11 GROUNDWATER RESOURCES

Summary

Objectives

- Maintain groundwater quantity and quality to the extent that the use of the groundwater resources is sustainable.

Pressures

- There are currently 3747 bores registered with the council and 279 resource consents to take groundwater in Northland, which equates to a volume of 49,602 m^3 of groundwater per day. This places a large demand on Northland's groundwater resources.
- Poorly constructed and maintained bores can result in groundwater contamination.
- Changes in land use can not only result in an increase in the quantity of water taken from an aquifer but can also influence the amount of rainfall infiltrating into the aquifer (recharge) and groundwater quality.
- The change in rainfall trends and temperature as a result of climate change is likely to result in decreased recharge to groundwater resources, and increased potential for saltwater intrusion in coastal aquifers.

State

- Due to the varying geology in Northland, there are a large number of aquifers scattered throughout the region. These aquifers include large sand and shell bed systems such as the Aupouri Peninsula to small alluvial aquifers such as Russell.
- Groundwater quality at the majority of monitored sites meets the *Drinking Water Standards for New Zealand 2005* (MoH 2005). The highest percentage of non-compliance with the drinking water standards for bacteria occurs in many of the coastal areas and in three of the volcanic aquifers: Ruatangata, Maunu and Maungakaramea.
- The majority of sites that exceed the guidelines for manganese and iron are fed from sand and gravel aquifers, while all sites monitored meet the guideline for nitrate.
- The majority of coastal bores monitored have higher electrical conductivity, and chloride and sodium levels than inland basalt aquifers, due to leaching from marine sediments.
- The mean age of groundwater in the following aquifers is likely to be greater than 45 years: Maungakaramea, Whatitiri, Three Mile Bush and Matapouri, which means that current groundwater quality may reflect the influence of historic land use activities in these areas.

- All results were below detection limit for pesticides at selected aquifers in Northland in 2002 and 2006, even though a site study in 2005 found pesticides to be mobile in Northland's Kiripaka soils.
- Of 45 Northland sites groundwater quality is improving at eight, deteriorating at seven and 15 sites showed slow changes in groundwater quality that probably indicates natural water-rock interaction. A further seven sites were identified as pristine.

Doing well

- Resource consent monitoring of bore construction and groundwater takes.
- State of the environment monitoring of groundwater quality and quantity as well as specific aquifer investigations.

Areas for improvement

- The number of people registering their 'permitted takes' and location of bores with the Council to enable greater understanding of the 'actual' amount of water taken from aquifers.
- Prioritise and implement recommendations in the preliminary hydrogeological reports based on current and potential future demands.
- Management of water allocation limits for aquifers in Northland to provide water use securities for uses and sustainable allocation of water resources.

11.1 Introduction

The Northland Regional Council has responsibilities under the Resource Management Act to control water use, and to monitor the quantity and quality of groundwater. Sustainable management of groundwater resources can only be achieved from accurate knowledge of the environment itself, including climate, water quantity, water quality, present water use and potential demand for water in Northland.

Groundwater quantity and quality in Northland is related to geology, soils, land use and rainfall. As a result of varying geology the groundwater resources also vary significantly in groundwater extent, quantity and quality. Aquifers in Northland range from small sand aquifers scattered along the east coast, large basalt aquifers in areas surrounding Whangarei, Kaikohe and Kerikeri, to larger sand/shell aquifer in the Far North.

Groundwater is an important source of water and is predominantly used for public water supplies, such as Poroti Springs, shown in the photograph (right), which flows from the Whatitiri aquifer and is used for public water supply.

Regional Policy Statement objective

Northland Regional Council has stated a number of objectives relating to groundwater within the Regional Policy Statement for Northland (NRC 2002). These seek to maintain groundwater quantity and quality to the extent that the use of groundwater resources is sustainable.

The Regional Policy Statement (RPS) objectives are:

- The maintenance or enhancement of the water quality of natural water bodies in Northland to be suitable, in the long term, and after reasonable mixing of any contaminant with the receiving environment and disregarding the effect of any natural events, for the purposes listed below:
  - Protection of uses of receiving water body, cultural purposes.
- The reduction and minimisation of the quantities of contaminants which adversely affect water quality entering water bodies, in particular those that are potentially toxic, persistent or bio-accumulative.
- Avoid, remedy or mitigate the adverse effects of discharges of contaminants on the traditional, cultural and spiritual values of water held by tangata whenua.
- The maintenance of water flows and levels in natural water bodies that are sufficient to preserve their life-supporting capacity, natural character, intrinsic values and any other associated or dependant values.
- The maintenance of groundwater levels to the extent that the use of groundwater resources is sustainable.
- The efficient use and conservation of water resources.

The NRC works towards these objectives by controlling activities which impact on groundwater and by monitoring groundwater to detect long term trends.

Environmental results anticipated

The following is the anticipated environmental results after the implementation of the policies pertaining to groundwater management in the Regional Policy Statement:

- Water quality is suitable for desired purposes.
- Contaminants in water bodies reduced.
- The adverse effects of contaminants in water bodies and coastal waters be avoided, remedied or mitigated.
- Protection of important freshwater habitats, particularly natural wetlands from reductions in surface water and ground water levels.
- Protection of the values of water bodies held by tangata whenua.
- Sustainable and efficient use of the water resources of Northland.
- Increased awareness of water conservation and the greater implementation of water conservation practices.

11.2 What are the pressures on groundwater resources?

Groundwater takes

Before 1980 groundwater water abstraction in Northland was relatively minor as water was mostly obtained from surface water supplies. Changing land use from traditional farming to horticulture and lifestyle blocks during the last two decades, together with a steady increase in subdivision and tourism, has resulted in an increase in groundwater abstraction and in turn an increasing pressure on many of Northland's aquifers.

Groundwater in Northland is used for agricultural, horticultural, public water supply, industry, and a variety of other purposes. Groundwater takes that meet the permitted activity take rules set out in the Regional Water and Soil Plan do not require resource consents. The majority of these water takes are for domestic and stock requirements.

Resource consents to take groundwater are monitored to provide information on the cumulative allocation in the aquifers. A summary of the bores registered with the Council, resource consents to take groundwater, and volumes allocated in the principal groundwater resources are shown in table 1 (below) and figure 1 (below).

Since the 2002 SOE report (NRC 2002b), the number of registered bores, groundwater consents and total volume of groundwater consented to be taken has increased. There is an additional 948 registered bores, 56 groundwater take consents, and 12,820 cubic metres of groundwater allocated via consents, when compared to the 2002 figures.

Table 1: Groundwater take consents, registered bores and water allocated by consent (m^3/day) for Northland aquifers

Aquifers	Number of consents	Number of bores	Allocation (m^3/day)
Aupouri	50	500	12,743
Coopers/Cable	7	47	617
Taipa	3	53	135
Russell	10	78	199
Kaikohe	7	41	1,476
Matarau	3	32	114
Other small coastal aquifers	17	278	268
Glenbervie	19	60	778
Three Mile Bush	12	93	1,050
Maunu	31	182	3,120
Maungakaramea	10	29	738
Ruawai	5	165	990
Mangawhai	15	64	710
Tara	5	11	612
Outside "at risk" aquifers	85	2114	26,052
Total	**279**	**3747**	**49,602**
Increase since 2002 SOE report	56	946	12,820

Many existing bores have not been registered with the NRC. Prior to 1999 bore logs were submitted to the Council on an informal basis. Recent surveys in coastal aquifers indicate only a small number of existing bores are actually registered with the Council.

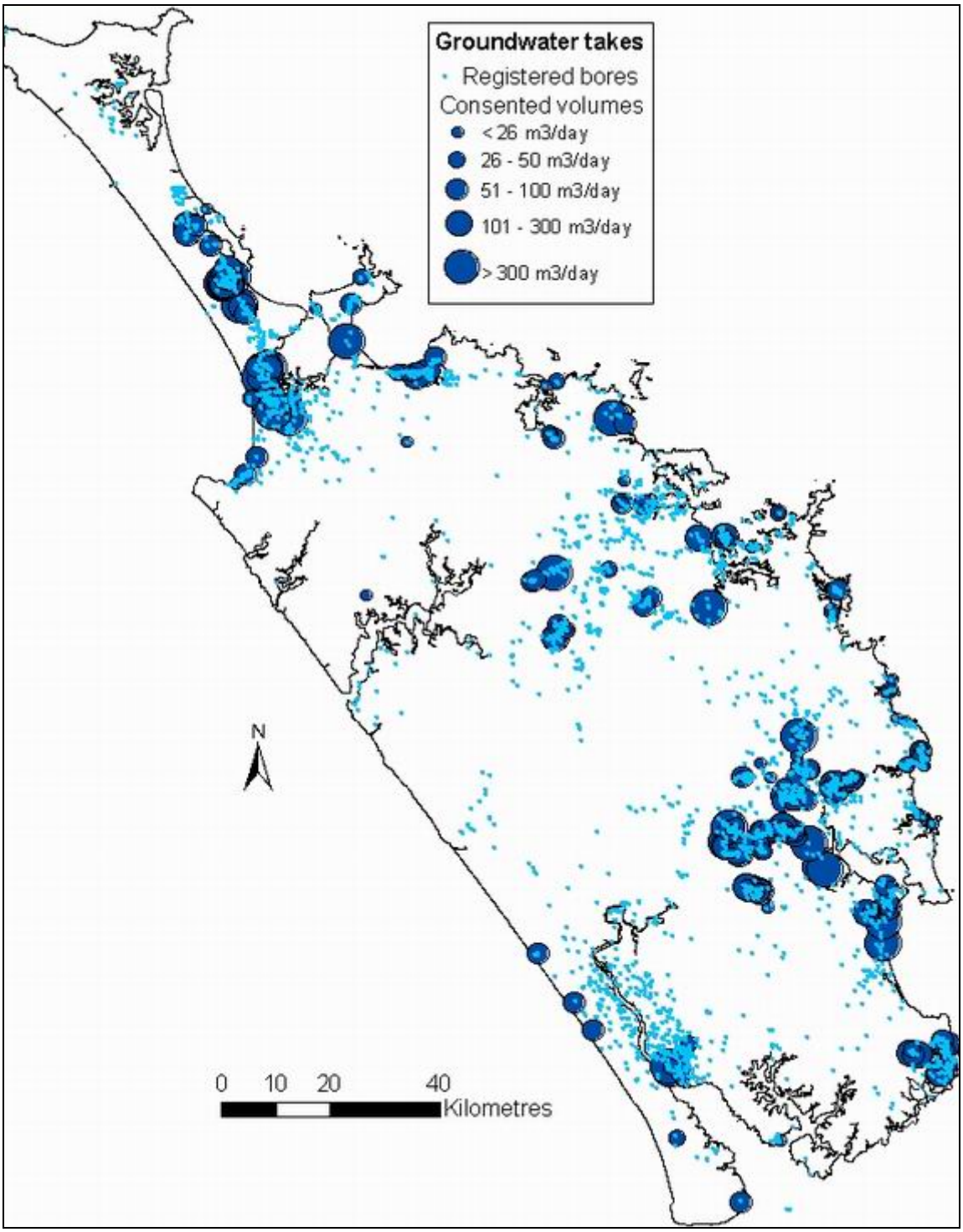
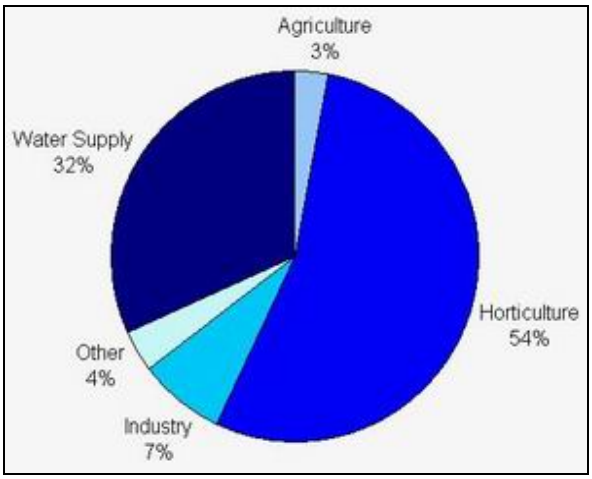


Figure 1: Registered bores and the volume allocated (m^3/day) by groundwater take consents.

