparison with the influence of the Wairau River. The boundary between the relative influence of Wairau River seepage water and the Southern Valleys recharge water is dynamic and shifts depending on seasonal conditions.

The Waihopai River recharges the Wairau Aquifer directly through drainage from its channel north of the SH6 bridge. Indirect leakage is also supplied from the re-watered Gibsons Creek/Upper Opawa River system. Flows in Gibsons Creek are artificially controlled from Waihopai and Wairau River water inputs. These inputs are restricted for environmental reasons when the flow of the Wairau River at Tuamarina is below eight m^3/s.

Areas closer to the Wairau River receive a higher proportion of recharge from natural channel leakage compared to rainfall. For example, the long-standing MDC monitoring well 3821 north-west of Renwick is almost wholly reliant on Wairau River water. This is not surprising given its proximity to the river channel. This contrasts with the MDC Blenheim municipal supply well 3120 at Springlands on the southern fringes of the Wairau Aquifer. This well receives up to 30% of its recharge from rainfall based on stable isotope measurements (Stewart - 2006).

Recharge originating from surface drainage is called land surface recharge. Land surface recharge can have a component of re-circulating irrigation water as well as rainfall. Irrigation water is not a significant component of surface recharge in Marlborough as drip irrigation is an

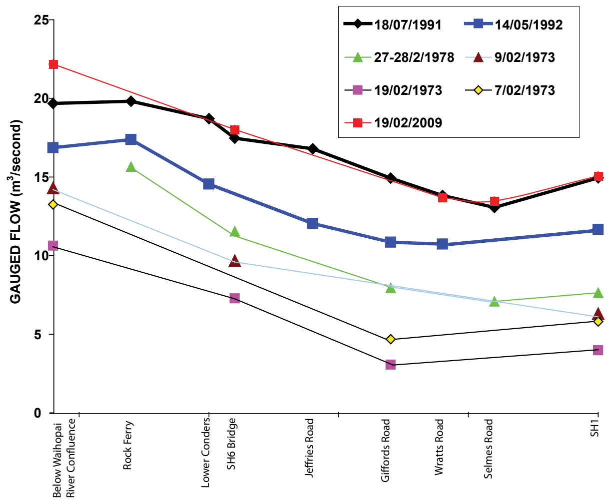


Figure 17.19: Wairau River flow loss gauging surveys

efficient and targeted way of applying water to vineyard, the predominant landuse. Spray irrigation and border dike methods, which are a large source of surface recharge, are not widely used on the Wairau Plain

The Wairau River is the ultimate source of most Wairau Aquifer water and the aquifers existence relies on a continuation of the present surface flow regime. The local economy, human communities and natural systems all depend on an undisturbed natural hydraulic link between the Wairau River and the Wairau Aquifer.

Wairau River losses to groundwater

The Wairau River loses channel water to the Wairau Aquifer at a base rate of around 7 m^3/s in the reach between the Waihopai River confluence and opposite about Selmes Road (Fig. 17.19). The river channel loses water to the aquifer because water in the channel sits at a higher elevation than neighbouring groundwater. The rate of water loss from the Wairau River has been quantified by gauging surveys of river flow at various points along the length of the river on the same day. A check on the amount of recharge is the total loss of groundwater from the aquifer as spring flow. One of the complicating issues with measuring Wairau River losses to the Wairau Aquifer has been the spilling of water from the Branch River scheme since its construction in 1984. These flow fluctuations add further uncertainty to what is already a difficult exercise measuring small differences between large flows in a braided river.

An MDC gauging survey in March 2009 was carried out when the Branch power scheme was shutdown to avoid the normal intermittent flow regime caused by releasing Lake Argyle water when generating power. The results of the survey confirmed the Wairau River is losing channel flow at the same rate as in the early 1970s when the last uninterrupted survey was conducted. This shows that in broad terms variations in the river regime, sediment discharge and climate haven't significantly affected the recharge process.

The elevation of Wairau River channel flow is used to study the link between Wairau River flow and aquifer response. It is this elevation difference that determines the flow of water between them.

