Chapter 18: Wairau Aquifer Coastal Sector

Introduction

Historically the coastal area of the Wairau Aquifer has not been separated from the rest of the aquifer in terms of water management. However increased demand on groundwater for crop irrigation has meant a greater focus on the interface between groundwater and seawater in this area due to the potential for seawater intrusion.

While a separate coastal corridor has been primarily defined by the MDC for management purposes, it also has unique hydrogeological properties. The area has older, more evolved groundwater and a highly confined structure. The Wairau Aquifer Coastal Sector (WACS) is a strip approximately two kilometres wide (Fig. 18.1). The southern boundary adjoins the Riverlands Aquifer just north of the Wairau Bar and extends north to near Rarangi Road, at which point it pinches out (Fig. 18.2). The boundary extends further inland at Rarangi to reflect the greater sensitivity of the seawater interface in this lower yielding area to pumping.

Historically the coastal margin of the Wairau Plain is an area where there has not been high rates of groundwater use. However, the expansion of residential blocks and the development of vineyards in the area has resulted in an increased water demand. The MDC has largely captured the corresponding changes in seasonal water levels and groundwater chemistry associated with the increased demand as part of the routine monitoring programme.

Groundwater systems

A layered sequence of two aquifer systems exists beneath the Lower Wairau Plain near the Cloudy Bay coast (Fig. 18.3). The Rarangi Shallow Aquifer (RSA) is

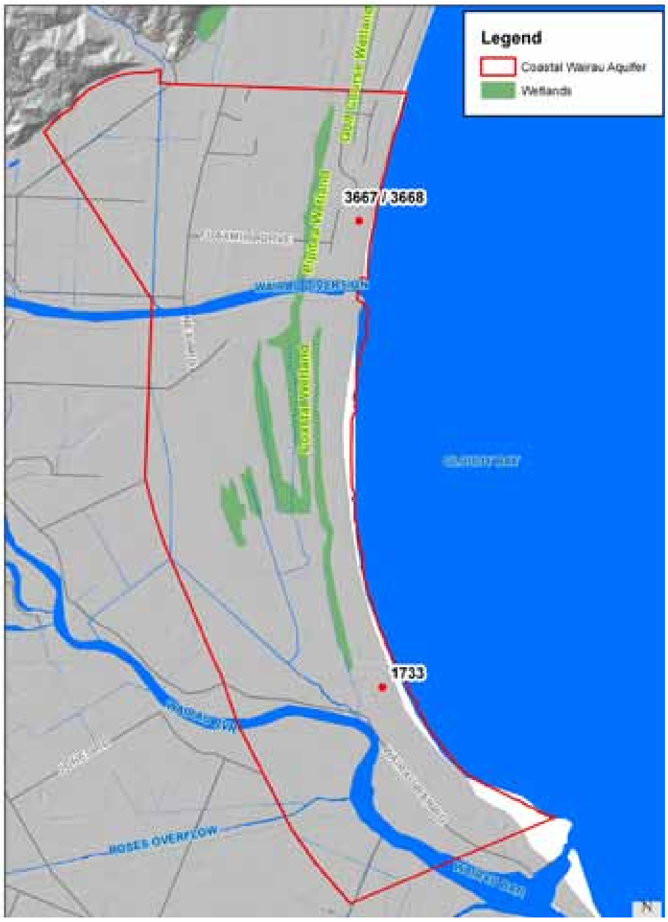

Figure 18.1: Wairau Aquifer Coastal Sector boundary

the uppermost groundwater system and is partially underlain by the Wairau Aquifer. The RSA is low yielding by Wairau Plain standards, and more susceptible to over-pumping by virtue of its small size, location next to the ocean and unconfined structure. By contrast the Wairau Aquifer is relatively high yielding due to a combination of very permeable gravels and a perennial source of recharge via its connection with the upstream Wairau River.

The WACS is less vulnerable to seawater intrusion than the RSA due to the presence of the natural confining layer which becomes thicker in a seawards direction. This layer together with an upwards hydraulic gradient, isolates the Wairau Aquifer from the neighbouring seawater (Fig. 18.3). However the exact nature and position of the boundary between the Pacific Ocean and the WACS is not well understood.