Seven percent of consents granted are for the taking of groundwater for industry as shown in figure 2 (below left). However, the volume actually allocated for industrial use equates to 37 percent of the total volume of groundwater allocated as shown in figure 3 (below right). Takes for industry are not always associated with water use as they may also relate to ground dewatering to enable earthworks. The majority of the industrial groundwater takes are outside the principal “at risk” aquifers.



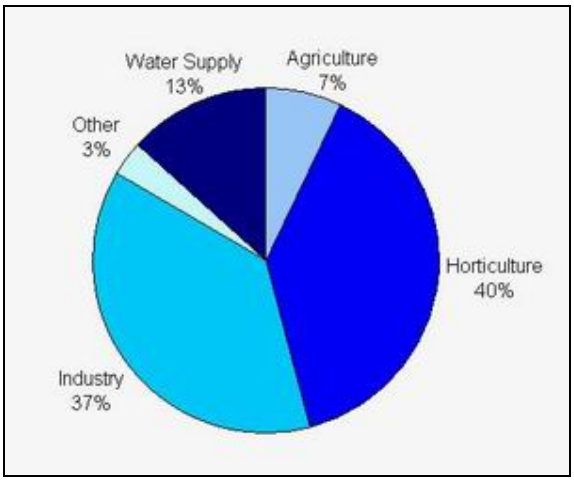


Figure 2: Percentage of groundwater take consents categorised by their use (left). Figure 3: volume allocated (m^3/day) by these consents (right).

Fifty-four percent of consents to take groundwater are for horticultural irrigation, which equates to approximately 40 percent of the total volume allocated. The distribution of the takes can identify areas where additional groundwater monitoring may be required to ensure the future allocation is sustainable.

Bore construction and maintenance

Poorly constructed bores can result in groundwater contamination. This can occur in a variety of ways including:

- Surface contaminants flowing down the bore into the aquifer due to inadequate grouting and sealing of the bore.
- Mixing of aquifers of different water quality.

A consent is now required prior to the installation or alteration of all bores in the region. Site inspections for all consented bores are carried out to ensure that the bore head is constructed in such a way as to prevent groundwater contamination.

Land use

Changes in land use can not only result in an increase in the quantity of water taken from an aquifer but can also influence the amount of rainfall infiltrating into the aquifer (recharge) and groundwater quality.

Development of forestry can result in interception of the rainfall via the tree roots and therefore reduces the recharge of an underlying aquifer. This can lead to a decline in the groundwater level and the amount of water flowing through the aquifer.

Land use changes into more intensive farming practices, including dairying and horticulture, can result in increased abstraction from aquifers. Intensifying land use can also potentially lead to groundwater contamination, due to the substances applied to the ground surface overlaying an aquifer.

Housing developments can also reduce the amount of recharge into an aquifer, as the rainfall is intercepted via paved areas and roofing and the water is diverted as surface stormwater flows.

The east coast of Northland has a large number of small coastal aquifers. Housing development in these areas can result in saltwater intrusion into the aquifer, due to

reduced recharge and increased use. Housing developments above aquifers can also increase the risk of groundwater contamination due to inappropriate or poorly maintained effluent disposal systems (septic tanks).

Groundwater quality pressures can also include discharges from farming activities, domestic wastewater, closed and existing landfills and industrial activities. Accidental spillages from underground storage tanks and road transported products may also result in contaminants entering groundwater.

Climate change

In August 2006, the National Institute of Water and Atmospheric Research Ltd (NIWA) carried out a comprehensive assessment on the impact of climate change and climate variability on Northland's water resources based on all available literature. The assessment considered natural climate variability in the Northland region and the potential effects of predicted climate changes over the next 50 to 80 years.

The main points of the assessment should be noted:

- All predictions suggest an increase in temperature, particularly during the winter;
- Overall annual rainfall may not change, however, rainfall trends for the next 30 to 80 years are for increased dry periods (drought and low flows) and increased high intensity rainfall events (floods); and
- The change in rainfall trends and temperature is likely to result in decreased recharge to groundwater resources, and increased potential for saltwater intrusion in coastal aquifers.

Additional work is required to assess the potential effects of increased drought frequencies and extreme rainfall events on surface water flows such as low flows and environmental responses.

11.3 What is the state of groundwater?

Monitoring and investigation is required to gain an understanding of the extent, quality and quantity of Northland's groundwater resources. This is in order to identify environmental issues and trends and promote informed environmental decision-making.

The state of the groundwater resource in Northland can be investigated by a number of methods. These include:

- Assessment of groundwater resource characteristics – drilling investigations and pump tests.
- Monitoring and assessing the quantity of groundwater resource, including monitoring taking and drilling activities, recharge and groundwater levels
- Monitoring water quality in a groundwater resource.
- Specific issue-based investigations.

Assessment of groundwater resource characteristics

Drilling investigations and pump testing has been carried out throughout Northland to identify the basic characteristics of the groundwater resources. A summary of the aquifer characteristics for the principal groundwater resources is shown in table 2 (below). Specific investigations and bore surveys have also been carried out for a number of aquifers to gain an understanding of sustainable yields, refer to section 11.4.

The location of the aquifers identified in the Regional Water and Soil Plan as "at risk" are shown in figure 4 (right). There are other groundwater resources throughout Northland, however, these are either relatively small or have not been identified as "at risk" due to low water demand or potential risk of saltwater intrusion or bore construction.

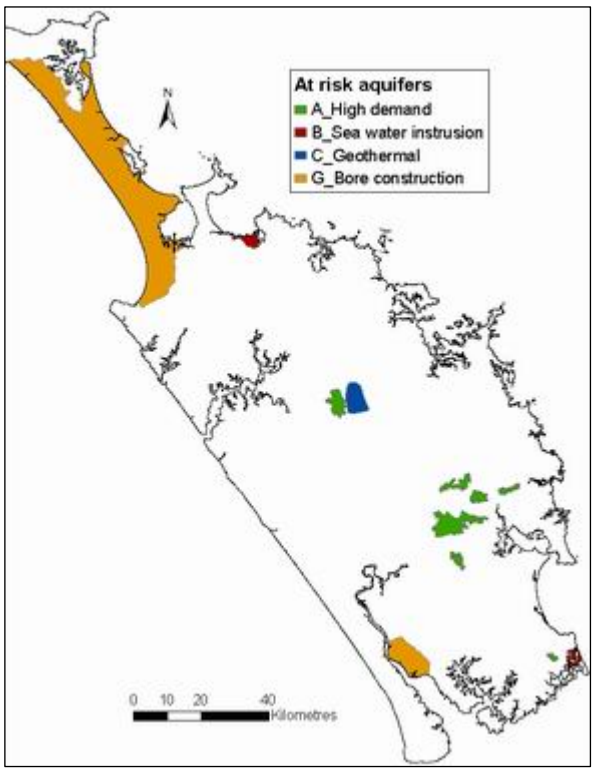


Figure 4: Aquifers identified as "at risk".

Table 2: Summary of the aquifer characteristics for principal aquifers in Northland.

Aquifer (zone)	Broad lithologic description	Status	Saturated thickness (m)	Transmissivity (m^2/day)	Storativity %
Aupouri (Lower Aupouri peninsula)	Predominantly quartz and feldspar sands overlying limestone/ sandstone/mudstone	Semi unconfined to confined	12-90	12-850	0.07-0.00002
Kerikeri/ Kaikohe	Basalt overlying cretaceous siltstone	Semi confined	50	70-170	0.020-0.072
Whangarei (Matarau)	Basalt flows, cones and dikes overlying sandstone/mudstone	Semi unconfined	8-20	108-3660	
Whangarei (Glenbervie)	Taheke Basalt overlying greywacke/ interbeded sandstone and mud stones	Semi confined	20-83	1 –36.78	0.002
Whangarei (Maunu)	Taheke Basalt overlying sandstone/mudstone	Semi unconfined	8-58	30 – 89	0.002-0.0006
Whangarei (Maungatapere)	Basalt with scoria overlying sandstone/mudstone	Semi confined	11-58	25-45	
Whangarei (Whatitiri)	Taheke basalt overlying sandstone	Confined	4-30	25-4000	0.00004-0.0003
Whangarei (Maungakaramea)	Basalt overlying Micaceous sandstone	Semi unconfined	45-55	3-400	0.03
Whangarei (Three mile bush)	Basalt with scoria overlying sandstone/mudstone	Semi unconfined	8-55	3 – 80	0.04
Mangawhai	Consolidated unweathered sands with quartz alluvial mud and gravel	Unconfined	8-50	5-440	0.00015-0.08
Taipa	Sand feldspathic with some quartz	Unconfined	6 to 7	90 – 150	0.085-0.2
Tara	Basalt flow with underlying sedimentary rocks	Semi unconfined	4-20	38-66	
Russell	Gravels overlying Waipapa group greywacke	Unconfined to semi unconfined		148-176	
Other shallow coastal aquifers	Predominantly sands/alluvial mud and gravel.	Unconfined			

Groundwater quantity

Groundwater recharge and discharge

The main source of recharge for the aquifers in the region is rainfall. Lake water loss has been identified as a minor source of groundwater recharge in some areas of Northland (e.g. Pakaraka and Aupouri).

Groundwater recharge tends to occur in winter months due to higher seasonal rainfall and decreased evapotranspiration. Generally drier summer conditions has minimal effect on groundwater levels, but drier than normal winter rainfall conditions result in reduced groundwater recharge and low groundwater levels at the start of the following summer.

Northland's highly variable geology has a major influence on surface water flow regimes and degree of groundwater recharge. In permeable unconfined sand aquifers, a high percentage of rainfall infiltrates quickly into the ground recharging the groundwater. In these areas there is minimal rainfall runoff contributing to stream flow. On the Aupouri Peninsula, the sand aquifer contributes little to stream baseflow as the groundwater level is typically below the stream bed level. The sand aquifers predominantly discharge at or near the coast.

The basalt aquifers in Northland generally have relatively rapid infiltration due to the fractured nature of the geology, and the existence of scoria cones. The predominant discharge from the basalt aquifers is spring flow originating on the edge of the basalt fields. This type of aquifer has considerable storage and the spring flow is generally maintained during dry periods. Spring flow is a major contribution to stream baseflow in the basalt areas.

Catchments with a significant component of relatively low permeability greywacke sediment allow less infiltration of rainfall and have relatively low aquifer storage volumes. Stream flows in these catchments tend to recede quickly during dry summer periods.

Groundwater level monitoring

Groundwater level is an important indicator for groundwater quantity. The groundwater level at different sites can vary significantly over time and seasons. The main influences on groundwater levels are the recharge of the aquifer, groundwater abstraction and the discharge from the aquifer to surface waters.

Decreases in groundwater levels can occur as a result of natural climatic conditions, changes in land use, or as a result of over abstraction.

There are currently 85 groundwater level sites monitored throughout Northland, as shown in figure 5 (right).

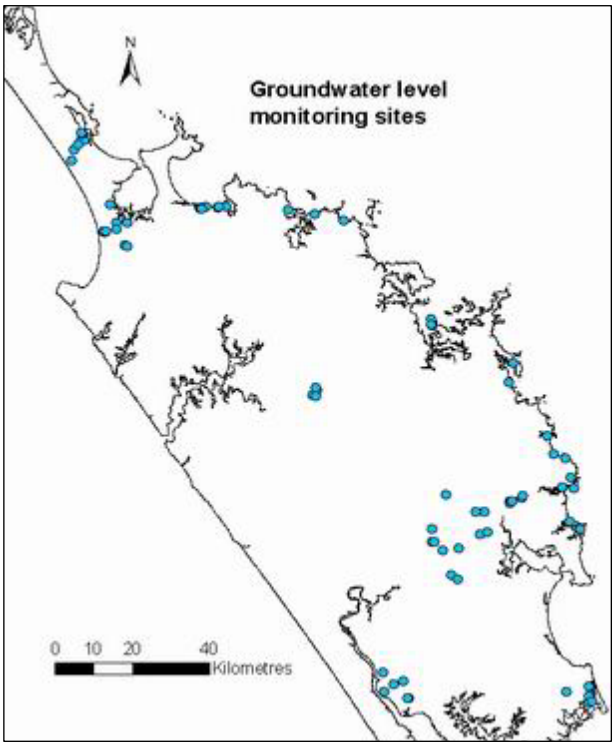


Figure 5: Groundwater level monitoring sites.