The permeability of the river bed sediments and the location of the channel relative to the aquifer also influence the recharge process. For example, if the channel moves further away from the south-bank, or its bed has a higher proportion of lower permeability sediments isolating the two water bodies, the rate of recharge is likely to be less.

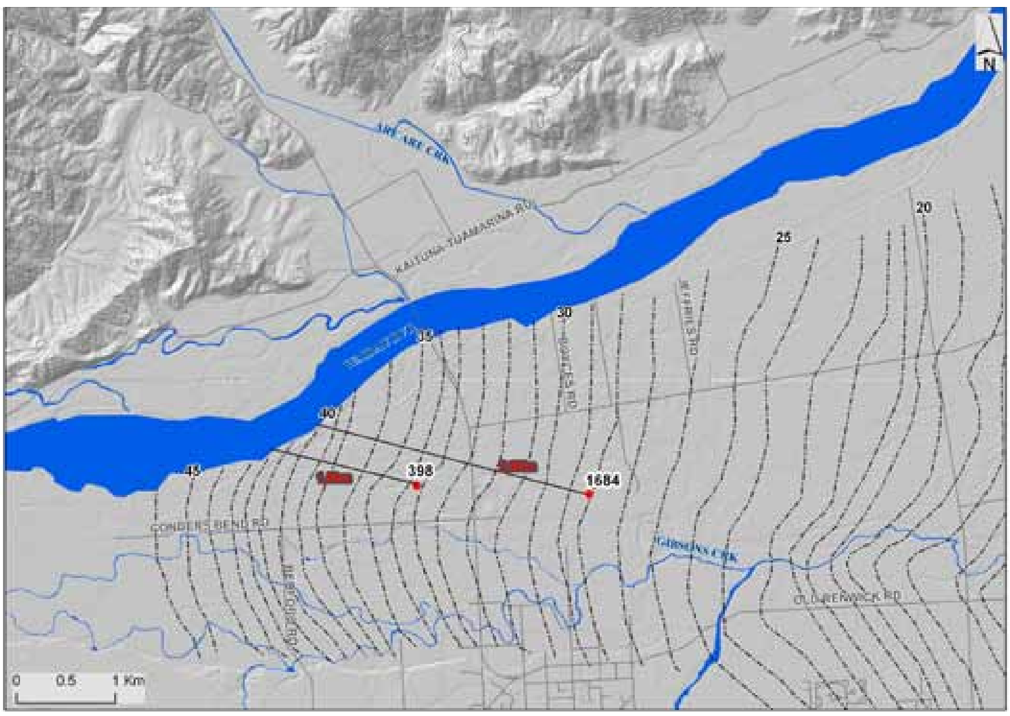


Figure 17.20: Wairau Aquifer water table contours and monitoring well locations

Due to the dynamic nature of the Wairau River, the sediments forming its bed change in size and distribution over time. Floods are known to alter the location of the channel and scour the bed of fine grained silts which tend to build-up under lower flows. Localised activities such as gravel extraction or flood control works are also likely to affect river interaction with groundwater.

Well response to floods

Variations in well levels close to the Wairau River provide an insight into

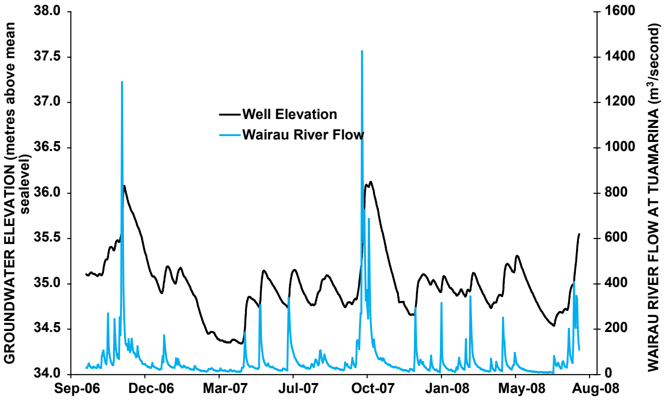


Figure 17.21: Wairau River versus Wairau Aquifer level

the interaction of groundwater and surface flows. The MDC monitoring well 3821/398 is located within 1.5 kilometres of the Wairau River and is a key site for understanding the aquifer recharge process (Fig. 17.20). This monitoring well has been operating since the early 1980s and represents the behaviour of the local unconfined gravels hydraulically connected to the river. The hydrograph for well 3821 matches the river stage hydrograph and this similarity confirms the hydraulic connection between the two (Fig. 17.21).

