# Chapter 26: Rarangi Shallow Aquifer

## Introduction

Rarangi is a semi-rural coastal area situated in the northeastern corner of the Wairau Plain. Prior to the turn of the century, Rarangi was almost entirely rural with landuse dominated by pastoral farming and the presence of only a few coastal beach houses. The subsequent increasing demand for coastal residential property has prompted subdivision of the majority of coastal land at Rarangi. This property boom coincided with expansion of viticulture throughout the Wairau Plain and much of the land at Rarangi that is suitable for viticulture has been developed within the last decade.

Subdivision of rural property and expansion of viticulture has also greatly increased demand for water in the Rarangi area. As early as 1988 the increasing pressure being placed on the Rarangi Shallow Aquifer (RSA) was noted, in terms of both water availability and water quality (Cunliffe - 1988).

The main limitation on water availability at Rarangi is that the Wairau Aquifer pinches out in the vicinity of Rarangi Road. Consequently, properties situated north of Rarangi Road are entirely dependent on the RSA for their water supply.

The RSA has been subject to an increased loading of septic tank effluent as the number of residential properties has grown. The establishment of vineyards in the area has also resulted in an increased use of fertilisers and agrichemicals.

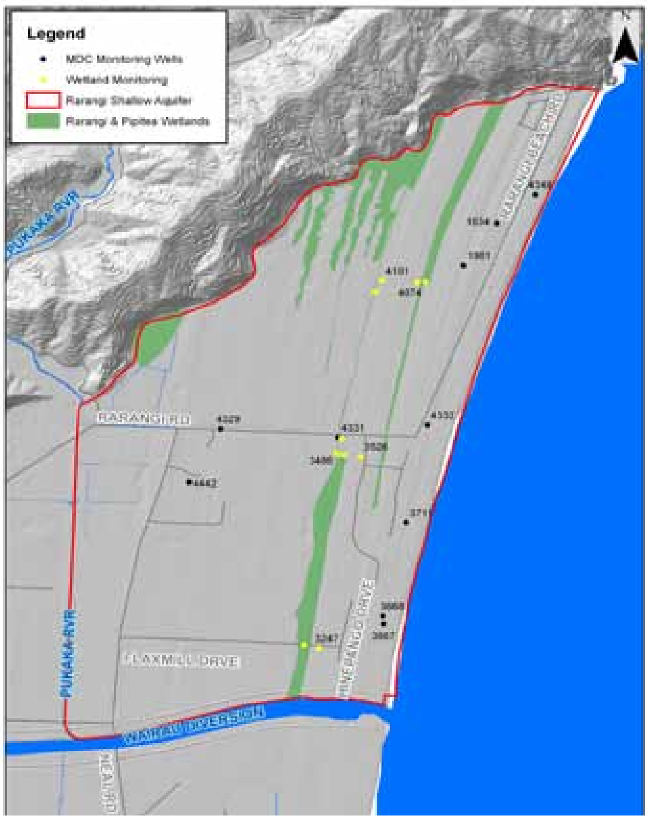


Figure 26.1: Rarangi Shallow Aquifer and key wells

The RSA's vulnerability to land use impacts and increase in water demand has prompted MDC to carry out a number of studies on different aspects of Rarangi's groundwater resources. The RSA is now the most intensively studied and monitored aquifer in Marlborough.

## Groundwater systems

The RSA underlies the Rarangi-Marshlands area at the northeast margin of the Wairau Plain. The aquifer covers an area of approximately 12 square kilometres. The northern and eastern margins of the RSA are bounded by the Richmond Range and Cloudy Bay respectively (Fig. 26.1). The RSA is underlain by the higher yielding Wairau Aquifer as far north as Rarangi Road. The western margin of the RSA is marked by the outcropping of terrestrial clays to the west of the Pukaka River and the southern extent of the RSA is the Wairau Diversion. Water-bearing sandy gravels do extend south of the Diversion, although their productivity is likely to be limited due to the narrow width of the aquifer southwards towards the Wairau Bar.

The Wairau Diversion and Pukaka River act as groundwater divides, and are convenient boundaries for water management purposes. There are currently no consented abstractions from shallow gravels south of the Diversion. Historically there has been no shallow groundwater use south of the Diversion because of the availability of water from the Wairau Aquifer. There is only a single shallow abstraction west of the Pukaka Stream, and there is limited potential for further abstractions in this area.

### Rarangi Shallow Aquifer definition

The RSA is an unconfined coastal aquifer hosted by the Rarangi Formation and consists of a thin layer of sands and fine gravels (Fig. 26.2).

The Rarangi Formation is a wedge of coastal sediments that thins towards the west and south. The saturated aquifer thickness reaches a winter maximum of seven metres in the central and northern areas. The thinnest

Figure 26.2: Sandy sediments surrounding well 0056

water bearing band is approximately three metres thick and occurs near the Pukaka River during late summer. The RSA thins to the southeast with saturated thicknesses as small as four metres near the coast north of the Wairau Diversion.

The RSA is underlain by the Dillons Point Formation which is predominantly composed of silt and fine sand of shallow marine origin. The Dillons Point Formation is up to 25 metres thick in the Rarangi area. The fine grain size and considerable thickness of the Dillons Point sediments create an aquitard separating the RSA from the underlying Wairau Aquifer. There is no direct hydraulic connection between the RSA and the Wairau Aquifer, although upwards leakage does contribute recharge to the RSA.

The existence of the Rarangi Formation indicates a geological shift from a passive shallow marine environment, representative of the Dillons Point Formation, to a higher energy coastal depositional environment. Because of this shift, the Rarangi Formation is lithologically distinctive, being composed almost entirely of beach sand with minor shell fragments and gravel. The sand and gravel sediments were deposited along an advancing shoreline as sea levels stabilised over the last 6,600 years (Pickrill - 1976, Gibb - 1979).

Sediments of the Rarangi Formation were originally derived from the Awatere Valley and White Bluffs, and have been transported northwards to Cloudy Bay by long-shore drift (Pickrill - 1986). The Rarangi Formation sediment distribution is constrained by the presence of the Wairau River and the Boulder Bank, which was laid down at the same time as the Rarangi Formation.

The Rarangi Formation reaches a maximum thickness of about ten metres along the most recent beach ridge, adjacent to the Richmond Range. Boreholes along the shoreline record two distinct sand and gravel beds up to five metres in thickness. Many of the household wells along the beach front penetrate to the coarser sandy gravels found at the base of the uppermost bed.

**Figure 26.3: Historic beach ridges.**

**Figure 26.4: Rarangi beach ridges and swales.**

The base of the aquifer is formed by marine silts of the Dillons Point Formation which is often marked by the presence of shell beds or carbonate-cemented sands.

The coastal origin of the Rarangi Formation has created a distinctive geomorphology of north-south trending paleo-beach ridges. The seaward and highest of these ridges is composed of coarser gravel deposits that appear at the surface as piles of small boulders (Fig. 26.3). Further inland, the ridges are composed of sand dunes.

Many of the beach ridges are interspersed with narrow swales consisting of finer sand, clay and peat. Many of the swales host permanent or ephemeral wetlands. These wetlands perform an important role in aquifer dynamics, and also influence groundwater chemistry. The north to south oriented beach ridges and swales run parallel to the coast (Fig. 26.4).