General groundwater level trends in aquifer systems

Kaikohe and Whangarei basalts

Due to the fast infiltration of rainfall through fractured basalt, groundwater levels in basalt aquifers increase rapidly in early winter, in response to winter rains. The groundwater levels typically peak in the early summer and decline to their lowest level in late summer.

The Whangarei Basalts groundwater levels peaked in 1989 and 2000, and were at their lowest during 1992, 1994 and 2005. The seasonal variations in groundwater levels in the Whangarei Basalt are a direct result of the rainfall variations. Less than average winter rainfall occurred during the winter months in 2004 and 2005.

The groundwater levels in the Whangarei Basalts measured at Puriri Park, Maunu, varies from the lowest recorded level of 12.8 metres below ground level (mbgl) to 8.3 mbgl, as shown in figure 6 (below).

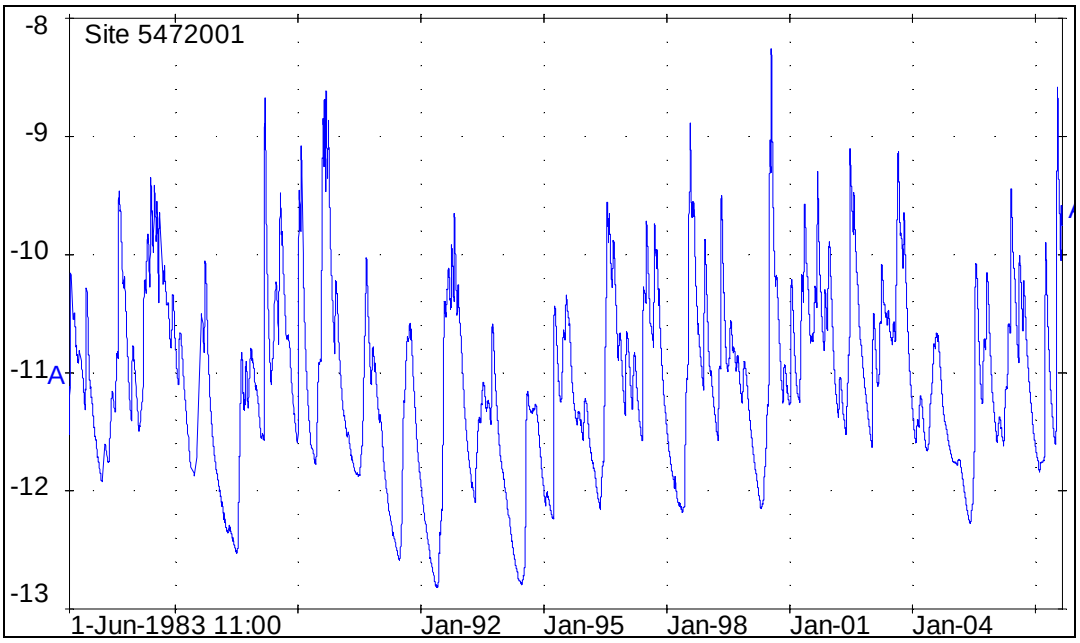


Figure 6: Groundwater level (metres below groundwater level) at Puriri Park site, Maunu.

Several groundwater level monitoring sites in the Whangarei Basalts also show the influence of pumping of neighbouring bores. This indicates that the Whangarei Basalt aquifer recovers reasonably quickly after a rainfall event, or when pumping has ceased.

Groundwater level in the Kaikohe Basalt Aquifer (with the exception of the Monument Hill site) has a seasonal trend of lower groundwater levels in the late summer to early autumn and higher groundwater levels in the winter and early spring. The seasonal fluctuation in groundwater level in the Kaikohe Basalt at State Highway 12 ranges from approximately 4.0 mbgl to 8.9 mbgl.

The groundwater level monitoring results at the Monument Hill site do not show the same seasonal pattern as other sites monitored in the Kaikohe Basalt. The groundwater level in the Kaikohe Hill generally peaks in December with the minimum level recorded around June. The groundwater level at Monument Hill has varied from 49.0 mbgl to 59.6 mbgl. This variation in groundwater level and the differing seasonal trend at Monument Hill is likely to be a direct result of groundwater abstraction from the site for the Kaikohe public water supply.

Mangawhai sand aquifer

The Mangawhai aquifer has a seasonal trend of lower groundwater levels in the late autumn (May, June and July) and higher groundwater water levels in the spring (October and November). The highest and lowest groundwater levels at Mangawhai Medical Centre are 3.5 mbgl and 6.6 mbgl, respectively.

A general decrease in the groundwater levels at the site occurred from 1990 to 1995 due to below average rainfall, particularly in the summer months. A recovery in groundwater level occurred from 1995 to 1999 due to an increase in rainfall during this period.

Aupouri sand aquifer

Groundwater levels in Hukatere forest area show fewer seasonal fluctuations than in the non-forested areas on the Aupouri Peninsula.

Groundwater levels peaked in 1989 and declined steadily until 1998, when they increased dramatically as shown in figure 7 (below). The groundwater levels are now close to the 1989 level. The period 1991 to 1994 was a period of intense El Nino weather conditions that caused dry weather conditions for much of the Northland region.

The variation in the groundwater levels in forested areas and non-forested areas, and the decline in the groundwater level until 1998 suggests the afforestation in the area has had a noticeable effect on the groundwater levels and recharge into the aquifer.

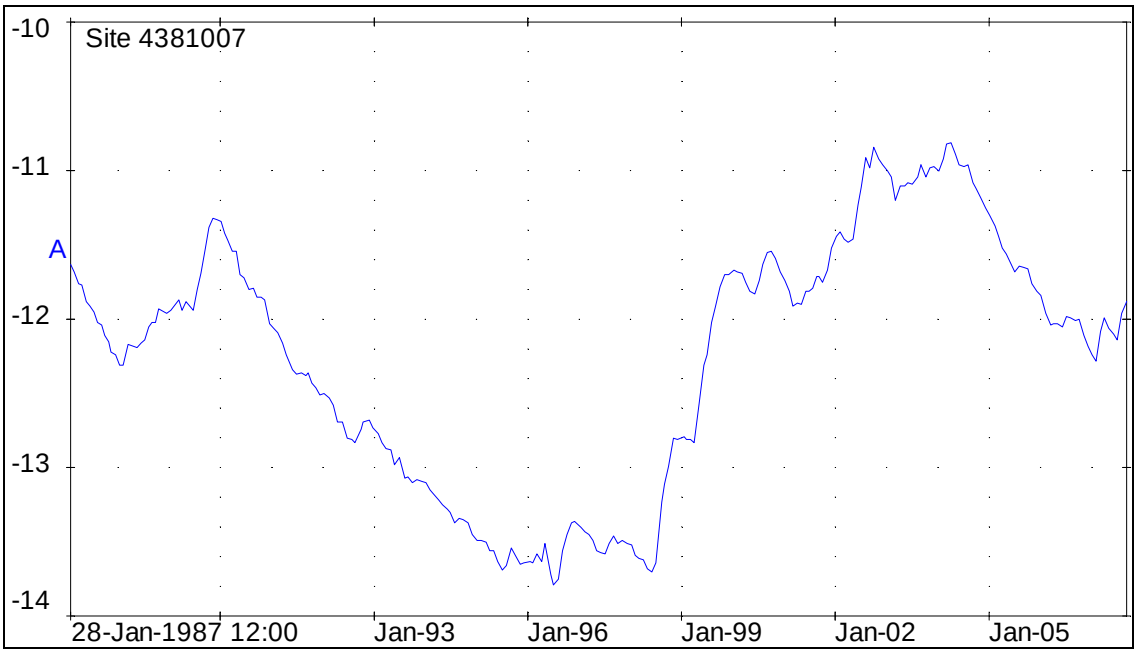


Figure 7: Groundwater level (metres below groundwater level) at Hukatere Forest site, Houhora.

Groundwater quality

The usefulness of groundwater is limited by its quality. The suitability of groundwater for drinking and other uses can be assessed through monitoring for key indicators. These indicators include:

- General parameters such as electrical conductivity, pH, alkalinity.
- Major cations such as calcium, magnesium, sodium, potassium, iron, and manganese.
- Major anions such as chloride, sulphate, nitrate, and phosphorus.
- Microbiological indicators such as *Escherichia coli.*
- Biocides including pesticides, herbicides and insecticides.

Generally when a groundwater system is contaminated as a result of human activities it is more costly and complex to clean up when compared to surface water contamination. It is therefore important to prevent contaminants entering aquifers.

Northland Regional Council monitors 32 groundwater sites as shown in figure 8 (right) at three-monthly intervals for the key indicators identified above with the exception of biocides. These sites are all listed in table 9 in Appendix A with information about each site.

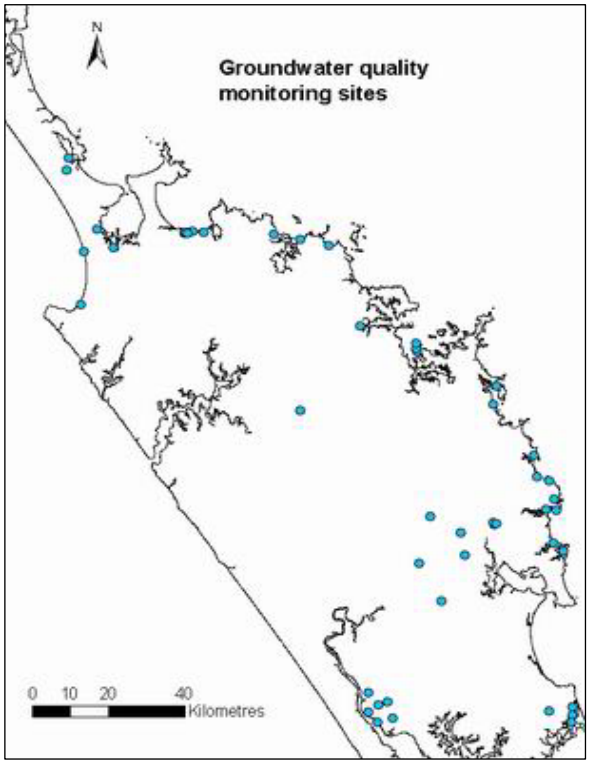


Figure 8: Groundwater quality monitoring sites

Groundwater quality at the majority of the sites monitored meets the *Drinking Water Standards for New Zealand 2005* (DWSNZ) (MoH 2005) for the majority of indicators except microbiological, iron, manganese and chloride. Table 3 (below) shows the limits for biological, iron, manganese and chloride.

Table 3: Drinking water standards for New Zealand (MoH 2005).

Indicator	Maximum Acceptable Value (MAV) of health significance	Guideline value for aesthetic determinants	Comment
E. coli	Less than 1 per 100 mL		
Iron		0.2 mg/L	Staining of laundry and sanitary ware.
Manganese	0.4 mg/L	0.04 mg/L	Staining of Laundry
		0.10 mg/L	Taste threshold
Chloride		250 mg/L	Taste threshold and corrosion

The hydrochemistry of Northland's groundwater resources is variable and reflects the aquifer geology from which the water is drawn. The median for all data for each site monitored is shown in table 12 in Appendix B.

Microbiological indicator (E. coli)

E. coli is used as an indicator of contamination of groundwater by faecal material. The drinking water maximum acceptable value (MAV) for *E. coli* is less than 1, so a positive sample indicates non-compliance with the standard.