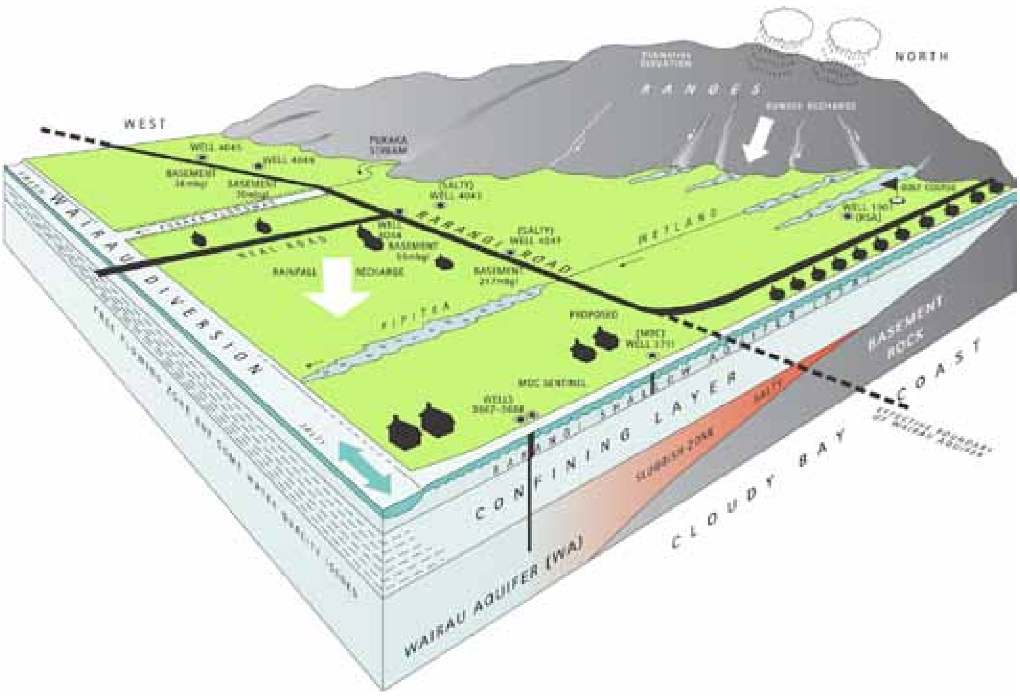

Figure 18.2: Wairau Aquifer Coastal Sector northern boundary

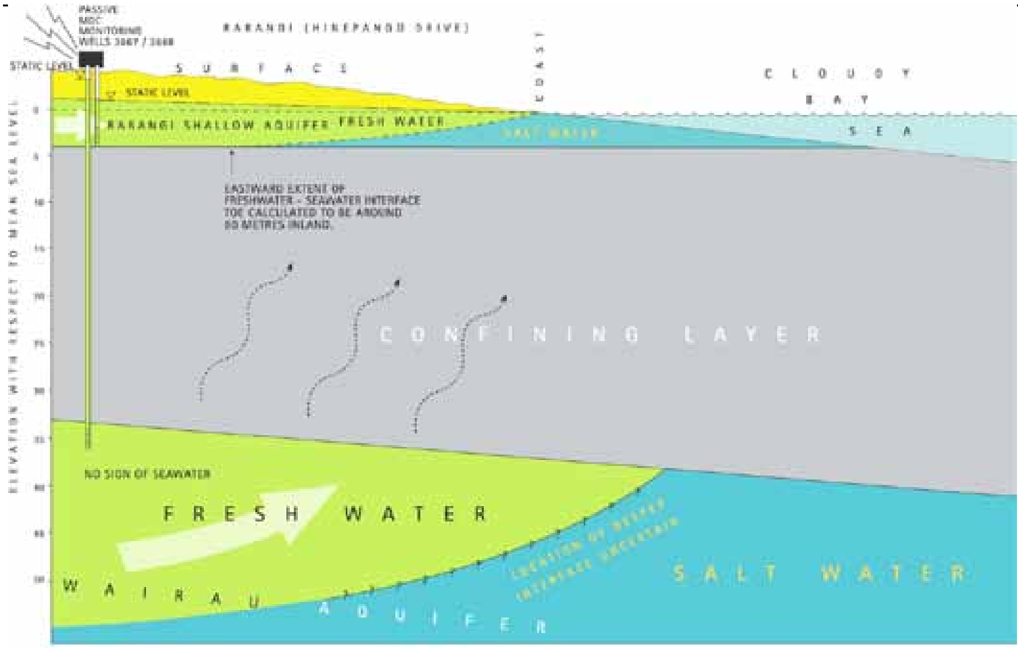

Figure 18.3: Coastal aquifer layered sequence

The WACS is the most highly confined part of the system because it is closest to the sea and these coastal deposits can reach thicknesses of tens of metres. The contrasting layers of materials near the coast affects aquifer behaviour. Observations made by Mr. L.J. Brown of the NZGS during the drilling of the 83.4m deep Wairau Bar exploratory well 1733 in 1987 show a clear sequence of five layers of sediments (Fig. 18.4). The uppermost layer of sands to a depth of approximately 12m represents the RSA. The RSA is underlain by a layer of fine grained marine clays, known as the Dillons Point Formation, that form the confining layer. Below the confining layer at a depth of about 40 metres, Wairau River gravels of the Rapaura Formation make up the WACS. These are the most productive gravels and supply most of the groundwater pumped from the coastal area. Deeper again lie less permeable, terrestrially derived gravels, with a higher clay content belonging to the Speargrass or Wairau Gravels Formations. These are not currently used as a source of supply because of the availability of higher yielding groundwater at a shallower depth.

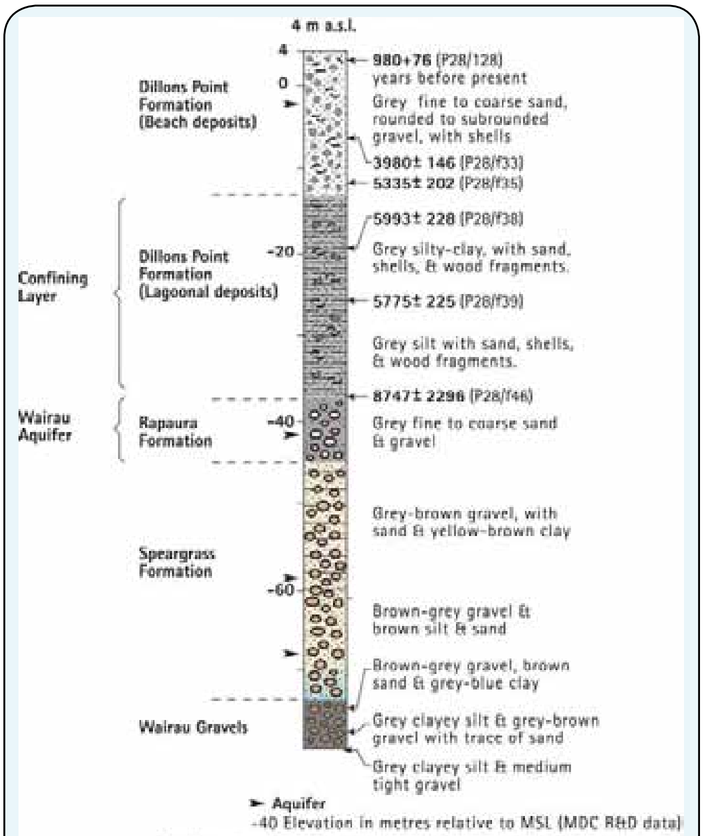

Figure 18.4: Coastal well 1733 lithologic section. The number of years since the material forming each layer was deposited is shown on the right hand side of the section. Ages are based on radiocarbon dating of organic material bought to the surface during drilling. There are no dates available for deeper material due to the lack of organic matter (Ota et al. - 1995)

The marine clays that confine the Coastal Wairau Aquifer are the reason for artesian pressures in some lower lying wells. However the clays are not completely impervious to flow. Upwelling groundwater over a large area of the Lower Wairau Plain is likely to account for the coastal wetlands at Marshlands and the Wairau Pa. Some water may also follow fissures or breaks in the confining layer caused by movement on the Wairau Fault. The permeability of the aquifer forming gravels located north of the Wairau Diversion channel are significantly lower than those opposite the Wairau River mouth. It follows that groundwater flow is more sluggish in northern areas with lower well yields and older, poorer quality groundwater.

An abundance of aquifer level information exists for both the RSA and the underlying Wairau Aquifer Coastal Sector. Information has been gathered because of the potential for seawater intrusion to affect both systems and groundwater levels and conductivity are regularly monitored (Fig. 18.5). More MDC monitoring wells exist in this area than anywhere else in the district.