## Recharge and flow patterns

### Rainfall recharge

The dominant source of recharge to the RSA is rainfall infiltration. The volume of rainfall that recharges the RSA depends on both rainfall intensity and soil hydraulic properties. Isohyetal maps of the Wairau Plain indicate that rainfall increases northwards towards the Richmond Ranges (Rae - 1987). Mean annual rainfall varies throughout Rarangi from around

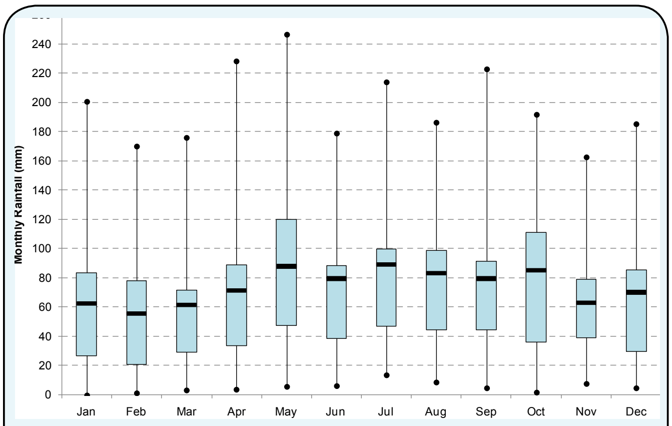


**Figure 26.5: Marshlands average monthly rainfall over 72 years. The whiskers indicate minima and maxima and the box portrays the interquartile range. The solid line in the middle of the box is the median.**

800 mm/year at the Diversion, to 1200 mm/year at the edge of the Richmond Ranges. Rainfall received in the Ranges north of Rarangi is around 1400 mm/year.

The only long-term rainfall record available for Rarangi is from Marshlands. This record consists of daily rainfall totals from June 1925 to December 1988 when the station was decommissioned. The nearest site that measures evapotranspiration is at Blenheim research station which has recorded potential evapotranspiration (PET) since January 1972. This information combined with the Marshlands rainfall record gives a seventeen year window of full climate information. Mean and median monthly rainfall is approximately 68 mm over the entire record. There is a general trend of high rainfall from May to October, and a drier summer, particularly during February (Fig. 26.5). The area is subject to climate extremes and any time of the year.

Rainfall recharge at Rarangi is considerably less than actual rainfall because of evapotranspiration losses. Recharge is also quite variable across the RSA as the infiltration of rainfall is largely dependent on soil properties.

Soils in the Rarangi area can be classified into three main types. The most extensive soil type is Taumutu gravel silt loam, which is associated with sandy sediments. This soil has a very low water holding capacity and allows nearly half of annual rainfall to infiltrate to the aquifer. The other two soil types are less critical to infiltration processes.

An estimate of recharge at Rarangi has been made with the Rushton soil moisture balance model (Rushton et al. - 2006). The model has been applied daily to the available seventeen years of full climate information. Annual rainfall recharge ranges from 180 to 630 mm/year for the period 1972-1988. Mean annual recharge is approximately 322 mm/year (4,287,365 $m^3$), which is 39% of the mean annual rainfall for the same period. The distribution of recharge throughout the year is highly variable, with very little infiltration between November and April. In most years there is no aquifer recharge during February.

The results of recharge modelling are plotted as a monthly depth-duration curve and compared with rainfall (Fig. 26.6). For about 45% of the record, during drier periods, there is no monthly recharge at all. This renders the RSA highly vulnerable to the effect of pumping during the drier months when there is greater water demand. When recharge does occur, it is significantly less than monthly rainfall.

## Stream recharge

Stream flow gauging measurements indicate that the contribution of aquifer recharge from the Pukaka River is not significant.

A small volume of recharge does enter the aquifer during winter and spring via the surface drainage network that connects the northern and southern wetlands. This recharge occurs because the aquifer recovers more rapidly along the foothills of the Richmond Range where rainfall infiltration is greatest. However, this recharge is not a net addition to the aquifer, more a redistribution of groundwater from northerly areas to southern parts of the aquifer.

## Upwards Wairau Aquifer leakage

The Wairau Aquifer contributes a fairly constant recharge to the RSA via vertical leakage through the Dillons Point Formation aquitard. This leakage is restricted to the southern part of the RSA where the Wairau Aquifer exists.

Water levels in the Wairau Aquifer are monitored at the MDC coastal monitoring well 3667 at Hinepango Drive, and are fairly constant across the area covered by the RSA. Water levels in the RSA are quite variable across the aquifer and have been measured in two

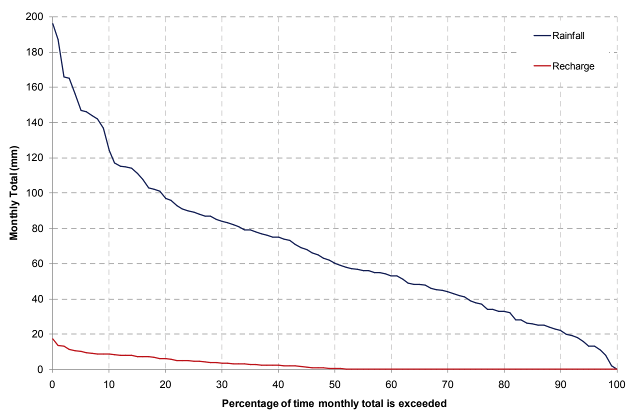


**Figure 26.6: Depth duration curve for monthly rainfall and recharge totals at Marshlands 1972 - 1988**

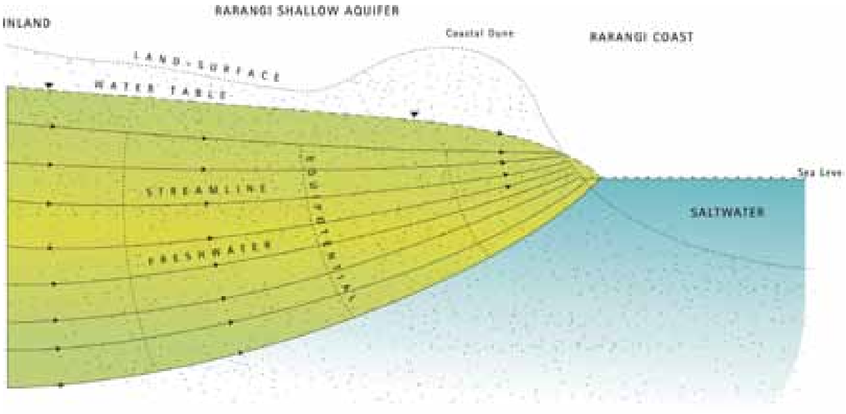


**Figure 26.7: Conceptual model of interface between groundwater and seawater at Rarangi**

piezometric surveys carried out by PDP in July 2002 and March 2003 (PDP - 2003). By subtracting the two water table surfaces from representative winter and summer Wairau Aquifer water levels, we can obtain the average difference in water level across the RSA of 1.34 metres. The difference in water level between the two aquifers does not vary greatly between winter and summer conditions.

The rate of upward flow to the RSA from the Wairau Aquifer is calculated to fall between 8 and 65 l/s depending on the value used for the conductivity of the aquitard.

## Coastal drainage

The RSA discharges most of its fresh water into Cloudy Bay. The subsurface contact between fresh groundwater and saline groundwater at the coastline is called the seawater interface. Because saltwater is denser than freshwater, saltwater underlies fresh groundwater along the coast, extending inland for a short distance as a saline lense (Fig. 26.7). The seawater interface is the boundary line separating the blue saltwater from the green freshwater.

The position of the interface is dynamic, being primarily determined by coastal groundwater levels in the aquifer. As seawater and fresh water levels rise and fall, the seawater interface moves seaward and landward naturally. Regular water level fluctuations caused by the tides and seasonally changing aquifer levels mean that the interface is diffuse rather than sharp.