The rise in groundwater level however, isn't only a function of river flow but also depends on how full the aquifer is at the time of the flood. In other words, the same magnitude flood event doesn't generate the same aquifer or well response every time. The greater the distance a well is from the river channel the longer the delay for the Wairau River flood-wave to arrive (Fig. 17.22). The rate at which the river flood wave moves also depends on the nature of the aquifer sediments. The higher the porosity of the aquifer gravels, the longer the lag-time between a flood in the river and the response in a well some distance away. This is because the gravels forming the unconfined Wairau Aquifer opposite the upstream part of the recharge reach have higher porosities of around 25% (Fig. 17.23). A flood wave generated by the Wairau River has to physically refill the gravels. This process slows the rate at which the flood wave propagates away from the channel. If the unconfined gravels are saturated with groundwater then well levels will rise faster and the wave will move inland more rapidly.

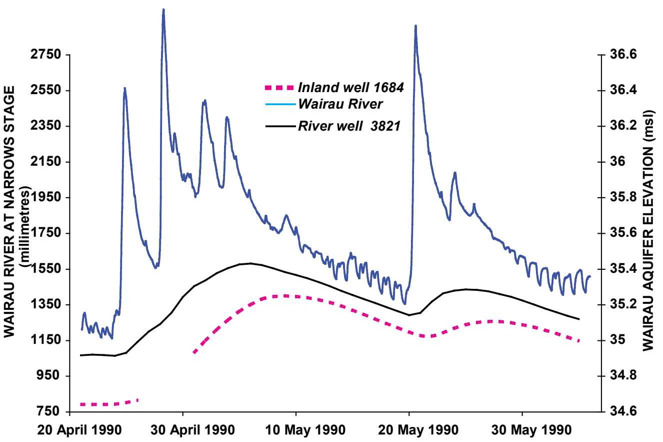


Figure 17.22: Wairau River flood wave

Figure 17.23: Wairau River recharge reach channel sediments

Flood waves generated by the Wairau River are not distinguishable in wells located more than about two kilometres directly south of the channel in the unconfined aquifer. This distance is slightly further opposite the semi-confined aquifer sector downstream of Selmes Road.

Flood waves are propagated further and more rapidly downstream of the Wairau River recharge zone. In this area the Wairau Aquifer becomes more confined and its geology consists of finer grained sediments with lower porosity. As a consequence the aquifer has less storage and it takes less groundwater to fill the gravels voids.

The effect of differences in aquifer structure and porosity on groundwater flow are clearly illustrated by the differing response of wells to a Wairau River flood event (Fig. 17.24). Levels in the unconfined aquifer well (3821) rise and recede slowly whereas the response at well 4577 in the semi-confined area at Selmes Road is characteristically more rapid and peaky. The response in the confined aquifer near the Cloudy Bay coast is similar in terms of timing and the shape of the Selmes Road hydrograph, but doesn't represent a bulk transfer of water, only a pressure effect.

Recharge rate

The rate at which water leaves the Wairau River is likely to vary depending on a number of factors. These factors include flow in the Wairau River or its

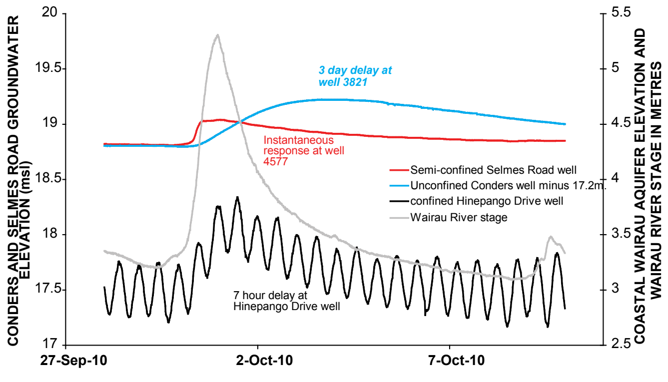


Figure 17.24: Aquifer response to a Wairau River flood

elevation (stage height), aquifer level, channel location relative to groundwater and the composition of the bed sediments. Most of these factors are natural, but recharge is also potentially affected by river management practices (Fig. 17.25).