Sources of *E.coli* in groundwater include effluent disposal and agricultural land use activities such as dairying, livestock and piggeries. Soil can act as a barrier and reduce the risk of microbial contamination of groundwater. However, direct contamination can occur due to poorly constructed bores and inappropriate or poorly maintained effluent disposal systems.

The highest percentage of non-compliance with the drinking water standards occurs in many of the coastal areas where small communities rely on septic tanks for sewage disposal and in three of the volcanic aquifers: Maungakaramea, Maunu and Ruatangata, as shown in figure 9 (below).

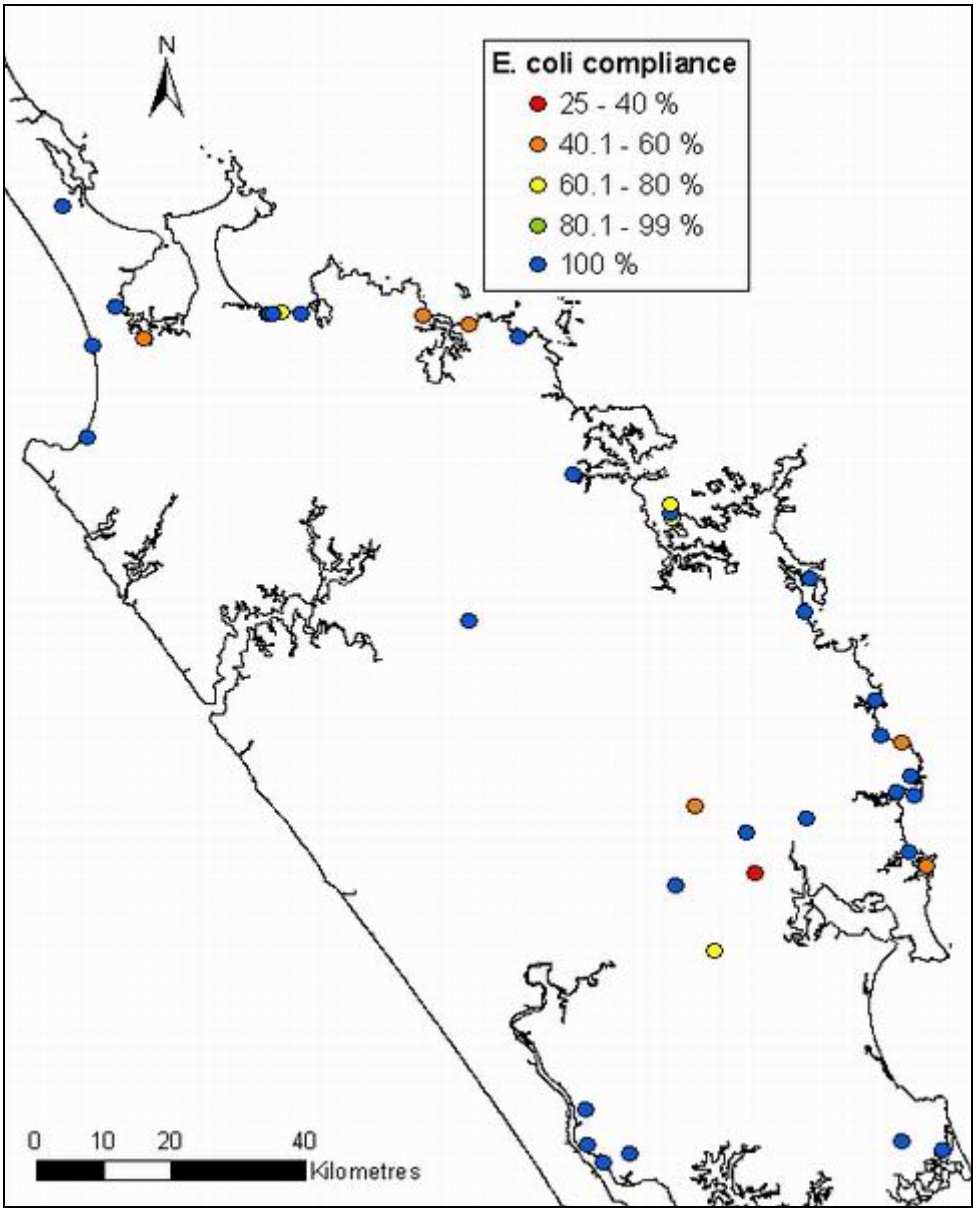


Figure 9: Percentage of samples that comply with the *E. coli* drinking water standard for monitoring record for all groundwater quality sites.

Iron and manganese

Iron and manganese occurs naturally in groundwater depending on the geology. The drinking water standards for New Zealand (MoH 2005) sets out the guideline values for iron and manganese for aesthetic purposes, and also the MAV for health purposes for manganese, as shown in table 3 (above).

Figure 10 (right) shows whether the median iron concentration for each site is compliant with the 0.2 mg/L drinking water guideline set for aesthetic purposes. The majority of sites that exceed this guideline are fed from sand and gravel aquifers.

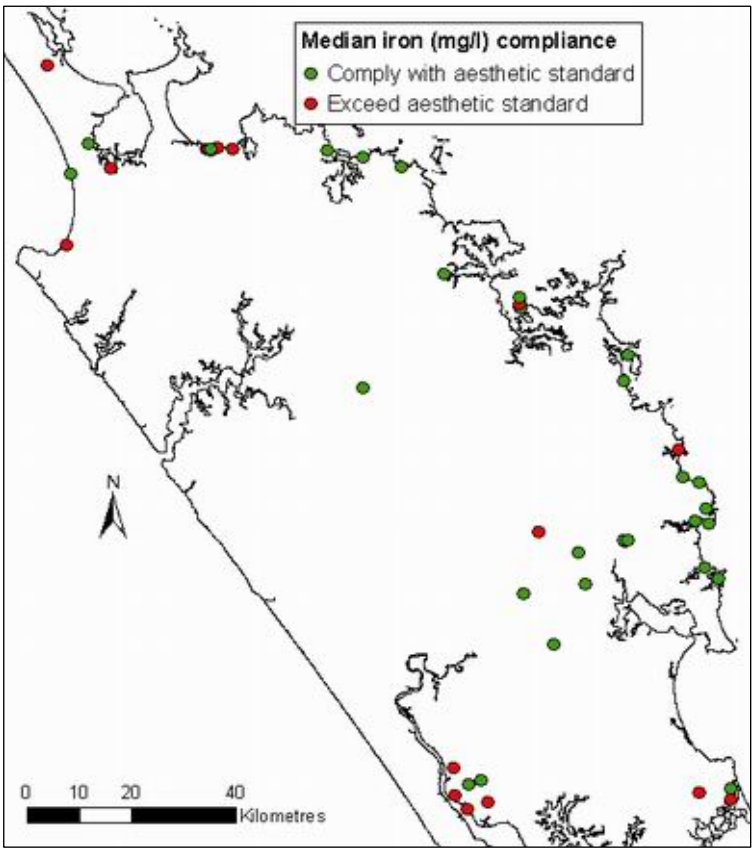


Figure 10: Compliance of median iron (mg/L) with standards

Figure 11 (right) shows whether the median manganese concentration for each site is compliant with the drinking water standards for aesthetic purposes and the MAV for health purposes. The sites that exceed both standards are fed from sand aquifers.

Excessive iron and manganese concentrations in groundwater gives water a rusty brown appearance, and can result in staining, irrigation system blockages and a general bad taste.

Elevated iron and manganese concentrations are derived from water–rock interaction, and there are few land uses that would contribute soluble iron and manganese.

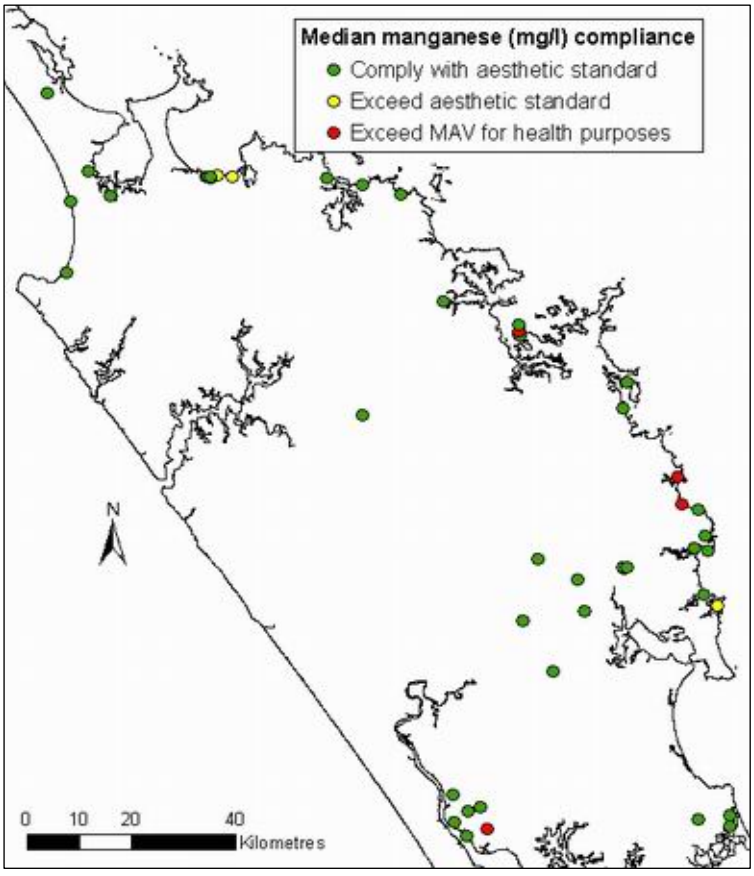


Figure 11: Compliance of median manganese (mg/L) with standards

Saltwater intrusion

Monitoring of groundwater level, chloride and electrical conductivity is undertaken to check for seawater intrusion. The median chloride for each site is shown in figure 12 (right).

The majority of coastal bores monitored have higher electrical conductivity, chloride and sodium levels than inland basalt aquifers, due to leaching from marine sediments. There is potential for seawater intrusion of coastal aquifers (such as Taipa, Ngunguru and Russell) during summer when groundwater levels decline due to increased abstraction and/or decreased recharge caused by below average rainfall.

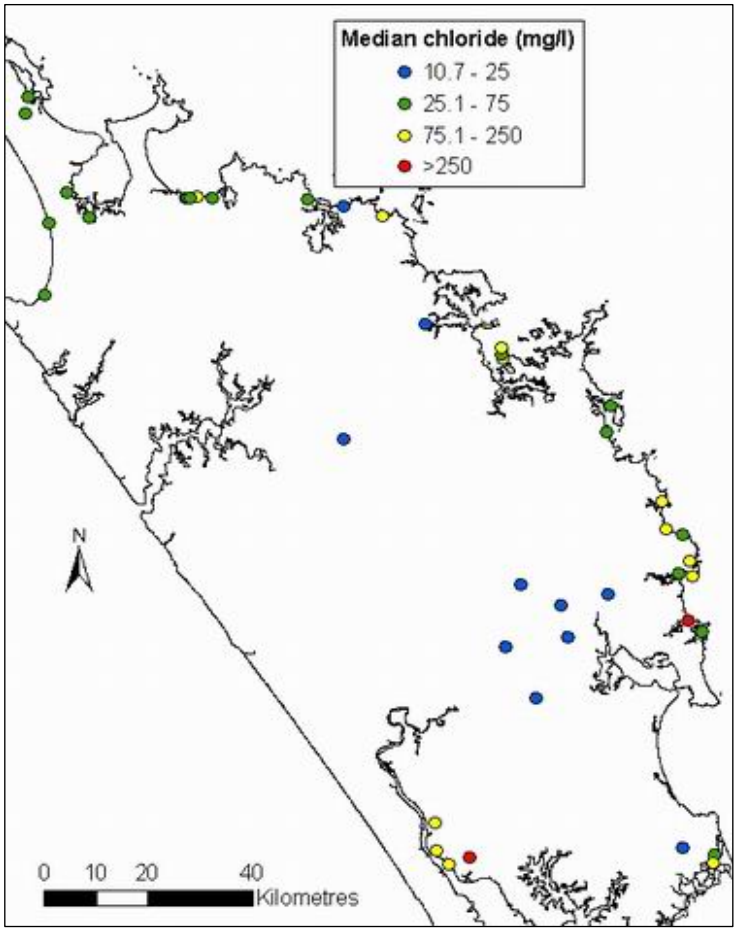


Figure 12: Median chloride (mg/L)

Nitrate

The median nitrate-nitrogen concentrations in all aquifers sampled are below the DWSNZ of 11.3 mg/L NO_3-N, as shown in figure 13 (right).