If an aquifer is over-pumped, the seawater interface can move inland and contaminate wells. This phenomenon is known as seawater intrusion. Seawater intrusion is a concern because contamination with just a small amount of salt water can make groundwater undrinkable. The chloride content of seawater is about 19,350 g/m$^3$ whereas values in the RSA are typically around 20 g/m$^3$, and the aesthetic guideline value for chloride is 250 g/m$^3$ (Ministry of Health - 2000). Seawater intrusion is a potential issue and is not thought to have occurred at Rarangi to date.

To provide an early warning of seawater intrusion the MDC maintains a network of groundwater monitoring wells along the Rarangi coastline. The monitoring wells provide a continuous record of water level and conductivity information for the RSA.

Conductivity values in the coastal monitoring wells have remained consistently between 15 and 40 mS/m, indicating that no saline mixing has taken place. The exception has been at the Rarangi North well 4349 which is located only 55 metres from the sea. This well has been subject to seawater contamination several times since it was drilled in 2004. These contamination events do not represent seawater intrusion caused by the lowering of groundwater levels, but appear to be caused by tidal surges during low pressure storm events.

Geophysical exploration techniques have been used to locate the position of the saline interface along the Rarangi coastline. Electrical resistivity surveys were carried out during December 2003, consisting of three transects oriented perpendicular to the coastline. Models of resistivity profiles indicate the level of salinity within the aquifer (Fig. 26.8). To date resistivity profiles confirm that there has been no significant inland movement of the interface. The profiles also show that the interface is sharper than expected. The position of the interface varies from approximately 15 m at well 4349, to 35 m at well 3711. These wells are situated 55 m and 175 m inland respectively.

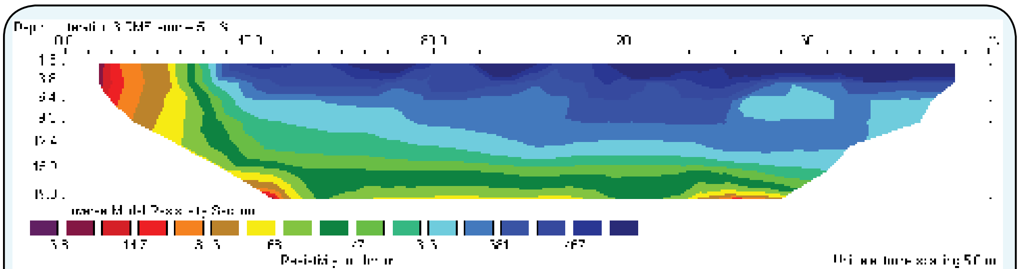

**Figure 26.8: Resistivity profile. The colours indicate the level of salinity with freshwater teal to blue in colour, saline water is red and a mixture is shaded green. Marine silts at the base of the RSA are also coloured green.**

Knowledge of the interface position has been used to determine values of critical water level at three of the MDC coastal monitoring wells (Table 26.1). The critical thresholds are minimum water levels that need to

| Sentinel Well | Name | Start | Distance To Coast (metres) | Critical Level (msl) |
|---|---|---|---|---|
| 3668 | Hinepango | Nov-2000 | 175 | 0.2 |
| 3711 | Bluegums | Jan-2001 | 175 | 0.3 |
| 4349 | Rarangi North | May-2004 | 55 | 0.2 |

**Table 26.1: Coastal sentinel well thresholds**

be maintained to ensure that the saltwater interface does not contaminate domestic wells. The thresholds were derived by first using the interface position to calibrate the Glover equation (Glover - 1964). The Glover equation was then used to model encroachment of the interface for different water levels in the three sentinel wells (Wilson - 2004).

## Well abstraction

Most groundwater pumped from wells tapping the RSA is for domestic supply purposes. The majority of these wells are located on beachfront properties within 300 metres of the coastline.

There are currently no consumption figures for domestic wells. Daily demand for smaller properties is estimated to be approximately 0.5 to 1 $m^3$/day depending on the season and time of year. Larger properties, such as those in Edgewater Estate and Blenheim Lifestyles subdivisions are likely to use slightly more to water gardens or shrubs, up to 2 $m^3$/day. The North Rarangi water supply provides potable water for the community to the north of the Golf Club from wells 0001 and 2414. Consumption for this area is estimated to be up to 60 $m^3$/day.

The only major consented abstraction from the RSA for irrigation purposes is by the Rarangi Golf Club, who have resource consent to take up 600 $m^3$/day. Between 2003 and 2007, Wither Hills Vineyards Limited had consent to take up to 1,100 $m^3$/day for vineyard irrigation. The renewal of this consent was strongly contested by the Rarangi community and the MDC, mainly because of the impact on wetland hydrology. The consent was eventually relinquished and an alternative irrigation supply granted from the Wairau Aquifer at Flaxmill Drive.

## Flow patterns

In 1989 the MCRWB conducted surveys of RSA winter and summer water levels. Contours of aquifer elevation showed that groundwater levels are highest along the foothills of the Richmond Range (Fig. 26.9 and Fig. 26.10).

The two surveys showed that water level changes between winter and summer conditions were very small. As expected, the major seasonal difference is that there are higher water levels and steeper flow gradients during the winter. A groundwater divide forms a central axis to the aquifer, running north-south