The precise relationship between aquifer recharge rate, antecedent aquifer conditions and the size of the flood event may never be known because of the practical difficulties of measuring these processes. Higher rates of recharge are likely to be associated with floods, and lower rates with low river flows or long periods of recession.

Measured losses of around seven m^3/s of channel flow under low river flow conditions are likely to represent the minimum rate of groundwater recharge. Under flood conditions the rate of leakage from the river is likely to be much higher for short periods, due to the increased hydraulic gradient between the two water bodies, although these high flow losses can only be estimated.

River controls on recharge

The Wairau Aquifer is continually losing water through its springs due to gravity drainage. This water is replaced by constant inputs of Wairau River recharge to maintain stable well levels. Volumetrically a fine balance exists between natural inflows in the form of river recharge and outflows via freshwater springs.

Under moderate to low flows the Wairau Aquifer drains faster through its springs than it is recharged. Therefore stable groundwater conditions and well levels depend on higher Wairau River flows to top-up the aquifer, in order to maintain springs at acceptable flow, keep the saline interface offshore and retain sufficiently high well water levels for users. This was demonstrated in the autumn to winter period of 1991 and again in 1992 when only natural processes were affecting the state of the Wairau Aquifer. Two of the lowest aquifer levels measured were experienced at the MDC monitoring

Figure 17.25: Wairau River recharge reach

well 3821 during this time. The pattern of groundwater recession mirrors the behaviour of the nearby receding river. In the absence of pumping the only explanation for the low aquifer levels are river related processes.

It is likely that without regular pulses of recharge water generated by Wairau River floods of 100 to 200 m^3/s magnitude, well levels would slowly recede as spring outputs exceed inputs.

Other factors controlling Wairau River losses to groundwater

One aspect of the recharge process that isn't fully understood yet is its sensitivity to changes in channel morphology. The following factors can all influence this process:

- the nature of the channel bed sediments
- the location of the active channel relative to the Wairau Aquifer on the south bank
- the degree of braiding or width of the floodway

It is likely that the position of the active channel and the width over which the river flows, will affect the rate of recharge. During pre-European times the Wairau River was spread across a wide channel with multiple braids. Over the past century or so, flood control works have constrained flow within a narrower floodway with usually just a single channel.

Just as changes in the water level of the Wairau River channel will affect the rate of recharge, so will the elevation of the channel bed. A fall in bed levels will reduce the rate of recharge. Conversely a localised build-up of river gravel will tend to increase the gradient between the Wairau River and Wairau Aquifer and hence increase the rate of recharge. Beyond a certain gradient, the accumulation of sediments will decrease the bed permeability and tend to isolate the two water bodies, resulting in less leakage to groundwater. Large floods are likely to benefit the recharge process by flushing fine silts or clays which clog the river gravels and increasing the rate of river losses to groundwater.

Geochemical indicators

Groundwater quality can be used to understand the interaction between rainfall and Wairau River recharge. For example, the chemistry of groundwater near the Wairau River channel generally matches that of river water (Fig. 17.26). The chemical composition differs with increasing distance from the river due to a lessening of the diluting effect of the river flow and the increasing influence of overlying landuses.