Aquifer levels have been stable in the higher yielding central area of the Wairau Aquifer Coastal Sector. The average elevation at well 1733 over the entire length of record from 1988 is 2.9 metres above mean sea-level. A maximum of 4.4 metres was observed during spring 1994; and a minimum of 2 metres coincides with the 1998 drought.

By comparison groundwater levels at the northern well 3667 shows a seasonal fall since the year 2000. This is a response to increased pumping and the lower yield

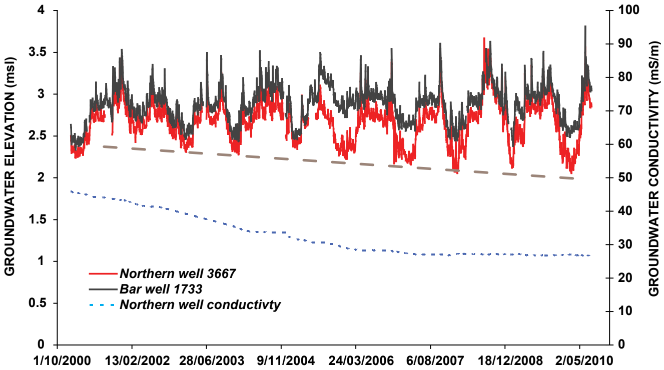

Figure 18.5: Wairau Aquifer Coastal Sector well elevations

of the Coastal Wairau Aquifer north of the Diversion channel. This summer divergence of around 0.5 metres since 2000 is mirrored at wells representing the southern Wairau Plain at Riverlands. This divergence demonstrates the sensitivity of lower storage aquifer areas on the edges of the Wairau Plain to pumping.

Although there is a greater seasonal range in aquifer levels in the northern Coastal Wairau Aquifer, the conductivity of groundwater is falling. This implies that increases in consented pumping is inducing younger, more dilute water from central areas of the Wairau Aquifer; rather than affecting the position of the seawater interface.

Recharge and flow patterns

The coastal sector relies on losses of Wairau River channel water in the recharge reach, around 15 kilometres to the west, to replenish drainage or pumping losses.

Another peculiarity of the WACS is the presence of a vertical pressure gradient. This induces groundwater to flow upwards, rather than follow the horizontal gradient that predominates in inland areas of the Wairau Aquifer.

One of the symptoms of vertical flow are the distinctive wetlands that exist in the central coastal area on land (Fig. 18.6).

These wetlands are thought to represent a partial outlet for the Wairau Aquifer due to their perennial nature in the severest of droughts. The wetlands also lie at the downstream end of the regional groundwater flow path.

Figure 18.6: Coastal wetlands

While the wetlands are separated from the Wairau Aquifer by the confining layer, the confining layer is likely to be sufficiently porous to allow up-welling groundwater to pass through at slow rates.

Knowledge of the aquifer dynamics associated with the deeper layers of the Coastal Wairau Aquifer is hampered by the lack of deep wells. The deepest coastal well is the 85 metre deep exploratory well 1733. In the absence of drilling results, a simplified model of what the deeper strata may look like has been developed. (Fig. 18.7) .

The model is based on existing knowledge of the regional geology and flow patterns, but remains our best estimate of what lies beneath ground level.

In the future, indirect methods like geophysics may help refine our knowledge of the geological structure. However, drilling is the only sure way to verify the exact type of strata, the position of the saline interface, and evaluate the chemistry of deeper groundwater.

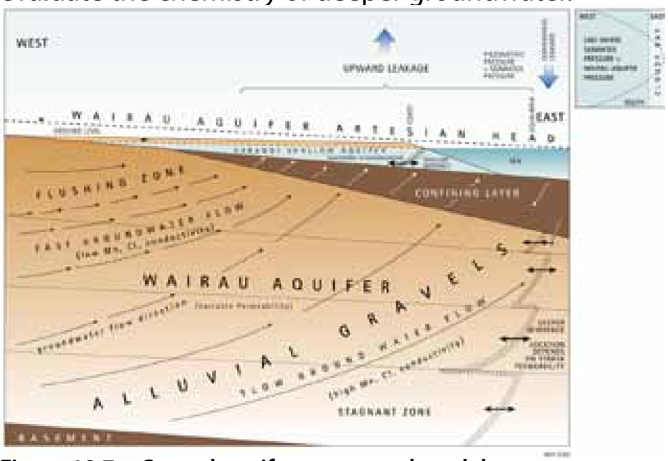

Figure 18.7: Coastal aquifer conceptual model

Seawater interface

The seawater interface is a natural boundary that exists between the inland freshwater aquifers and the ocean. Its position is a balance between offshore flow of the lighter freshwater versus denser seawater. The seawater interface is likely to vary seasonally and it only becomes a problem if too much water is withdrawn and it migrates inland to intercept wells (Fig. 18.8). When seawater is drawn into a well it is known as saltwater intrusion.