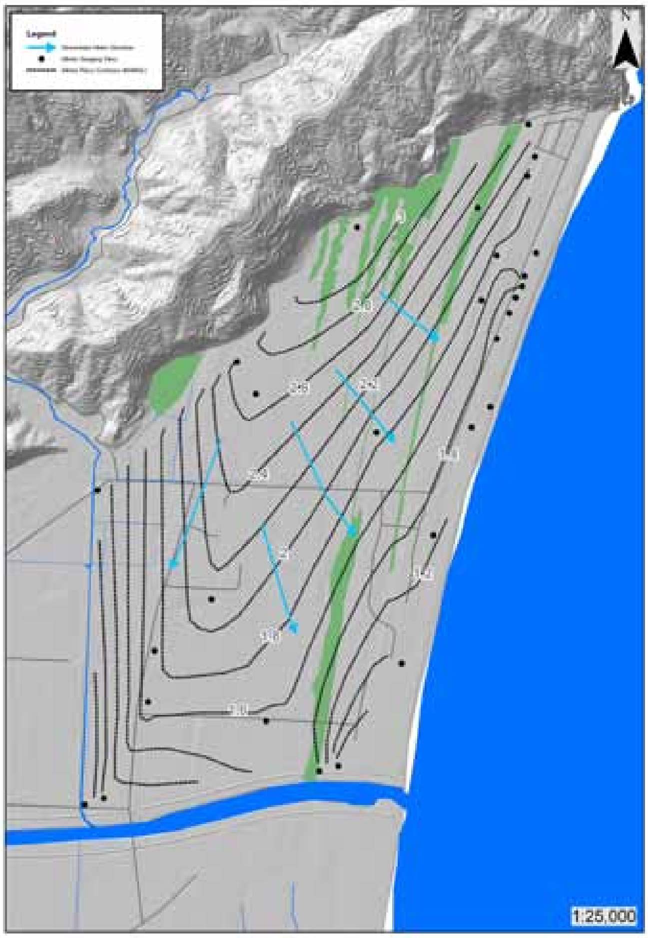


**Figure 26.9: RSA winter water table**

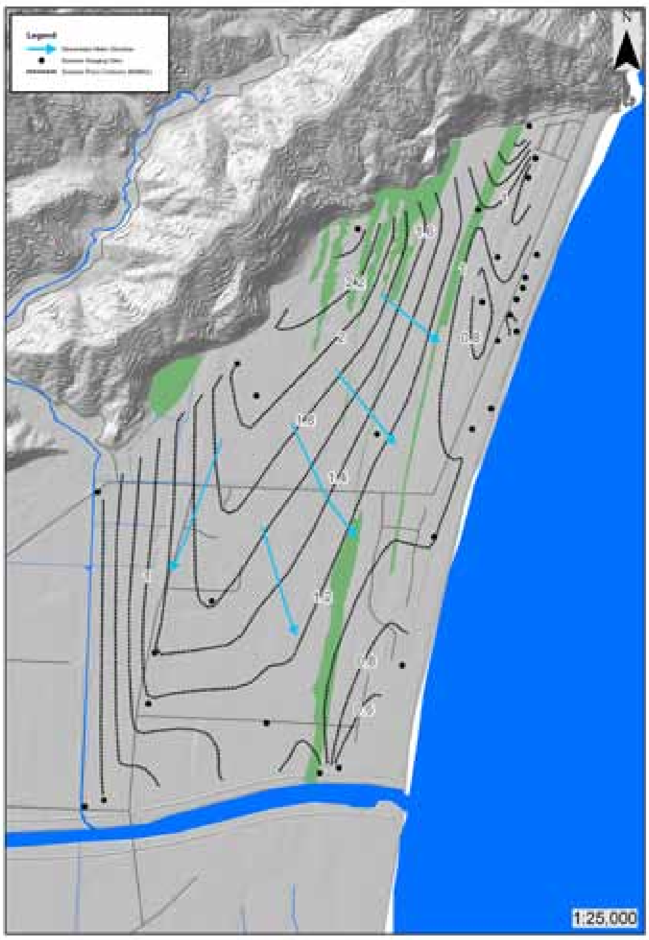


**Figure 26.10: RSA summer water table**

just to the east of Neal Road and the water table slopes away from this central axis towards Cloudy Bay, the Pukaka River, and the Wairau Diversion. These three boundaries drain water from the aquifer and dictate the overall pattern of groundwater flow. The shape of the water table surface indicates that the RSA is primarily recharged by rainfall infiltration, and also indirectly by hillside runoff. The dominant direction of groundwater flow in the aquifer is southeast, towards Cloudy Bay.

## Groundwater dependant wetlands

A series of natural wetlands and agricultural drains occur throughout the Rarangi area. They are hydraulically connected to the RSA with the exception of the northern most wetlands next to the Pukaka Range, which are elevated above the water table.

Wetlands are formed where groundwater intercepts the surface in low lying depressions (Fig. 26.11). Some of the more elevated northern wetlands near the ranges do become perched above groundwater because of the build-up of silts and organic matter in the wetlands which prevents them from draining (PDP – 2005).

Detailed water table and wetland level surveys and precise measurements of their relativity over time showed that the Rarangi Wetland Complex is hydraulically dependant on the RSA and sensitive to small changes in the groundwater table due to the flat water table gradient (MDC – 2007), (Preece – 2007).

Pumping from the RSA for residential or domestic use has limited impact on the wetlands because abstraction rates are low and wells are located nearer the coast.

During wet periods the wetlands are full of water and they recharge adjoining groundwater. Conversely in drier periods when levels are lower in the wetland channels, the wetlands rely on recharge water originating from the RSA (Fig. 26.12). The wetlands and drain network therefore play an important role in rapidly distributing water throughout the Rarangi Shallow Aquifer.

Figure 26.12: Contrasting seasonal groundwater levels in Golf Course Wetland 2007

Wetlands that are reliant on groundwater for their recharge are known as fens (Preece - 2007). The plants and habitat they support are known as groundwater dependent ecosystems. Naturally enough these fens are formed in topographic depressions, or swales where the Rarangi Shallow Aquifer is closest to the surface.

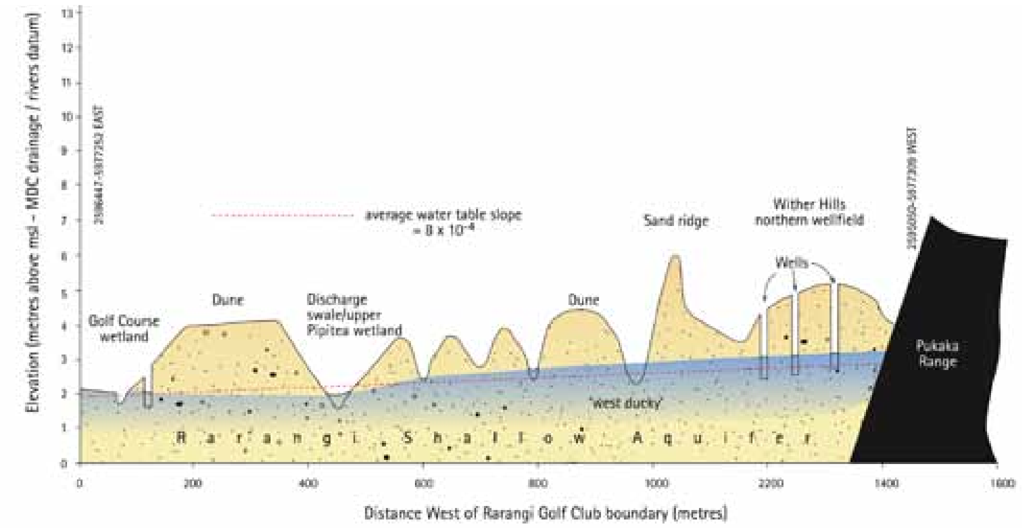


Figure 26.11: Rarangi geography

The wetland area reaches its maximum extent in spring when Rarangi Shallow Aquifer levels are at their highest, and shrink in size in summer as well levels fall (Fig. 26.13). In summer as the RSA groundwater levels fall further in the north, the more southerly located Hinepango-Pipitea wetland is often the most extensive.

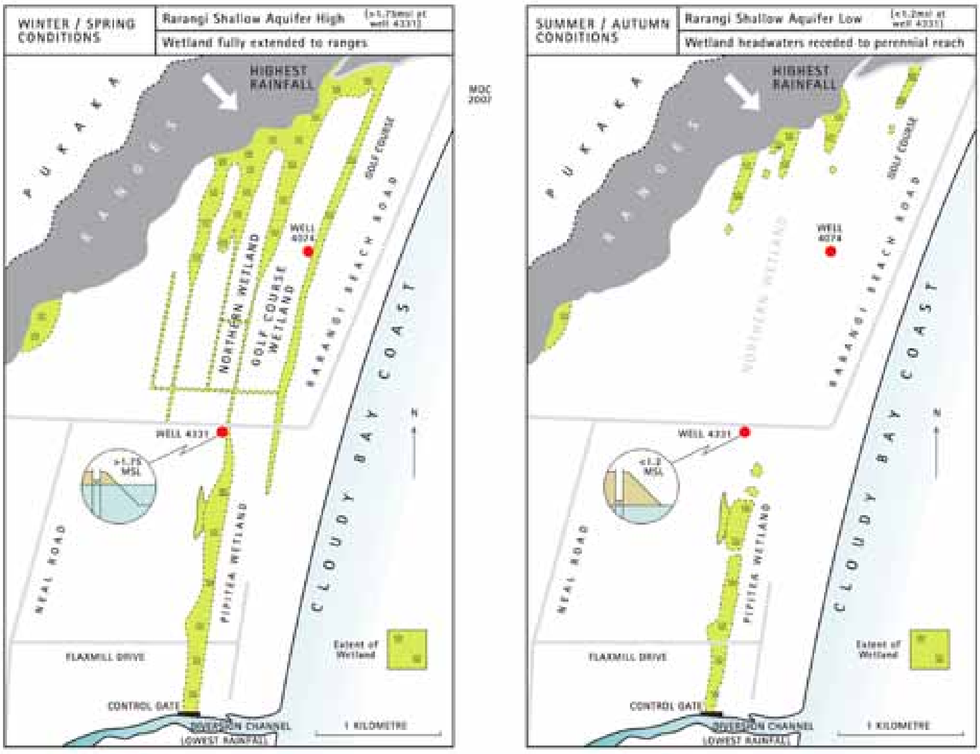


**Figure 26.13: Seasonal changes in wetland area and aquifer level**

The dynamics of the wetlands or drains and their interaction with the RSA are best understood if they are split into a northern and a southern group which are connected by an artificial drain mid-way along Rarangi Road.