However not all aspects of water chemistry are the same with the pH of groundwater being lower than that of the river water (Fig. 17.27). Nitrate levels are

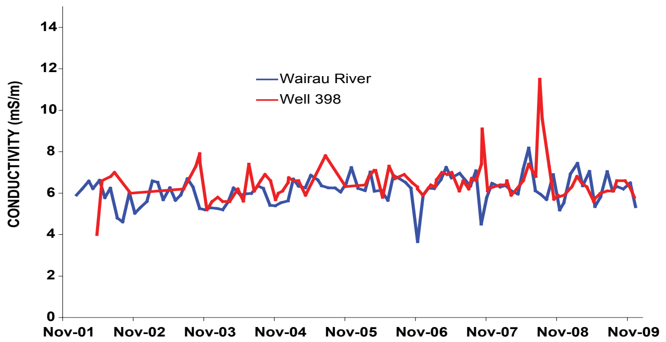


Figure 17.26: Wairau River versus riparian groundwater conductivity

however higher in the groundwater than in the river water. The likely explanation is that rainfall leaches substances from the soil layer downwards to the water table. This changes the chemical composition of the river recharge water within a short distance of the channel.

Groundwater pH is lowered due to the generation of carbonic acid in the soil zone through natural biochemical processes, which is subsequently leached downwards to the water table. Groundwater nitrate levels rise as nutrients are flushed downwards.

Artificial recharge

One human activity that generally raises aquifer levels are re-watering projects or leaky streams. One of the earliest works undertaken by the MCRWB was in fact a groundwater recharge project. Water from the Waihopai River was diverted into an old stream channel and Gibsons Creek flowed once again.

The initial re-watering of Gibsons Creek took place in 1960 and its modern equivalent associated with the Southern Valleys Irrigation Scheme (SVIS) began operation in 2004. Recharge from Gibsons Creek channel losses became a less effective device during the 1980s and 1990s due to the natural sealing of the channel bed by fine sediments, which reduced downwards leakage to groundwater. In 2010 Gibsons Creek water is once again supplementing recharge of the Wairau Aquifer across its entire unconfined area from almost the Waihopai River in the west, to the spring belt in the east.

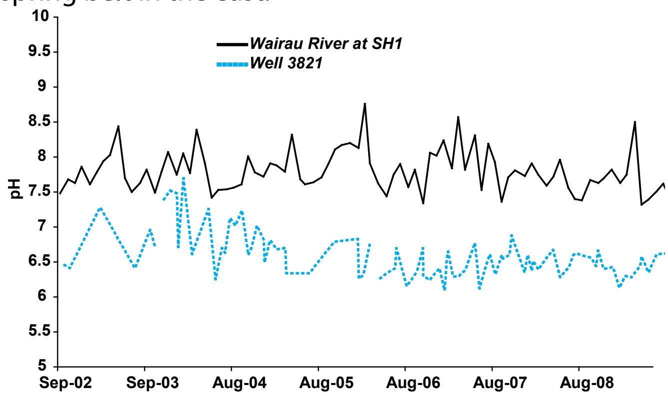


Figure 17.27: Wairau River versus riparian groundwater pH

Drainage and abstraction

Groundwater leaves the Wairau Aquifer through a combination of natural processes and man-made abstraction. The importance of each mechanism varies seasonally with pumping from wells for crop irrigation or drinking water being more important in summer. Conversely there are higher rates of aquifer through-flow or drainage towards sea-level in winter when natural groundwater flow gradients are at their maximum.

Natural drainage

The combined discharge of spring-fed outflows from the Wairau Aquifer amounts to somewhere in the vicinity of 7 m^3/s depending on the time of year. This means a very high proportion of the recharge originating from the Wairau River returns to its source within a relatively short time.

The smaller portion of groundwater flow that remains within the confined aquifer, flows slowly eastwards under a steadily reducing gradient. The fate of groundwater flow once it reaches the Cloudy Bay coast remains uncertain and may never be satisfactorily resolved unless there is deep drilling.

Historically a submarine outflow was thought to be the most likely scenario, although in more recent times, onshore diffuse upwards flow is considered more likely, as it accounts for the year round existence of coastal springs. While there are no direct measurements to confirm the origin of the water recharging the coastal wetlands, groundwater is the most likely source (Fig. 17.28).

According to a undersea geophysical survey by the NIWA research vessel R.V. Tangaroa of the sediments forming Cook Strait, the confining layer which caps the Wairau Aquifer extends offshore by about 10 kilometres. This new information suggests that there is no direct outlet for the Wairau Aquifer to the sea (Barnes and Pondard - 2010).