The position of the seawater interface remains undefined. The interface is likely to be located further offshore opposite central areas, based on higher natural rates of groundwater flow beneath the central Wairau Plain compared to Rarangi or Riverlands. This is supported by the results of the aquifer testing of the MCRWB exploratory well 1733 in 1987. Continuous pumping at the very high rate of 11,520 m^3/day showed no sign of a change in groundwater quality or increase in salinity. This suggests the interface is relatively distant opposite the Wairau River mouth.

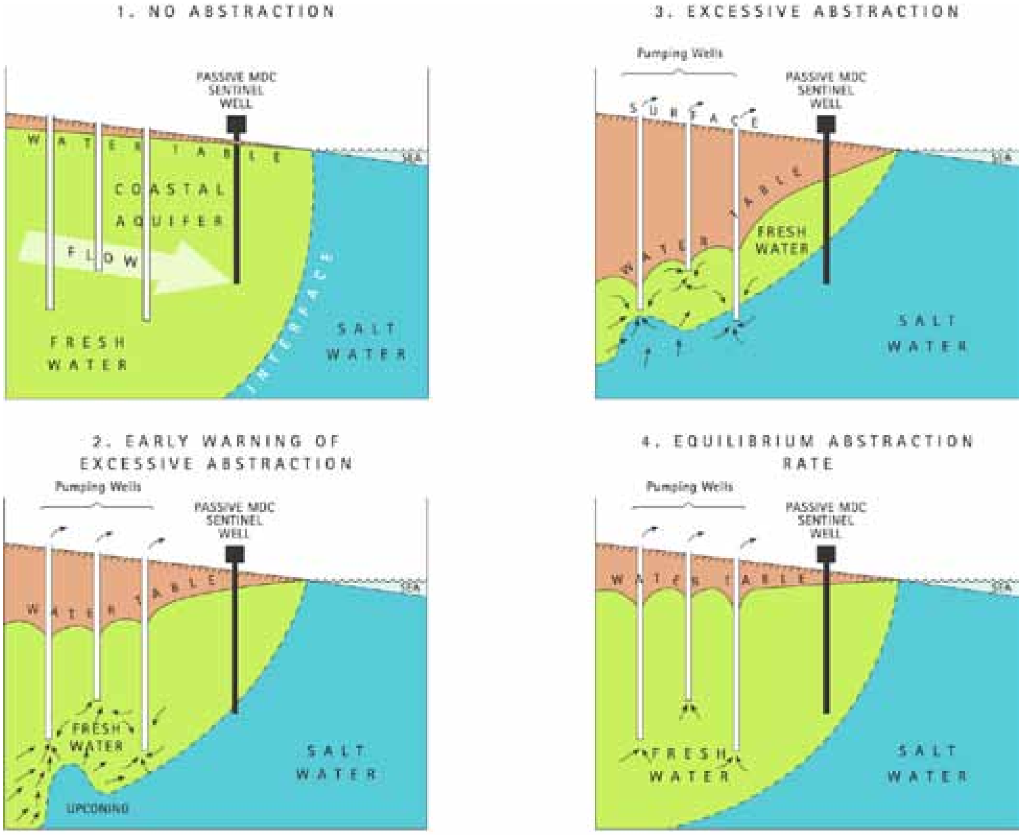

Figure 18.8: Seawater intrusion management scenario

The MDC Bar well 1733 is the longest standing of the sentinel well sites near the mouth of the Wairau River opposite the central plain (Fig. 18.9).

The ratio of the well's tidal range to the ocean's tidal range is called the tidal efficiency of the aquifer. A comparison for the 10th of August 2010 showed that the well level varied by 66% when compared to the rise and fall of the sea level over the same time period (Fig. 18.10). Because the well is so close to the coast, there is very little time difference between high tide and the peak level in the Bar well. However significant time delays exist for inland wells due to the travel distance of the wave.