## Northern wetlands

The northern wetlands are located next to the Pukaka Ranges and carry a high proportion of hillside runoff. The Golf Course wetland is the most accessible of the northern wetlands as it forms the western boundary of the Rarangi Golf Course (Fig. 26.14).

The hydraulic link between groundwater and the wetlands was confirmed through monitoring of paired groundwater (Fig. 26.15). Following rain wetland water levels are higher than the aquifer. In drier periods the RSA levels are higher and groundwater recharges the wetland. In some cases water is retained within the wetlands throughout the year because the base of their channel is lined with impermeable silts. Aquifer tests have shown that the bed conductance of some wetlands is low, as they are not perfectly sealed (PDP - 2004b).

**Figure 26.14: Golf Course wetland**

## Pipitea Wetland

The Pipitea Wetland channel runs south from Rarangi Road and collects water from areas to the northwest, before draining to the Wairau Diversion channel. Monitoring of groundwater and Pipitea Wetland levels was carried out between September 2003 and June 2005 (Fig. 26.16).

The extent of the wetlands and the elevation of the RSA affect the responsiveness of both to rainfall (Fig. 26.17).

When RSA water levels are above about 1.5 metres elevation, the wetlands are saturated and the hydrograph shows a highly dynamic response to rainfall events.

When RSA water levels at Rarangi Road are between 1.5 and 1.2 metres elevation the hydrograph starts to lose its responsiveness and the northern wetlands become perched above the water table. This reduces the capture area for groundwater seepage to the Pipitea Wetland.
When aquifer levels fall below 1.2 metres elevation the wetlands are restricted to south of Rarangi Road. Under these conditions a significant rainfall event of at least 20 mm/day is needed to generate any recovery in groundwater levels.

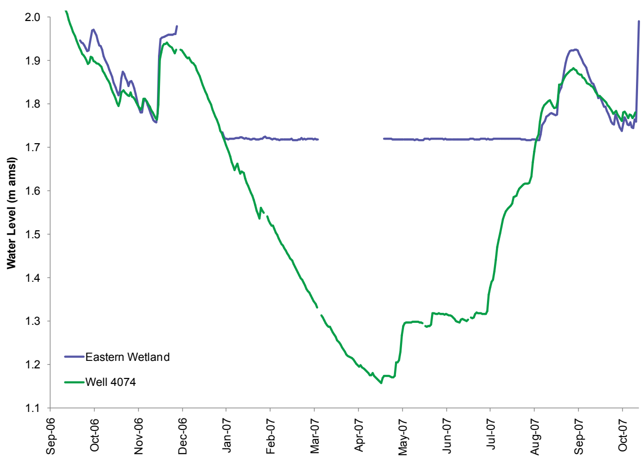


**Figure 26.15: Rarangi Shallow Aquifer versus Golf Course wetland elevation**


**Figure 26.16: Hydrographs for Pipitea Wetland and nearby RSA wells**

All MDC monitoring wells show a seasonal pattern with water levels peaking in spring, and short-term responses to rainfall followed by rapid drainage.

Coastal wells have the smallest seasonal variation in level because the sea acts like a hinge, constraining the minimum level they can drain to. They also fall more rapidly because of the steeper hydraulic grade nearest the coast. The North Rarangi well 4349 shows the greatest sensitivity to either rises in sealevel due to ocean storms or throughflow of groundwater. This is because it is closest to the coast and has a restricted storage volume. Inland wells such as 1901 and 4329, and those further from wetlands, show less sensitivity to individual recharge events and have a larger seasonal variation, but drain more slowly from spring onwards. The inland well 4331 responds like a surfacewater body due to its proximity to the Pipitea Wetland.

## Hydraulic properties

The hydraulic properties of the RSA are well known from aquifer test results. A variety of sediment types form the RSA, ranging from sandy gravels along beach ridges, to peaty clays within inter-ridge swales.

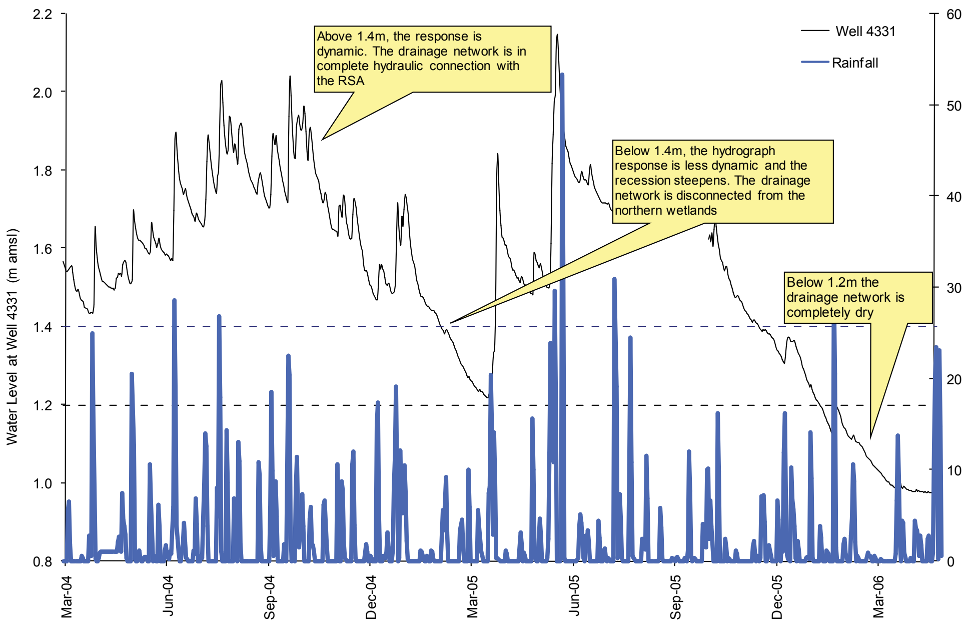


**Figure 26.17: Hydrographs for Pipitea Wetland and nearby RSA wells**

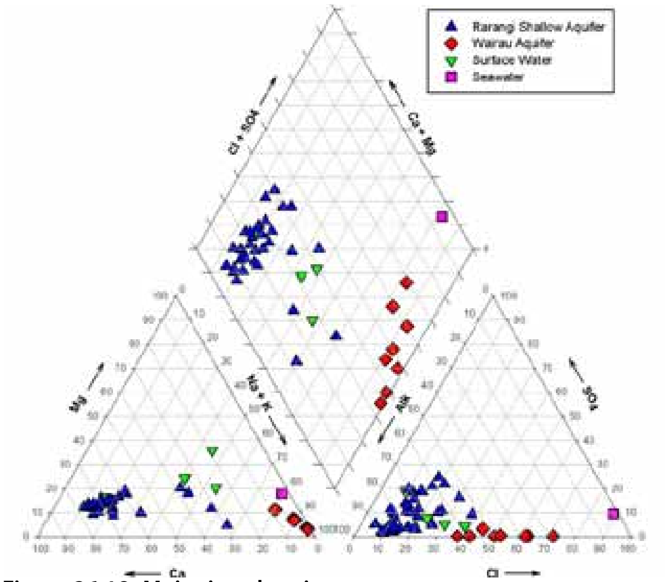


**Figure 26.18: Major ion chemistry**

It was expected that aquifer properties would also be highly variable throughout the aquifer, but in fact they are relatively homogeneous. However aquifer properties are not available for peaty or clay-rich material and their hydraulic conductivities may be much lower. The mean transmissivity value is 450 $m^2$/day and the mean storage value is 0.13.