Nitrate-nitrogen concentrations in several of the basalt aquifers fluctuate seasonally. Higher nitrate concentrations occur during winter when higher seasonal rainfall causes leaching of nitrogen to the water table. Although below the DWSNZ, nitrate levels are elevated in Maungakaramea, Whatitiri and Ruatangata basalt aquifers. The primary sources of nitrogen in these aquifers are likely to be animal waste, the discharge of dairy effluent to land and fertiliser use.

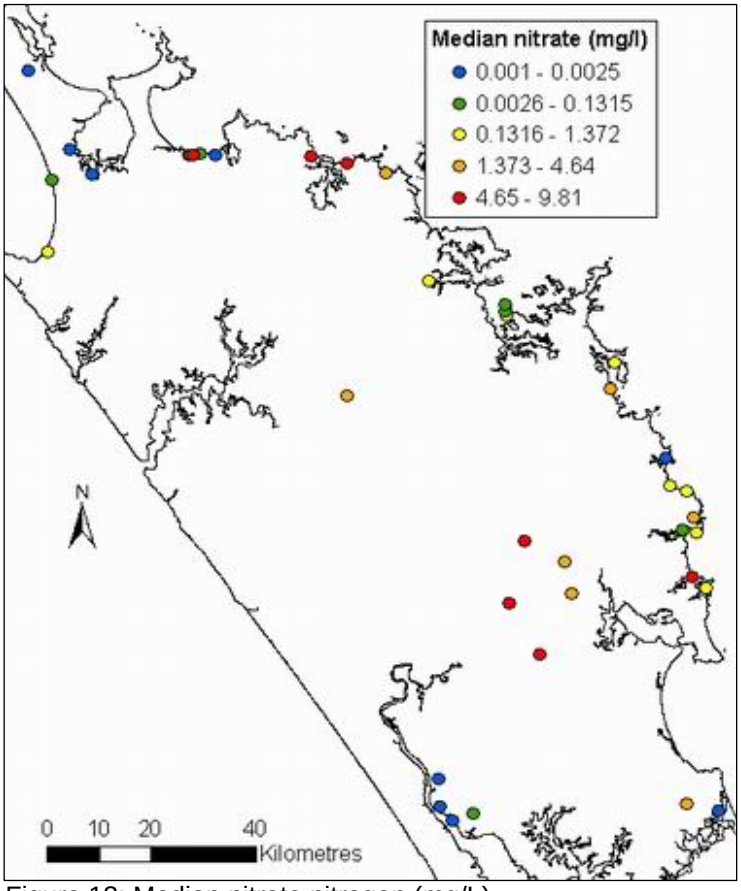


Figure 13: Median nitrate nitrogen (mg/L)

The absence of organic material in these basalt aquifers means that nitrates are likely to be persistent as there is little potential for reduction through denitrification. Recent age analysis indicates that these aquifers have a mean resident age of around 45 years. This suggests that the nitrates present in the groundwater may be a result of historic land use activities that occurred around 45 years ago. Further age distribution analysis of groundwater is required to assess the risk of nitrate levels in the aquifers exceeding drinking water standards in the future.

Elevated levels of nitrate nitrogen also occur in several coastal aquifers, including Pataua North, Taipa and Tauranga Bay. The source of nitrogen in these areas is likely to be on-site effluent disposal.

General groundwater quality trends

Categorisation of sites

Daughney and Reeves (2005 and 2006) carried out multivariate analysis on selected parameters from groundwater sites throughout New Zealand. The same approach was applied to all groundwater data from Northland from 1996 to 2006 as part of a national analysis (MfE 2007). The aim of this analysis was to determine distinctive groups of groundwater quality characteristics (hierarchical facies) for aquifers throughout New Zealand. The result of this analysis is that each site is assigned two categories, one based on the medians and the other based on trend analysis.

The medians for all sites for all parameters from 1996 to 2006 are available in Appendix B and the results of the trend analysis are available in Appendix C. Note results were not calculated when there was less than three results for a parameter at a site. The seasonal Mann Kendall test was used to detect trends at a 95% confidence interval. For more information on data analysis techniques see Daughney and Reeves (2005 and 2006) and MfE 2007.

The categorisation results for Northland's 32 groundwater monitoring network sites and the following aquifer investigations, Ruawai, Russell and Taipa, are presented in Appendix D. A summary of these results is presented below.

Median category

The groundwater quality results were used to categorise sites into two main clusters, and then sub-clusters. Those sites that are within Cluster 1 can be described as surface dominated and those within Cluster 2 subsurface dominated.

Based on median values of selected water quality parameters (Daughney and Reeves 2005) of 46 Northland sites, 21 are from groundwater showing surface-dominated characteristics and suggests the groundwater is moderately to highly impacted by humans (clusters 1A-1 and 1A-2). Four sites show surface-dominated characteristics with little human impact (clusters 1B-1 and 1B-2) and 21 show subsurface-dominated characteristics (clusters 2A and 2B), as shown in table 4 (below).

It is important to note that this cluster analysis does not have a separate category for aquifers with water quality that is influenced by saltwater. Therefore Northland's coastal aquifers tend to fall into the cluster described as moderately to highly impacted by humans (clusters 1A-1 and 1A-2).

Table 4: Sites split into categories (hydrochemical facies) based on median values of selected water quality parameters (adapted from Daughney and Reeves 2005).

Threshold 1 cluster	1				2	
Category description	Surface dominated Oxidised Unconfined aquifer Low to moderate total dissolved solids (TDS) Ca-Na-Mg-HCO_3 water				Groundwater dominated Reduced Higher TDS Ca-Na-HCO_3 water	
Threshold 2 cluster	1A		1B			
Category description	Signs of human impact (HI) Rainfall recharge? Moderate TDS Na-Ca-Mg-HCO_3–Cl water		Little HI River recharge? Low TDS Ca-Na-HCO_3 water			
Threshold 3 cluster	1A-1	1A-2	1B-1	1B-2	2A	2B
Category description	Moderate HI Carbonate/clastic aquifer Ca-Na-Mg-HCO_3-Cl water	Most HI Volcaniclastic or volcanic aquifer Ca-Na-Mg-HCO_3-Cl water	Carbonate or clastic aquifer Ca- HCO_3 water	Volcaniclastic or volcanic aquifer Ca-Na-Mg-HCO_3-Cl water	Moderately reduced Majority unconfined High TDS	Highly reduced Majority confined Highest TDS
Number of sites	7	14	0	4	17	4

Trend category

Based on Daughney and Reeves' (2006) trend analysis and clustering techniques on selected water quality parameters of 45 Northland sites, eight are improving (dilution cluster), seven are deteriorating (impact cluster) and seven sites were clustered as pristine, as shown in table 5 (below). One third (15 sites) show slow changes in groundwater quality that probably indicates natural water-rock interaction.

Table 5: Sites split into categories based on trend analysis of selected water quality parameters (adapted from Daughney and Reeves 2006).

Cluster	Temporal pattern	Possible causes	Number of sites
Dilution (D)	Rapid decrease in Na, Ca, HCO_3 and/or Cl over time	Change in pumping regime of hydrogeologic conditions	8
Impact (I)	Increases in Ca, Cl, K, Mg, Na, NO_3-N and/or SO_4 over time	Increasing proportion of recharge from rainfall relative to rivers over time, increasing human/agricultural impact in recharge area	7
Silica (Si)	Rapid increase in SiO_2 without accompanying changes in other analytes at a similar rate	Unknown at this stage	8
Pristine (P)	Decreases in K, Mg and/or NO_3-N over time, often with accompanying decreases in Ca, Na, Cl and/or SO_4	Increasing proportion of recharge from rivers relative to rainfall over time, decreasing human/agricultural impact in recharge area	7
Water-rock (WR)	No or only slow changes in most analytes over time	Natural water-rock interaction	15

Other monitoring

Age testing

Groundwater is generally a mixture of water of different ages due to the mixing processes that occurs within an aquifer. The age of groundwater is expressed as “mean residence time” and is not a discrete age but a distribution of ages based on these mixing processes. Understanding the mean residence time and the age distribution is important for the management of groundwater resources. For example, if the mean age of groundwater in a particular aquifer is found to be approximately 50 years with limited age distribution, then water quality results would indicate the effects of use 50 years ago and will not indicate the influence of any recent land use change.

During 2005-06 five water samples were collected and analysed to determine the average age of the groundwater (mean residence time) delivered from bores in the Northland region. Samples were collected from groundwater quality monitoring bores at Maungakaramea, Mangawhai, Whatitiri, Three Mile Bush and Matapouri and analysed for tritium, CFC and SF6 isotopes.

The initial age estimates are provided in table 6 (below). However, further analysis is required to ensure accurate interpretation of the results, and also provide an understanding of the distribution of age and mixing processes within an aquifer. The bores will be resampled in approximately five years.

Table 6: Mean residence time for groundwater in five Northland bores.

Site of bore	Initial mean residence time estimate (years)
Mangawhai	3 ± 3
Whatitiri	3 or 45 (likely to be 45)
Maungakaramea	45 ± 3
Three Mile Bush	50 ± 3
Matapouri	40 ± 3

The relatively old age recorded in the Matapouri bore may indicate the sand aquifer is recharged by old water upwelling from the surrounding greywacke. The analysis for the Whatitiri sample indicated two possible ages (3 or 45). However due to the depth and geology of the Whatitiri bore, the mean residence time is likely to be around 45 years. Additional sampling and analysis is required to confirm this.

Pesticides surveys of groundwater

The Institute of Environmental Science and Research (ESR) carried out national surveys of pesticides in groundwater in 1994, 1998, 2002 and 2006. In 1994 samples were collected from groundwater bores in five areas with horticultural land use, as shown in table 7 (below). No pesticides were detected.

Table 7: Pesticide results for Northland sites surveyed in 1994, 1998, 2002 and 2006.

Year	1994	1998	2002	2006
Sites sampled	Houhora Kaitaia Kaikohe Whangarei Tara	Ahipara Taipa Kaikohe Whangarei Tara	Ahipara Taipa Kaikohe Glenbervie Tara	Aupouri Taipa Glenbervie Maunu Maungakaramea Tara
Pesticides detected at	No sites	Only at Tara (well below MAV)	No sites	No sites

In 1998 samples were taken from five groundwater bores and analysed for 42 pesticides at a significantly lower detection limit than the 1994 survey. Tara was the only site at which pesticides were detected. Terbuthylazine was present at a concentration of 0.28 mg/m^3, well below the maximum acceptable value for drinking water of 8.0 mg/m^3 (Ministry of Health, 2000).

In 2002 no pesticides were detected in the five bores sampled. In October 2006 samples from six bores were analysed for acidic herbicides and a suite of organochlorine, organophosphorus and organonitrogen pesticides. No pesticides were detected in any of the samples.

Pesticide movement through soils

Landcare Research, ESR and GNS collaborated on a study examining contaminant movement through soils (Close et al. 2004). The aim of the study was to assess the contamination risk to groundwater from the application of pesticides to different soil types around New Zealand.

A study site on basalt soils at Maungatapere near Whangarei was set up in November 1999. Selected pesticides were applied to the site, and both soil and soil water samples were taken.