Balancing the rate at which groundwater is abstracted with natural rates of throughflow is the best means of avoiding seawater intrusion. To understand and manage the risk of seawater intrusion, the MDC established a network of seven sentinel wells since 2000.

Based on monitoring information gathered from the sentinel network there is no indication of seawater intrusion having ever occurred in the aquifers near the Cloudy Bay coast.

Instruments monitoring aquifer level and conductivity at sentinel wells provide an early warning of an inland migration of the interface between groundwater and seawater. If seawater intrusion was to occur, restrictions would be placed on consented water users taking from wells which directly affect aquifer levels at the coast and direct management would continue until the interface returned to an acceptable position.

Aquifer salinity and pressure relative to mean sea-level is monitored on a continuous basis by the MDC at its sentinel well network.

Hydraulic properties

The elastic nature of the marine clays confining the Wairau Aquifer Coastal Sector, allows the nearby ocean tides to compress them every six hours.

Because the confining layer extends inland as far as Blenheim, the tidal loading effects are also propagated this far west.

WACS yields are relatively high beneath the central Wairau Plain, but drop-off dramatically on the edges at Rarangi and at Riverlands as the gravels thin and become clogged with clays. These differences reflect the lack of uniformity in the way in which tidal effects are propagated inland.

The presence of the confining layer capping the WACS means it has naturally low storage. Large pumping rates in the Wairau Aquifer can generate small, but extensive drawdown cones spreading out for several kilometres from the well. The confining layer also isolates the aquifer, meaning recharge water has to travel a long distance from north-west of Renwick. This recharge taking several decades or more.

Figure 18.9: Wairau Bar well 1733

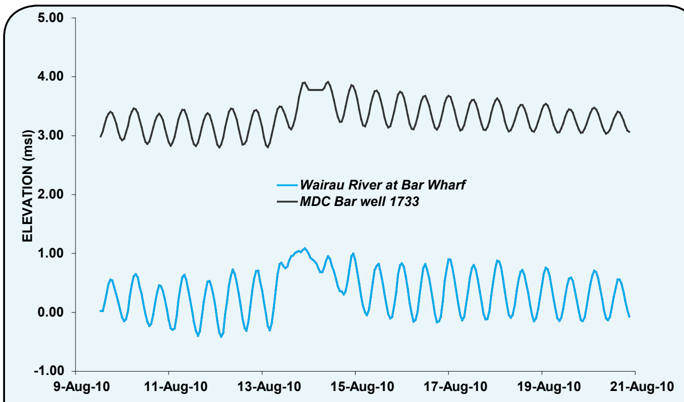

Figure 18.10: Ocean tides versus aquifer tides. The pattern is disturbed on the 14th of August by a moderately large Wairau River flood event.

The northern boundary of the Wairau Aquifer is based on estimated values of aquifer transmissivity derived from drillers measurements of specific capacity (Fig. 18.11).

Groundwater chemistry

The chemical nature of groundwater is currently the most important tool available for defining the position of the Cloudy Bay freshwater/saltwater interface. Seawater has a distinctive signature, which is dominated by chloride and sodium salts. Freshwater on the other hand is dominated by bicarbonate. The ratio of chloride to bicarbonate has been used to distinguish the origin of Coastal Wairau Aquifer groundwaters.

Of particular interest is chloride which reaches concentrations of about 19,000 parts per million in seawater. Salinity can be approximated by conductivity which has the advantage of being measured in the field rather than the laboratory.

Due to its confined structure, oxygen levels in groundwater are low throughout the WACS and reduced chemical conditions prevail. As a result groundwater naturally contains higher levels of dissolved salts than inland areas of the Wairau Aquifer, along-with characteristically low levels of nitrate. In areas where organic matter is present, the groundwater chemistry also displays low levels of sulphate and elevated levels of iron, manganese and sometimes arsenic.