## Groundwater chemistry

RSA groundwater is relatively young and dilute and its chemistry is distinct from the more evolved water of the underlying Wairau Aquifer. Wetland water has a similar chemistry to that of the RSA, but is significantly more reduced because of its exposure to organic matter.

The difference between the calcium-bicarbonate type water of the RSA, the wetlands and the Wairau Aquifer is clear when the major ion chemistry is plotted on the Piper Diagram (Fig. 26.18). The Piper Diagram confirms that RSA water changes towards a chemistry that is characterised by increased levels of calcium, and at its coastal margin, higher sodium and chloride. This reflects the high proportion of shells forming the sandy aquifer and the influence of sea-spray at the coastal margin. As a consequence of the high proportion of calcium, some RSA groundwater is classified as moderately hard and there may be difficulties forming a lather with soap.

Dissolved oxygen levels in RSA groundwater are low compared to others in

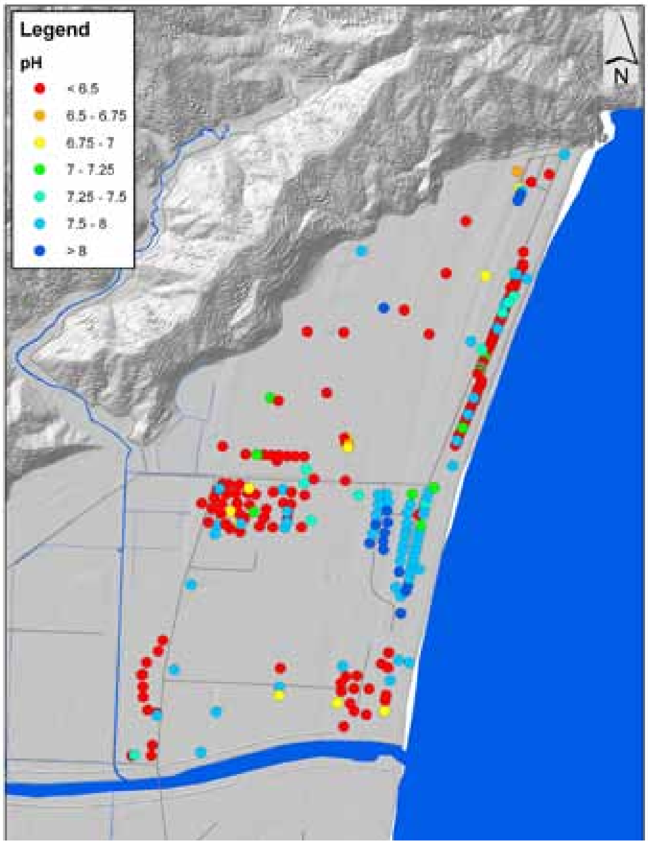


Figure 26.19: Rarangi Shallow Aquifer pH

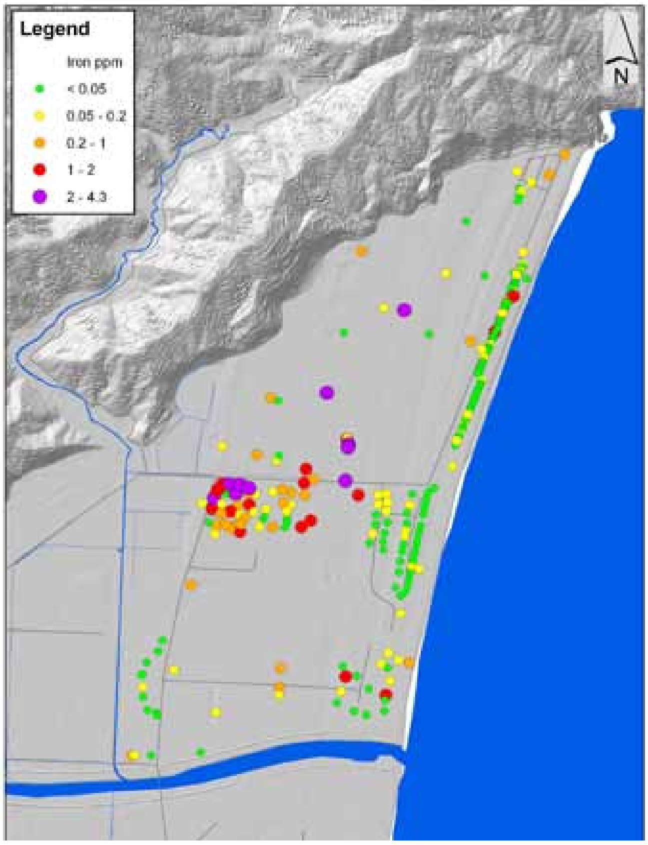


Figure 26.20: Rarangi Shallow Aquifer iron concentrations

Marlborough. This is surprising considering the aquifer is largely composed of porous coarse sands that are open to the atmosphere, and the water table is close to the surface.

Given that recharge is predominantly from rainfall infiltration which entrains oxygen and the average aquifer turnover time is only five years, we would expect the RSA groundwater to be enriched in oxygen, or aerobic (Stewart - 2004).

While this may be the case in some areas, the RSA is more reduced than expected which implies that natural processes involving organic matter are consuming the oxygen. These conditions are created by the abundance of peaty material found in wetlands, or organic material in buried swamp deposits, including the Dillons Point strata which underlies the RSA. This is consistent with the presence of high arsenic, iron and manganese concentrations in inland parts of the RSA and near wetlands. Aerobic conditions occur where there is no organic matter such as along the coastline on the high dune. As a consequence, oxidising conditions exist in this area and levels of iron, manganese and arsenic are relatively low compared to groundwater further inland.

There is a large range in the pH of RSA groundwaters from 6.4 to 8.1 although there is very little pattern to its distribution (Fig. 26.19).

Naturally high levels of iron and manganese commonly cause water quality issues in some Rarangi wells. A large range in natural concentrations exist , with the highest values associated with inland wells or wetlands and low levels in coastal wells (Fig. 26.20). Levels of iron above 0.2 parts per million can cause aesthetic issues for householders by causing brown staining. The average observed manganese concentration equals the level at which staining of whiteware occurs, while the maximum value exceeds the drinking water guideline.