The study found evidence of preferential flow at the Northland site, which is consistent with the highly structured soil profile and intense rainfall that occurred at the site following pesticide application. The results indicated that pesticides are much more mobile in Northland Kiripaka soils than would be expected from literature values. This needs to be considered before pesticide application in areas with Kiripaka soils above aquifer systems.

Groundwater and surface water interaction

In many cases throughout Northland, groundwater emerges as springs and contributes to the flows of many streams and rivers in the region. Low groundwater levels in these areas can result in decreased flows in the streams and rivers particularly during periods of dry weather. Similarly poor groundwater quality can result in adverse effects on surface waters.

Orifice weir used for pump testing.

Surface water catchments surrounding basalt areas, such as Whangarei, Kaikohe and Kerikeri, are predominantly spring fed. Seepage from lakes and rivers can also recharge groundwater; however, surface water recharge in Northland is relatively minor compared to rainfall recharge.

Specific groundwater investigations

A number of investigations have been carried out as a result of specific issues arising in aquifers. These investigations include hydrogeology assessments of the Three Mile Bush, Glenbervie, Maungakaramea, Kaikohe, Aupouri, Coopers Beach and Mangawhai aquifers and additional groundwater quality investigations in the Ruawai, Russell and Taipa aquifers. The groundwater quality results from these investigations are presented in Appendices A to D.

Three Mile Bush aquifer investigation

The Three Mile Bush basalt aquifer is located directly west of Kamo, Whangarei. The study area comprises a 13.2 square kilometre basalt plateau at an elevation of approximately 230 metres above mean sea level. Groundwater from this aquifer is predominately used for horticultural irrigation, stock water and domestic water supplies.

The main issues potentially affecting groundwater quality and quantity in the Three Mile Bush area are:

- Groundwater abstraction.
- Bore construction and location.
- Land use change.

The study provided an assessment of the groundwater resources in the area, with the following recommendations:

- Further refinement of sustainable yield in the event of an increase in groundwater demand.
- Groundwater level survey to increase knowledge of groundwater flow.
- Increase in ongoing groundwater level monitoring in the northern part of the aquifer.
- Concurrent monitoring of spring and stream flow at a number of locations within the study area.
- Soil infiltration tests carried out to improve understanding of the groundwater recharge dynamics.
- Groundwater quality monitoring in other bores across the aquifer to identify potential groundwater quality issues.

Additional water level monitoring will commence in the northern part of the aquifer and the existing monitoring of groundwater level and quality, including anions, cations and bacteria, in the Three Mile Bush basalt aquifer will continue in the future.

For more information refer to the full report available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Research-and-reports/Groundwater/Three-Mile-Bush/

Glenbervie aquifer investigation

The main findings of the preliminary hydrogeological investigation for the Glenbervie groundwater resource (SKM 2005) completed in February 2005 are summarised below.

The Glenbervie basalt aquifer is located approximately three kilometres east of Kamo and was formed as a result of volcanic activity from two eruptive vents, Pukepoto and

Puketotara scoria cones. The total study area is 8.7 km^2. Groundwater from this aquifer is predominately used for horticultural irrigation and as a supplementary domestic supply.

The base of the aquifer varies from 31 to 107 m below ground level. The total annual average rainfall recharge to the aquifer is estimated to be between 4,227 m^3/d and 8,684 m^3/d. The aquifer discharges into springs and surrounding streams. The volume of water discharging from the aquifer has been estimated to be approximately 5,400 m^3/d. However this estimate is based on limited information. Groundwater generally flows from the higher elevation ground near the Puketotara and Pukepoto scoria cones towards the basalt boundary.

Groundwater yields in bores throughout the aquifer are highly variable depending on the extent of fractures and weathered basalts intercepted by bores. Consented allocation is 704 m^3/d and it is estimated that the total allocation (including permitted abstraction) could be up to 789 m^3/d.

Bores screened close to or through the overlying soil and weathered rock may experience poor water quality.

Based on the information available the sustainable yield for the aquifer is estimated to be in the range of 1,680 m^3/d to 3,480 m^3/d. This suggests that further groundwater can be allocated from the aquifer. However, it is important to note that any new applications to take groundwater will be assessed on a case-by-case basis, as abstraction in close proximity to springs and streams can also potentially affect surface water users.

The report makes a number of recommendations including:

- Undertake concurrent monitoring of spring and stream flow at a number of locations within the study area.
- Soil infiltration tests are carried out to improve understanding of the groundwater recharge dynamics.

For more information refer to the full report available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Research-and-reports/Groundwater/Glenbervie/

Maungakaramea groundwater resources

The Maungakaramea basalt aquifer is located approximately 14 km southwest of Whangarei. The total study area is approximately 10.4 km^2. Most of the study area is relatively flat, at an elevation of approximately 140 metres above mean sea level. The centre of the aquifer is a scoria cone, forming a “horseshoe” hill with an elevation of 225 metres above sea level.

Groundwater is generally used for horticultural irrigation, stock drinking, public and domestic water supply. The main potential groundwater issues are:

- Groundwater abstraction including effects on spring and stream flow.
- Land use change.

Based on the findings from the study, the following recommendations were made:

- Survey groundwater bores and springs to obtain information on flow direction, recharge and sustainable yield estimates.
- Increase groundwater quality monitoring to evaluate the existing water quality and long-term trends.
- Carry out soil infiltration tests to improve understanding of the groundwater recharge.
- Increase groundwater level monitoring (to daily).

Monitoring of groundwater level and quality, including anions, cations and bacteria, in the Maungakaramea area will continue in the future. In the event of an increase in groundwater demand in the future, further of the above recommendations will be implemented.

For more information refer to the full report available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Research-and-reports/Groundwater/Maungakaramea/

Kaikohe aquifer investigation

A water resource report for Kaikohe was prepared in 1992. Due to additional monitoring undertaken in the past 15 years, the aquifer has been reassessed in the hydrogeological investigation of the Kaikohe groundwater resource finalised in February 2007. The main findings are summarised below.

Groundwater from this aquifer is predominately used for public water supply, irrigation and stock and domestic requirements for the surrounding rural area.

A soil moisture water balance model (SMWBM) was used to determine surface water runoff, infiltration and groundwater recharge. Based on this modelling the sustainable yield for the Kaikohe scoria cone and the surrounding basalt was estimated to be approximately 360 m^3/d and 5,010 m^3/d, respectively. The total consented groundwater abstraction for the aquifer is 870 m^3/d. This suggests that further allocation can occur. However, abstractions from bores can affect nearby spring flows, so although the total allocation for the aquifer is less than the sustainable yield, individual consented allocation needs to be assessed on a site-specific basis.

The report makes a number of recommendations including:

- Future pump testing.
- Gaugings of springs and streams coinciding with groundwater levels.
- Bore and water survey to assess permitted takes.

Monitoring of groundwater level and quality, including anions, cations and bacterial, in the Kaikohe area will continue in the future.

For more information refer to the full report available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Research-and-reports/Groundwater/Kaikohe/

Aupouri aquifer investigation

A groundwater flow model was developed in 2000 for the Aupouri Aquifer following a noticeable decline in groundwater levels since 1990 at Northland Regional Council monitoring wells in this aquifer. The model was developed to assess sustainable yields from the aquifer.

Results of the model indicate that the aquifer is not over allocated. The observed decline in groundwater level was considered to be caused by periods of below average rainfall. The planting of *Pinus radiata* forest is also considered to have caused a reduction in groundwater recharge over some of the modelled area.

For more information refer to the full report available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Research-and-reports/Groundwater/Aupouri/

Coopers Beach, Cable Bay and Mangonui aquifer investigation

The main findings of the preliminary hydrogeological investigation for the Coopers Beach, Cable Bay and Mangonui groundwater resource (SKM 2005b) finalised in July 2005 are summarised below.

Cable Bay, Coopers Beach and Mangonui are small coastal townships located in Doubtless Bay, Northland. The basalt aquifer study area is approximately 17 km^2, encompassing these towns and extending inland to the top of Cable Bay Block Road. The predominant land use is residential near the coast and rural for the remainder.

Groundwater from this aquifer is predominately used for reticulated water supplies and private supplementary domestic supplies.

The bores in the area range from 11.5 to 155 m below ground level. The total annual average rainfall recharge to the aquifer is estimated to be between 3,214 m^3/d and 9,641 m^3/d. The aquifer discharges into springs and surrounding streams and the coast. The volume of water discharging from the aquifer has been estimated to be approximately 8,750 m^3/d. However this estimate is based on limited information. Groundwater generally flows in a northerly direction towards Doubtless Bay.

Groundwater yields in bores throughout the aquifer are highly variable depending on the extent of fractures and weathered basalts intercepted by bores. Consented allocation is 828 m^3/d and it is estimated that the total allocation (including permitted abstraction) could be up to 939 m^3/d.

Based on the information available the sustainable yield for the aquifer is estimated to be in the range of 1,280 m^3/d to 3,860 m^3/d. This suggests that further groundwater can be allocated from the aquifer. However, it is important to note that any new applications to take groundwater will be assessed on a case-by-case basis, as abstraction in close proximity to the foreshore has the potential to result in saltwater intrusions.

The report makes a number of recommendations including:

- Monitoring of groundwater levels and quality to assess the potential for seawater intrusions at Cable Bay, Coopers Beach and the Mangonui waterfront.
- Groundwater level monitoring further inland to assess seasonal variations and the effect of abstraction.
- Measurement of spring and stream flows to assess potential adverse effects of increased groundwater demand.

Monitoring of groundwater level and quality, including anions, cations and bacterial, in the Cable Bay/Coopers beach and Mangonui area will continue in the future.

For more information refer to the full report available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Research-and-reports/Groundwater/Coopers-Beach-Cable-Bay-Mangonui/

Mangawhai aquifer investigation

The main findings of the hydrogeological Investigation for the Mangawhai groundwater resource (SKM 2005c) finalised in August 2005 are summarised below.

Mangawhai Village and Mangawhai Heads are coastal townships located approximately 50 km south of Whangarei. This area, in particular Mangawhai Heads, is currently experiencing an enormous increase in subdivision. Groundwater in the area is used mainly as a supplementary domestic supply for many of the residences, and to a lesser extent for horticultural irrigation and stock drinking water.

The predominant surface geology of the study area is Waitemata sandstones and mudstones, overlain with clays (weathered Waitemata), sands or alluvium. The sands are located on the peninsula at Mangawhai Heads and around the sand spit, while the alluvium is located in the stream valleys. The main source of groundwater is from the sand and Waitemata formation. Groundwater yields for the sand aquifer range between 12 and 409 m^3/d, and 9 to 454 m^3/d from the Waitemata formation.

The study indicated elevated chlorides, boron, fluoride and lithium concentrations occur in some bores located at low elevations near Mangawhai Village and along the southern end of the estuary. It is likely that these bores intercept discrete fractures within the Northland Allochthon and Waitemata rocks, through which thermal upwelling may occur. It is possible that elevated concentrations occur in other bores throughout the study area that encounter these persistent fractures or high permeability zones, in particular near the Waipu Fault or around igneous intrusions. However, there is currently no groundwater quality data to verify this.

Due to the complex geology, the recharge and discharge estimates have a large degree of uncertainty. Further investigation is required in order to estimate the sustainable yield.

Based on the preliminary findings the following recommendations were made:

- A model based on dynamic estimates of groundwater recharge is recommended for a more accurate assessment of sustainable yield.
- A monitoring round in the Riverside Motor Camp bore that includes boron, fluoride and lithium is recommended to assess the source of saltwater.
- A saltwater intrusion and groundwater level monitoring bore be established in the sand aquifer.

Monitoring of groundwater level and quality, including anions, cations and bacterial, in the Mangawhai area will continue in the future.

For more information refer to the full report available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Research-and-reports/Groundwater/Mangawhai/

Russell aquifer investigation

The Russell aquifer is potentially at risk of saltwater intrusion from overuse and the effects of urbanisation and land use changes. A hydrogeological update on the aquifer was prepared in 2001. The main findings of this report suggest that the aquifer system is likely to be over allocated and the reticulation of sewage greatly reduces recharge into the groundwater system.