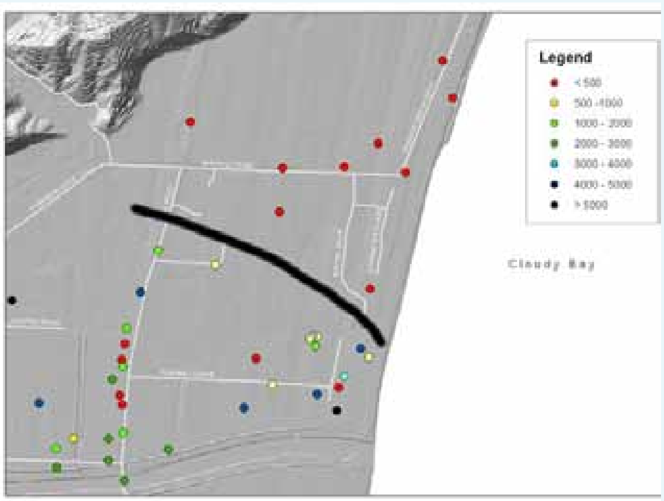

Figure 18.11: Calculated transmissivity based on well yield. The WACS northern boundary is marked by the heavy black line.

There is a significant variation in groundwater chemistry across the WACS. This variation reflects a diminishing concentration of oxygen, natural differences in the permeability of the aquifer forming gravels, rates of groundwater movement and the degree of interaction with local minerals. This makes chemistry a good indicator of the relative age and residence time of groundwater.

Groundwater is in contact with local rocks for longer in areas north of the Diversion Channel where flow is more sluggish. This groundwater is older and more mineralised as a consequence. This is illustrated by the evolved chemical signature of groundwater from the MDC monitoring well 3667 at Rarangi (Fig. 18.12). The composition is dominated by sodium, chloride and to a lesser extent bicarbonate. While these are the principal components of seawater, their presence is not an indication of saline intrusion, rather the composition reflects the residual influence of salts trapped in the gravels that have yet to be flushed away by groundwater flow. Sodium and chloride levels are present in much lower concentrations in groundwater from central parts of the Coastal Wairau Aquifer. In these areas higher rates of groundwater throughflow have presumably flushed them from the gravels over thousands of years.

The chemical composition of well 1733 groundwater (Fig. 18.13) is only slightly evolved from the Wairau River water it originated from 30 years previously (Fig. 18.14). The key differences from the parent Wairau River water are increased sodium from contact with the marine sediments and less calcium due to cation exchange. Conversely, there is an increase in magnesium, less sulphate due to chemical reduction and a resulting increase in bicarbonate.

This shows that while groundwater slows considerably as it approaches the coast in central areas due to low permeability, it doesn't change its chemistry significantly. Friction effects are much more pronounced on the edges of the main axis of flow at Rarangi, and as a result groundwater is almost stagnant.

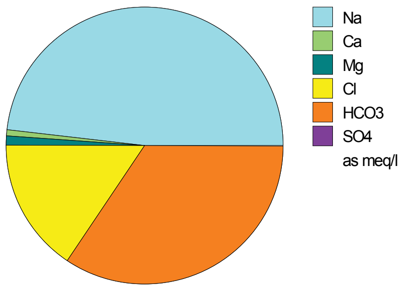

Figure 18.12: Well 3667 groundwater chemical composition

The proportion of chloride is actually lower in Coastal Wairau Aquifer water compared to Wairau River water, which might reflect differences between when the samples were taken. While Wairau River water has a slightly higher proportion of chloride relative to the other major ions, the actual chloride concentration is lower than groundwater from either of the two wells. In other words the surface water is more dilute.

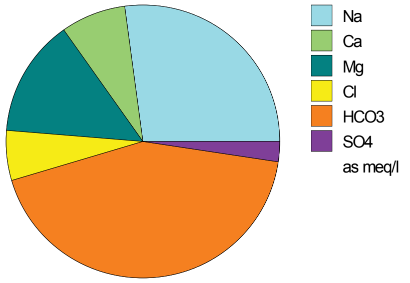

Figure 18.13: Well 1733 groundwater chemical composition

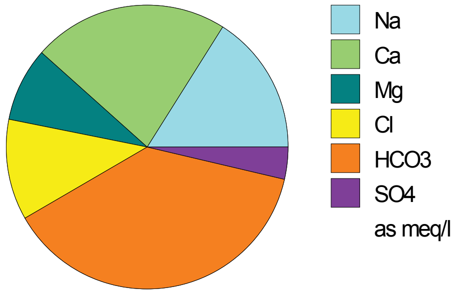

Figure 18.14: Wairau River @ SH6 chemical composition

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