Chloride concentrations are higher in wells close to the coast where salts from sea spray builds up over the drier months and are leached down to the shallow water table by rainfall. Peak chloride concentrations also coincide with the maximum electrical conductivity of groundwater measured at MDC monitoring wells along the Cloudy Bay coastline (Fig. 26.21). These wells automatically measure the conductivity of groundwater

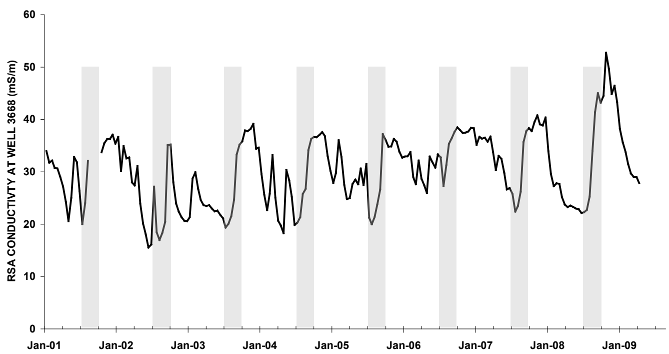


Figure 26.21: Rarangi Shallow Aquifer electrical conductivity

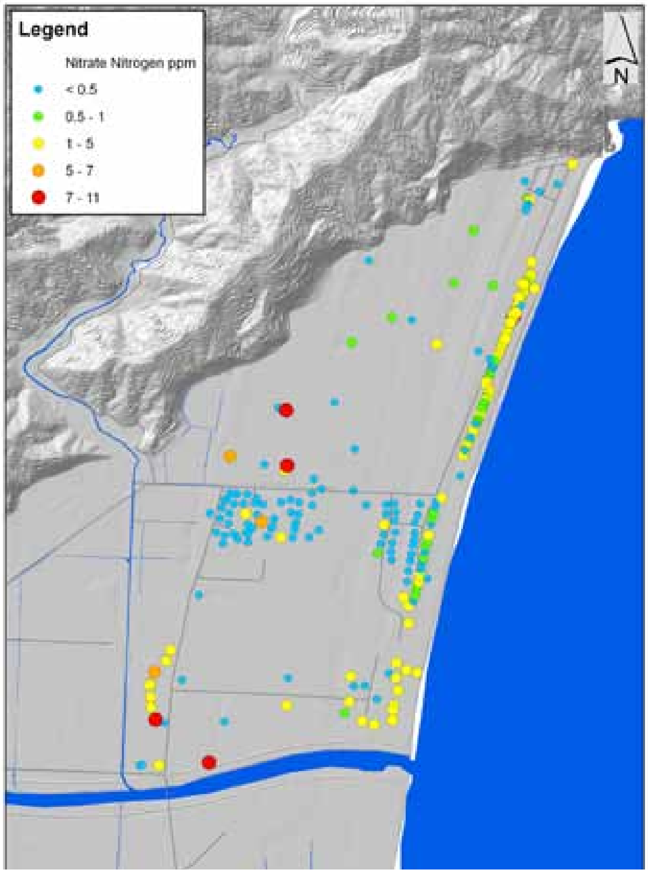


**Figure 26.22: Rarangi Shallow Aquifer nitrate-nitrogen concentration**

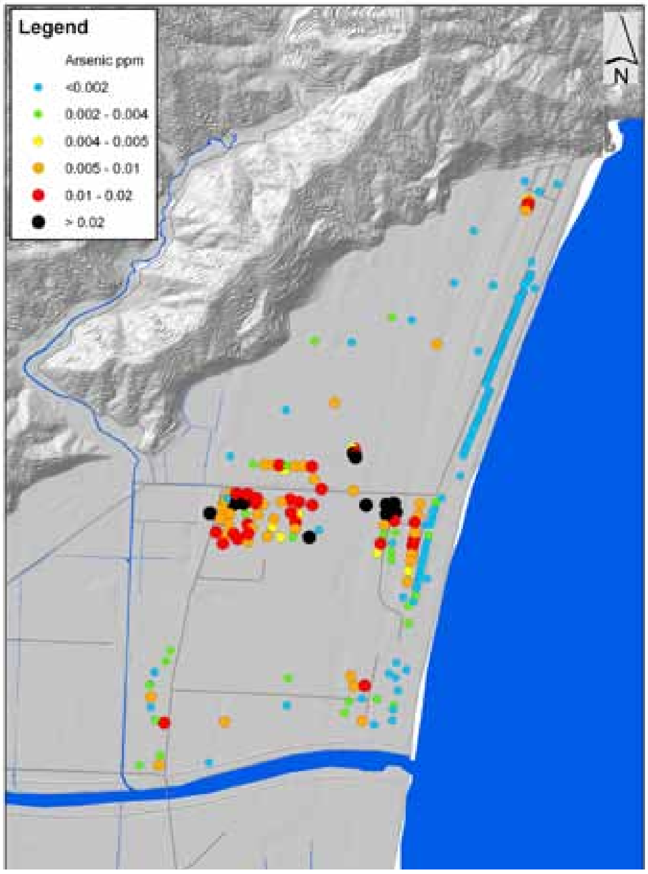


**Figure 26.23: Rarangi Shallow Aquifer arsenic concentration**

on a continuous basis to detect any movement of the seawater interface. Conductivity is particularly sensitive to the presence of sodium or chloride, the primary salts in seawater. Seawater intrusion is not the cause of increases in groundwater conductivity based on MDC resistivity surveys which show the interface is typically over 100 metres seawards of monitoring wells. The RSA is vulnerable to land use contamination because of its free draining soils, unconfined nature, and shallow water table. Levels of nitrate are slightly elevated in coastal wells due to the use of fertilisers (Fig. 26.22). Wells sampled for nitrogen isotope analysis by MDC in 2004 to determine the source of the nitrate showed that it originates from a fertiliser source, not human or animal wastes (Stewart - 2004a). However inland wells associated with the same landuse, have low nitrate levels and it is likely that natural denitrification processes are removing nitrate from the groundwater.

Elevated levels of sulphate down gradient of the golf course suggest that local land-uses are influencing groundwater quality. Sulphate levels are higher than expected for groundwaters where reduced chemical conditions are known to dominate near wetlands. This may reflect the use of fertilisers by home-owners, or possibly sulphide oxidation.

## Arsenic

Elevated levels of arsenic were first discovered in the RSA as part of routine measurements at the North Rarangi community water supply in 2001. Since then there have been several intensive studies to determine its source and distribution in the aquifer (PDP Ltd - 2002 & 2003, ESR - 2003, Taylor - 2004, Wilson and Davidson - 2005). Two extensive sampling surveys were carried out to determine the extent of arsenic contamination in June 2003 and February 2005, by MDC in collaboration with the Marlborough Public Health unit. Around 220 individual water supplies were tested with 20% of wells having arsenic concentrations above the maximum acceptable value (MAV) required for potable water supply (Ministry of Health - 2000). The surveys showed that arsenic is also present in the Wairau Aquifer beneath Rarangi in concentrations above background levels.

Wells in the RSA with elevated arsenic concentrations tend to be situated near wetlands or poorly drained Waimari soils (Fig. 26.23).

To assess the seasonal variability in arsenic levels four properties near the corner of Rarangi and Neal Roads were sampled on a monthly basis from 2004 to 2008 (Fig. 26.24). Results showed that arsenic concentrations are more seasonally variable at sites where concentrations are higher overall.