As a result of these findings, a numeric groundwater modelling exercise was undertaken to better understand recharge and discharge dynamics, the effects of reduced recharge and refinement of the sustainable yield. Although the modelling exercise estimates a high volume of water may be sustainably taken from the aquifer ($225m^3/d$), the exercise also suggests that the reticulation of wastewater is likely to increase the potential for saltwater intrusion during prolonged dry periods.

Several meetings were held with water users and, as a result of the investigations, telemetered monitoring equipment has been installed in bores near the Russell foreshore to provide real time data and a pre-warning of increased risk of saltwater intrusion for groundwater users in the area.

For more information refer to the full report available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Research-and-reports/Groundwater/Russell-Groundwater-Modelling-Report/

Ruawai aquifer investigations

The main findings of the Ruawai aquifer management zone bore survey and preliminary hydrogeology study finalised in December 2003 are summarised below.

The Ruawai plains are located approximately 26 kilometres south east of Dargaville. The plains consist of alternating layers of fine and coarse alluvium underlay with sedimentary rocks. The predominant land use is urban near the coast, and rural for the remainder.

Groundwater from this aquifer is predominately used for public water supply for the Ruawai township and stock and domestic requirements for the surrounding rural area.

A bore survey was carried out to obtain more accurate information on hydrogeology and water use within the study area. Thee main aquifer zones were identified:

- A recharge zone to a depth of 10-20 m (shallow aquifer).
- A lateral flow zone at depths of 20-40 m (intermediate aquifer).
- A zone of high groundwater pressure (artesian) at depths greater than 40 m (deeper aquifer).

The shallow aquifer is influenced by mixing of tidal water and is vulnerable to contamination from land use activities. The shallow groundwater is also linked to the surface water in drains and therefore may include surface water quality.

The deeper aquifer is relatively old water (>50 years). Water quality from this aquifer is generally good, and the potential for contamination from land use activities is considered to be low under the current demand. However, in the event the artesian pressure declines due to poorly maintained bores allowing water to run to waste, the risk of contamination increases.

The sustainable yield for the shallow and deeper aquifer were estimated to be in the order of 10,000 m^3/d and 27,000 m^3/d, respectively. The current groundwater abstraction from the Ruawai aquifer is estimated to be 1,200 m^3/d, which is significantly less than what is potentially available.

The report makes a number of recommendations including:

- Real time groundwater pressure monitoring.
- Investigate groundwater contamination on shallow groundwater and surface water interaction.
- Consider options to address issue of flowing artesian and uncapped bores.

Monitoring of groundwater level and quality, including anions, cations and bacterial, in the Ruawai area will continue in the future.

For more information refer to the full report available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Research-and-reports/Groundwater/Ruawai/

Awanui aquifer investigation

Awanui is located in the southern end of the Aupouri aquifer, just north of Kaitaia. The area has a large number of abandoned flowing artesian bores which discharge into the Awanui drainage network. Due to the potential cost of bore closure a modelling investigation has been undertaken to assess the effects of bore closure on the Aupouri aquifer.

The conclusions of this investigation are that bore closure will result in a quick increase in groundwater levels in the shell bed and sand aquifers in the Awanui area and sand dunes to the north west, minimum effects on surface flows and more water being available for efficient users. If groundwater allocation increases in the Awanui and Sweetwater area it is highly recommended that closure of flowing artesian bores be considered.

For more information refer to the full report available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Research-and-reports/Groundwater/Awanui/

Taipa aquifer investigation

Taipa is a small coastal settlement located on a sand spit in Doubtless Bay. A small aquifer exists in the sand spit. The aquifer has saltwater bodies on the northern and western boundaries. It has a small recharge area and is highly at risk from saline intrusion.

Dewatering to enable the installation of sewer pipelines occurred in the early 1990s. This dewatering resulted in saline contamination of several bores along the western boundary of the estuary. A further incident occurred in 1999 as a result of a leaking underground petrol tank. Specific groundwater monitoring has been undertaken in the area. Although the monitoring indicates the groundwater quality at the sampling sites meets the New Zealand drinking water standards, long term water quality and quantity monitoring will continue due to the sensitivity of the system.

11.4 What is being done?

Policy documents

One of the main objectives for groundwater management in Northland is the sustainable use and development of Northland's groundwater resources while avoiding, remedying or mitigating adverse effects on groundwater quantity and quality. The Regional Water and Soil Plan (RWSP) (NRC 2007) recognises 43 aquifers, and a geothermal aquifer as potentially 'at risk' due to water demand, surrounding land use, surface water interaction or proximity to seawater and septic tank discharges.

The rules in the RWSP restrict groundwater takes, use, diversions and drilling activities depending on the potential effects of the activities.

The rules permit groundwater takes for reasonable stock and domestic requirements provided specific criteria are met. The criteria, amongst other things, limits the daily permitted groundwater take depending on the location and the potential for adverse effects as a result of the take. For example smaller volumes are permitted to be taken from coastal 'at risk' aquifers. In the event the permitted criteria specified in the rules can not be met then resource consent to take groundwater is required from the Regional Council.

Installation or alteration of a bore that is not temporary in nature (i.e. back filled within 14 working days) also requires resource consents.

NRC staff member carrying out bore construction compliance check (right).

Monitoring

Resource consents to take groundwater, and drill a bore are subject to specific conditions. These conditions are imposed to avoid and/or minimise the potential adverse effects as a result of the activity. Monitoring the exercise of resource consents is carried out to ensure the conditions are complied with and the bore construction activities do not result in adverse effects on the environment.

Monitoring of the general state of the groundwater resources in Northland also occurs. The primary aims of the state of the environment monitoring is to gain a regional perspective on baseline water quantity and quality of different aquifers and trends in groundwater quantity and quality over time as a result of climate, land use and groundwater abstraction.

Monitoring also ensures the management of the groundwater resources in Northland is sustainable and consistent with the objectives and policies of the Regional Policy Statement and Regional Plans.

The results of resource consent and the state of the environment monitoring can provide information on which to base future management decisions. In the event of groundwater monitoring highlighting issues in particular aquifers, specific investigations are initiated.

Groundwater quality monitoring

The National Groundwater Quality Monitoring Network was established in 1996 to gain an understanding of seasonal and long-term variation in groundwater quality. This network initially consisted of seven sites in Northland sampled on a quarterly basis. These sites are located in the areas of Houhora, Paparore, Ahipara, Kaikohe, Tutukaka, Whangarei and Tara. The samples are analysed for major cations, anions, nutrients and minor elements such as iron and magnesium.

The Northland groundwater quality network has been extended over the past five years to gain a greater knowledge of groundwater quality throughout the region. The network currently includes an additional 32 sites sampled quarterly, shown in table 8 (below). Twenty-two of these sites are located in coastal aquifers, which are analysed for saltwater and bacterial indicators every six months and chemical properties (the same set as for the national programme) on the sampling runs in between. Groundwater levels are also recorded at each site, where access is available. The remainder of the sites are located in basalt aquifers, which are sampled quarterly for a full range of determinants.

Table 8: Additional groundwater quality sites added to seven initial network sites since 1996.

Coastal	General
Ruawai	Maunu Basalt
Mangawhai Heads east	Whatitiri Basalt
Mangawhai Heads west	Three Mile Bush Basalt
Mangawhai Village	Matarau Basalt
Sandy Bay	Glenbervie Basalt
Taupo Bay	Kerikeri Basalt
Tauranga Bay	Maungakaramea Basalt
Te Ngaire Bay	Tara Basalt
Tapeka Point	
Pataua Bay	
Whananaki Bay	
Taiharuru Bay	
Ngunguru	
Whangaumu Beach	
Matapouri Bay	
Oakura Bay	
Bland Bay	
Russell	
Cable/Mangonui Bay	
Coopers Beach	
Taipa	
Waipapakauri Beach	
Waipapakauri East	
Houhora	

Groundwater level monitoring

Groundwater level monitoring has been undertaken in the Northland region since the mid 1970s. Since that time the network has been developed in response to the identification of groundwater issues.

Groundwater level monitoring is currently undertaken in all of the principal aquifer systems in the Northland area. Levels are monitored at eight sites by automatic recorder and manually at a further 77 sites (of which 33 sites are monitored quarterly and 44 monthly). The monitoring wells have been selected to provide regional coverage and target-specific environmental concerns.

The groundwater level sites at Russell, Poroti West, Puriri Park, Ruawai and Tara are now telemetered to provide real time data, which is valuable for monitoring water availability in areas of high demand or aquifers at risk of saltwater intrusion.

Specific groundwater investigations

A number of investigations have been carried out as a result of specific issues arising in an aquifer. These investigations include the assessment of hydrogeology of the Three Mile Bush, Glenbervie, Maungakaramea, Kaikohe, Aupouri, Coopers Beach and Mangawhai aquifers. Additional groundwater quality investigations have been carried out in Ruawai, Russell and Taipa aquifers.

Due to the lack of recent groundwater information for the Oakura and Matapouri aquifers, specific groundwater investigations are in progress. These investigations will gain information on the current sustainable allocation for these groundwater resources and the current groundwater quantity and quality information.

11.5 Where to from here?

The following are key points towards implementing improved future management of groundwater in Northland over the next five years:

- Continue state of environment monitoring and assessments of sustainable yields for aquifers. Priority aquifers should be those with limited assessment to date but potential increase in demand due to land use change.

- Undertake mean age testing and age distribution of aquifers in Northland to help analyse groundwater quality.

- Encourage all water users to register their 'permitted takes' and locations of bores with the Council to enable greater understanding of the 'actual' water taken in aquifers.

- Ensure accurate water metering of consented takes and water use analysis to enable a better understanding of the volume of water abstracted from aquifers and the effects on water resources.

- All groundwater monitoring bores are to be inspected and, if required, work undertaken to prevent potential contaminants entering the bore. This will reduce the risk of microbiological contamination (*E. coli*) resulting from poor construction of monitoring bores.

- Management of water allocation limits for aquifers in Northland to provide water use security for users and sustainable allocation of water resources.

- Review of the Regional Plan rules to ensure they are adequate for requiring that assessments of the cumulative effects of subdivision, land use and development on water resources are undertaken and thus avoiding inappropriate development.

- Undertake flow measurement of springs in volcanic areas, coinciding with groundwater level measurements to gain a better understanding of surface and groundwater interaction, and groundwater discharge.

- Prioritise and implement recommendations in the preliminary hydrogeological reports based on current and potential future demands.

11.6 What can you do to help?

You can help protect Northland's groundwater resources by:

- Ensure the location of your bore is registered with the Council. This enables the Council to consider you as an affected party for activities proposed to be undertaken on neighbouring properties i.e. large groundwater takes or discharges on neighbouring properties.

- Make sure your bore meets requirements and is maintained appropriately.

- Register your groundwater use with the Council as this helps the Council sustainably manage groundwater resources now and in the future. Registering your "permitted" take can also ensure your take is protected in the event of future development in your area.