A blanked off aquifer is consistent with the lack of saline water that was observed during the drilling of the 1987 MDC Bar test well (1733). This well was drilled to a depth of 84 metres below the surface within 150 metres of the Cloudy Bay coast. It also poses the question as to the position of the boundary between freshwater and seawater, and the possibility of groundwater occurring offshore beneath Cloudy Bay.

An earlier interglacial marine mud formation which could potentially act as a confining layer for aquifers underlying the Wairau Aquifer was identified buried beneath the sea floor. Evidence of these earlier

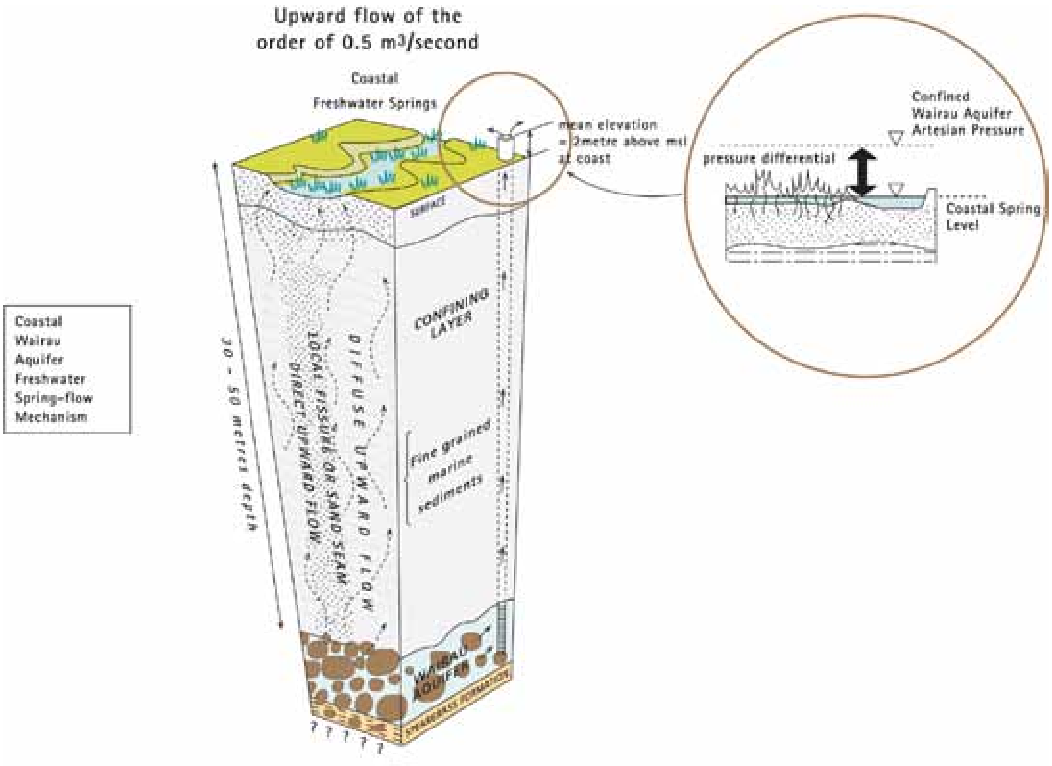


Figure 17.28: Coastal aquifer spring mechanism

formations is rarely seen in land based drilling results, presumably because they have been eroded by the fluvial action of the Wairau River in ancient times.

The geophysical survey also discovered that the Wairau Fault terminates off-shore, and doesn't directly connect with the North Island or Wellington fault systems. This finding was based on an analysis of the sedimentary sequence infilling the rift caused by movement along the Wairau Fault underwater. The effects of eight earthquakes over the past 18,000 years were identified with an average recurrence interval of just over 2,000 years (Barnes and Pondard - 2010).

Abstraction

One very significant output from the aquifer that has yet to be quantified at a district wide scale, is the only component of the water cycle that we can measure directly. This is the withdrawal of water by pumping from water wells. Rain and evapotranspiration are indirect measurements whereas groundwater flow can be directly metered.

While most water permits are now required to have a flow meter to directly measure consumption, it may take another decade before there is complete information available to provide annual balances for individual aquifers.

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