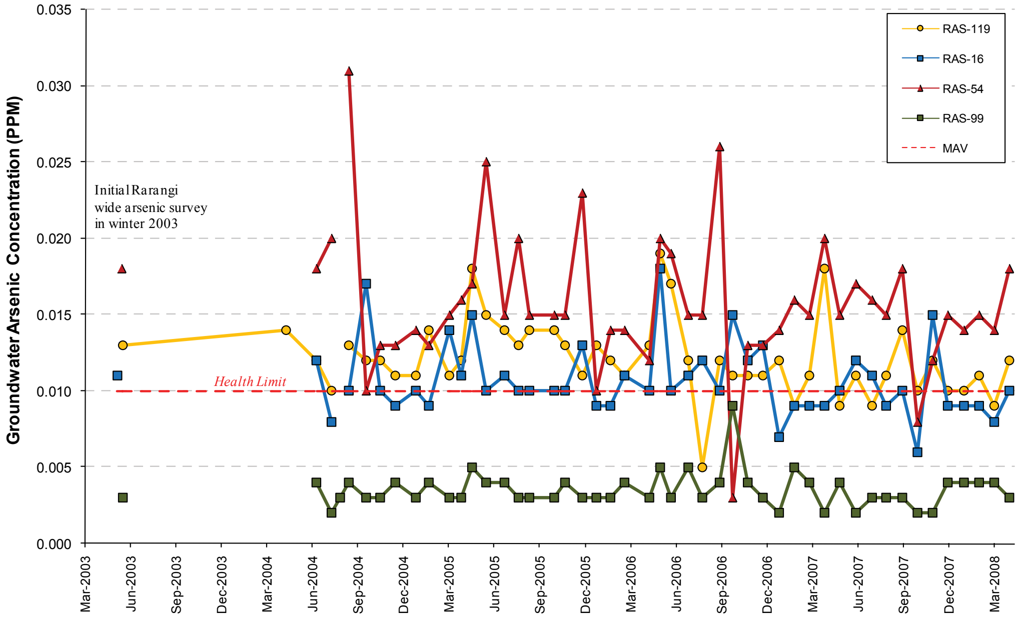


**Figure 26.24: Monthly variation in total arsenic**

The origin of most arsenic found in RSA groundwater is naturally occurring with the exception of sheep dips or old farm landfills. Arsenic commonly occurs in the schist or greywacke basement rocks forming the local ranges. The most common form of arsenic is the sulphide mineral called arsenopyrite. As part of the natural weathering processes this mineral is eroded over geological time and carried down to the Cloudy Bay coast by the Wairau River to be deposited as part of the sediments forming the RSA (Fig. 26.25). When initially deposited the arsenic was in its stable oxidised state and dispersed through the sands or fine gravels. On arrival at Rarangi however, it becomes concentrated in peat deposits or adsorbed onto iron rich coatings of sands or other particles (PDP – 2003).

Arsenic is only a problem for human health if it becomes soluble in groundwater and is then used for drinking water. For arsenic to become soluble certain chemical conditions must exist. The most common trigger mechanism to release arsenic into groundwater is reducing chemical conditions, although oxidation of sulphide minerals is another mechanism.

Reducing conditions involve moderately high pH and low dissolved oxygen levels. This combination of factors is commonly associated with wetlands or their buried counterparts. The chemical conditions of Rarangi

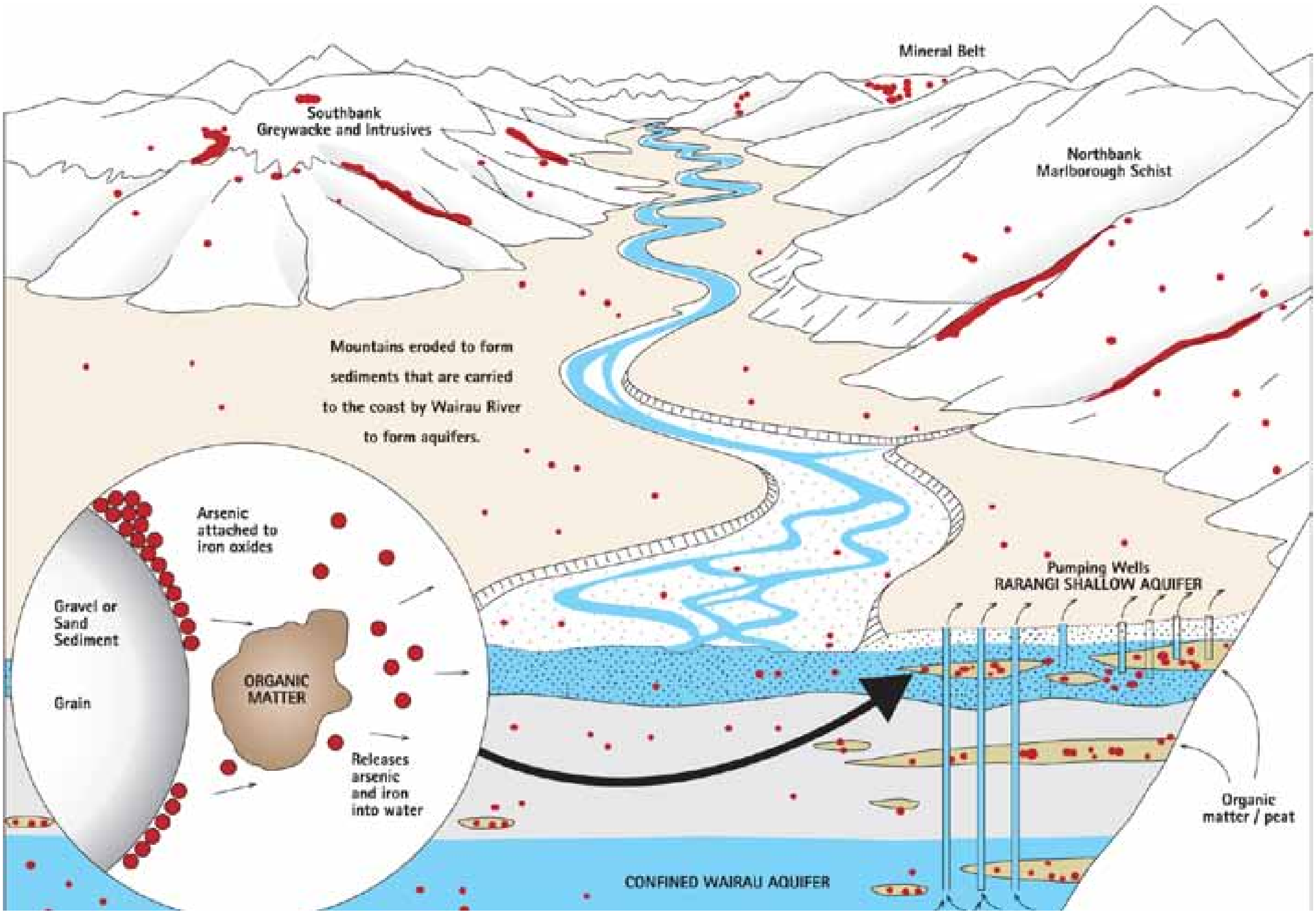


**Figure 26.25: Natural arsenic mobilisation process**

groundwater are not constant and vary seasonally, causing arsenic to come and go from groundwater depending on the aquifer conditions.

Treatment of arsenic enriched groundwater usually involves a two step process. Firstly it is oxidised by exposing it to the atmosphere to form a precipitate, then this solid material is removed from the water by filtration.

### Groundwater age and origin

Rarangi Shallow Aquifer groundwater has been sampled 28 times for the analysis of oxygen isotope tracers. The results show it is predominantly recharged by rainfall infiltration (Stewart - 2008), although surface runoff is also possible (Taylor et al. - 1992). $\delta^{18}O$ values range between –5.4 and – 8.10, with a mean of –6.5. The large range of recorded values is due to seasonal variability in recharge (Taylor - 2004). Wells with less negative $\delta^{18}O$ values are located in sandy areas close to the coast, and are likely to reflect year-round rainfall recharge. Less permeable soils cause the evaporation of summer rainfall and more negative $\delta^{18}O$ values.

RSA groundwaters have also been analysed for CFC and $SF_6$ to determine the age of the water (Stewart - 2004b). All of the samples analysed for CFCs showed a large disparity between CFC-11 and CFC-12 ages. This indicates some microbial degradation, most likely as a result of wetland interaction.

The $SF_6$ and tritium dating techniques are less affected by these processes. Eight samples from a variety of locations in the RSA returned $SF_6$ ages of up to 19 years. The average residence time for groundwater in the aquifer is five years (Stewart - 2004b).

Ten samples from 1972 to 2005 were analysed for tritium giving ages from 2.5 to 10 years (Stewart - 2008). One sample (Well 0005) returned a much older age of 38 years. This indicated the variability in groundwater that can occur within even a simple groundwater system.

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