For more information refer to the 'Save Our Groundwater' brochure on the Regional Council website at the following link:

http://www.nrc.govt.nz/upload/1794/Save%20our%20Groundwater.pdf

and the 'Your Well Water Might Be Making You Sick' brochure at the following link:

http://www.nrc.govt.nz/upload/1792/Well%20Water%20-%20might%20be%20making%20you%20sick.pdf

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http://www.nrc.govt.nz/Resource-Library-Summary/Plans-and-Policies/Regional-plans/Regional-Water-and-Soil-Plan/

Note: All aquifer investigation reports are available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Research-and-reports/Groundwater/

11.8 Appendix A: Site information

Table 9: State of the Environment monitoring sites

Site name	Site number	Easting	Northing	Depth to top/bottom of open area		Bore depth (m)	Aquifer lithology	Aquifer confinement	Land use	Land cover
Aupouri - Waipapakauri	101820	2526566	6684980	67	108	108	Sand	Semi-confined	Forestry	Afforestation (imaged, post LCDB 1)
Aupouri - Paparore	102039	2529703	6690598	70	79	79	Shellbeds	Confined	Horticultural	Herbaceous Freshwater Vegetation
Aupouri - Ahipara	105914	2525555	6671052	27.5	31.7	31.7	Sand	Semi-confined	Horticultural	High Producing Exotic Grassland
Aupouri - Houhora East	106736	2522409	6709063	76.25	79.25	79.25	Shellbeds	Confined	Urban	Orchard and Other Perennial Crops
Aupouri - Houhora West	104890	2521803	6705899	48	55	55	Sand	Semi-confined	Horticultural	Orchard and Other Perennial Crops
Aupouri - Awanui	106737	2534086	6685817	29.95	32.95	32.95	Sand	Semi-confined	Horticultural	High Producing Exotic Grassland
Bland Bay	105226	2633825	6649538	6	7	7	Sand	Semi-confined	Urban	Estuarine Open Water
Cable Bay	106694	2554597	6689934	4.6	27.4	27.4	Basalt	Semi-confined	Urban	High Producing Exotic Grassland
Coopers Beach	107034	2557608	6689693	25	45	45	Basalt	Confined	Urban	Afforestation (imaged, post LCDB 1)
Glenbervie	105916	2632962	6613473	16.5	67	67	Basalt	Semi-confined	Horticultural	Indigenous Forest
Kaikohe	101920	2582750	6643339	61.8	88	88	Basalt	Semi-confined	Urban	Built-up Area
Kerikeri	106728	2598388	6665309			33	Basalt	Semi-confined	Horticultural	Indigenous Forest
Mangawhai - South	103138	2653128	6562217	22	40	40	Sandstone	Semi-confined	Urban	High Producing Exotic Grassland
Mangawhai Heads	103192	2653202	6563899	28	38	38	Sandstone	Semi-confined	Urban	Estuarine Open Water
Matapouri	106697	2647362	6624929	7.7	8.7	8.7	Sand	Semi-confined	Urban	Indigenous Forest
Maunu	106742	2625345	6605448	18	60	60	Basalt	Semi-confined	Urban	High Producing Exotic Grassland
Ngunguru	106698	2646643	6617455	6	16.9	16.9	Greywacke	Semi-confined	Urban	Estuarine Open Water
Oakura	108361	2632864	6644664	8.2	9.2	9.2	Sand	Semi-confined	Urban	High Producing Exotic Grassland
Oakura Foreshore	106696	2632829	6644758	9.4	10.4	10.4	Sand	Semi-confined	Urban	High Producing Exotic Grassland
Pataua North	108263	2648426	6608630	5.4	6.4	6.4	Sand	Semi-confined	Horticultural	Built-up Area
Ruatangata	106741	2616352	6615369	11	39.3	39.3	Basalt	Semi-confined	Urban	High Producing Exotic Grassland
Sandy Bay	108262	2644253	6625999	11	18	18	Greywacke	Semi-confined	Urban	High Producing Exotic Grassland
Taiharuru	108261	2651154	6606564	8	12	12	Greywacke	Semi-confined	Horticultural	Herbaceous Saline Vegetation
Tara	104886	2647103	6565000	32	49	49	Basalt	Semi-confined	Horticultural	High Producing Exotic Grassland
Maungakaramea	108590	2619276	6593751	12	76	76	Basalt	Semi-confined	Horticultural	High Producing Exotic Grassland
Taupo Bay	108333	2575875	6689221	5	6	6	Sand	Unconfined	Horticultural	Manuka and or Kanuka
Tauranga Bay	108326	2582761	6687859	3	8	8	Sand	Unconfined	Horticultural	High Producing Exotic Grassland
Te Ngaire Bay	108341	2590096	6686160	8.2	11.2	11.2	Greywacke	Semi-confined	Forestry	Manuka and or Kanuka
Three Mile Bush	106739	2624214	6611317	9	18	18	Basalt	Semi-confined	Urban	High Producing Exotic Grassland
Tutukaka	106545	2648793	6620001	12.8	55	55	Greywacke	Unknown	Urban	Manuka and or Kanuka
Whananaki North	108260	2643542	6631370	18	23	23	Greywacke	Semi-confined	Horticultural	Estuarine Open Water
Whangaumu	106695	2649412	6617169	4.5	12.5	12.5	Greywacke	Semi-confined	Urban	Estuarine Open Water
Whatitiri	106740	2613444	6603530	27	61.53	61.53	Basalt	Confined	Horticultural	Orchard and Other Perennial Crops

Table 10: Monitoring sites of the Ruawai aquifer investigation

Site name	Site number	Easting	Northing	Depth to top/bottom of open area		Bore depth (m)	Aquifer lithology	Aquifer confinement	Land use	Land cover
Ruawai	102110	2602594	6562033	53	59.2	60.7	Sand	Confined	Horticultural	Estuarine Open Water
Ruawai - East	105206	2606426	6563275	33.5	39.5	39.5	Sand	Semi-confined	Horticultural	High Producing Exotic Grassland
Ruawai - South East	106920	2600256	6564816	60	66	66	Sand	Semi-confined	Horticultural	High Producing Exotic Grassland
Ruawai - Central	106693	2600073	6569968			23	Sandstone	Semi-confined	Horticultural	High Producing Exotic Grassland

Table 11: Monitoring sites of the Russell aquifer investigation

Site name	Site number	Easting	Northing	Depth to top/bottom of open area		Bore depth (m)	Aquifer lithology	Aquifer confinement	Land use	Land cover
Russell - North	108360	2612807	6659390	11.5	33.5	33.5	Greywacke	Semi-confined	Urban	Estuarine Open Water
Russell - Foreshore Central	104744	2612870	6659387	11	44	44	Greywacke	Confined	Urban	Estuarine Open Water
Russell - Foreshore North	104745	2612804	6659442	1.8	3.65	8.23	Gravel	Unconfined	Urban	Estuarine Open Water
Russell - Tapeka Point	108335	2612814	6660805	12	35	35	Greywacke	Semi-confined	Urban	Manuka and or Kanuka
Matauwhi Bay - Foreshore	102368	2613195	6658642				Greywacke	Unknown	Urban	Estuarine Open Water
Matauwhi Bay - North	102367	2613202	6658707				Greywacke	Unknown	Urban	Estuarine Open Water

Table 12: Monitoring sites of the Taipa aquifer investigation

Site name	Site number	Easting	Northing	Depth to top/bottom of open interval		Bore depth (m)	Aquifer lithology	Aquifer confinement	Land use	Land cover
Taipa - North	104650	2553145	6689652	5	6	6	Sand	Unconfined	Urban	High Producing Exotic Grassland
Taipa - Northwest	104653	2552798	6689650	3.2	6.2	8.6	Sand	Unconfined	Urban	High Producing Exotic Grassland
Taipa - West	107790	2552626	6689497	3	9	9	Sand	Unconfined	Urban	High Producing Exotic Grassland
Taipa - Central	101759	2553302	6689498	6.5	8.5	8.5	Sand	Unconfined	Urban	Built-up Area
Taipa - Northwest Foreshore	102332	2552922	6689665	5	7	7	Sand	Unconfined	Urban	High Producing Exotic Grassland

11.9 Appendix B: Medians for all data for all sites monitored

Table 13: Medians for all data for State of the Environment monitoring sites (NA = No result available)

Site name	Site number	Bromine (mg/L)	Calcium (mg/L)	Chlorine (mg/L)	Cond (uS/cm)	Fluorine (mg/L)	Iron (mg/L)	Hydrogen carbonate (mg/L)	Potassium (mg/L)	E. coli (n/100mL)	Magnesium (mg/L)	Manganese (mg/L)
Aupouri - Waipapakauri	101820	0.07	16.4	41.7	278	0.08	0.01	71	2.17	<1	3.71	0.011
Aupouri - Paparore	102039	0.18	33	53	410	0.06	0.06	148	2.7	NA	5.6	0.11
Aupouri - Ahipara	105914	0.09	4.1	33	180	0.02	1.40	34.5	1.75	NA	3.5	0.04
Aupouri - Houhora East	106736	0.20	31.7	63.3	448	0.10	0.09	124	3.81	<1	3.14	0.02
Aupouri - Houhora West	104890	0.33	6.5	32	210	0.08	1.40	48	1.6	NA	4.4	0.058
Aupouri - Awanui	106737	0.17	23.9	69	488	0.13	0.52	160	6.01	0.82	5.99	0.044
Bland Bay	105226	0.05	75.6	33.8	542	0.12	0.01	262.5	1.22	<1	8.6	0.0003
Cable Bay	106694	0.27	11.3	82.2	629	0.03	3.40	205	3.74	1	11.9	0.27
Coopers Beach	107034	0.03	44.6	33.4	516	0.03	1.14	240	1.28	<1	16	0.3
Glenbervie	105916	0.05	39	14.6	320	0.07	0.01	156.5	1.01	NA	6.2	0.003
Kaikohe	101920	0.05	10.8	10.7	177	0.02	0.01	64.5	1.5	NA	6.25	0.003
Kerikeri	106728	0.05	1.3	15.5	88	0.03	0.00	9.5	0.11	<1	1.68	0.022
Mangawhai - South	103138	0.39	13.1	161	857	0.24	0.04	280.5	1.55	<1	3	0.016
Mangawhai Heads	103192	0.18	14.2	46.7	406	0.09	0.98	158	2.75	<1	7.21	0.15
Matapouri	106697	0.13	61.7	55	737	0.63	0.01	301	4.26	2	28	0.004
Maunu	106742	0.03	11.5	15.4	181	0.03	0.01	56	0.68	1	6.84	0.0009
Ngunguru	106698	0.12	38.7	36.4	436	0.40	0.05	174	5.47	<1	9.7	0.075
Oakura	108361	NA	NA	51.2	715	NA	NA	NA	NA	<1	NA	NA
Oakura Foreshore	106696	0.24	77.6	107.7	821	0.36	0.01	288	5.97	<1	10.4	0.0008
Pataua North	108263	0.74	85.4	282.5	1436	0.09	0.01	NA	NA	<1	22.05	0.002
Ruatangata	106741	0.07	1.4	15.7	109	0.03	0.26	8	0.23	2.87	2.16	0.04
Sandy Bay	108262	0.59	2.5	103	455	0.03	0.01	NA	NA	<1	8.29	0.404
Taiharuru	108261	0.53	20	74.3	441	0.04	0.01	69	NA	0.29	12.2	0.282
Tara	104886	0.08	4.4	17.8	NA	0.05	0.23	27.5	1.5	NA	4	0.007
Maungakaramea	108590	NA	9.4	23.5	248	0.03	0.01	48	0.71	3	NA	NA
Taupo Bay	108333	0.38	88.6	38.5	625	0.05	0.01	NA	NA	0.78	NA	0.0003
Tauranga Bay	108326	0.03	106.5	22.5	568	0.04	0.01	299.5	NA	0.6	4.55	0.001
Te Ngaire Bay	108341	0.38	NA	79.1	630	0.31	0.01	285	NA	<1	10.9	NA
Three Mile Bush	106739	0.03	7.6	13.3	159	0.03	0.01	41	0.54	<1	5.69	0.0007
Tutukaka	106545	0.56	4.1	117	583	0.11	0.01	NA	2.9	NA	8.2	0.009
Whananaki North	108260	0.40	27.6	102.5	552	0.16	2.11	101	NA	<1	11.85	1.12
Whangaumu	106695	0.40	0.4	110	733	0.44	0.01	151	7.05	<1	0.62	0.0003
Whatitiri	106740	0.09	9.9	16.9	201	0.03	0.03	52.5	1.08	<1	6.46	0.001

Table 13 continued: Medians for all data for State of the Environment monitoring sites (NA = No result available)

Site name	Site number	Sodium (mg/L)	Ammoniacal nitrogen (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	pH	Phosphate (mg/L)	Silica (mg/L)	Sulphate (mg/L)	Total dissolved solids (mg/L)	Temp (DegC)
Aupouri - Waipapakauri	101820	31.7	0.005	0.001	0.024	8.2	0.087	31.6	9.7	NA	18.5
Aupouri - Paparore	102039	40.5	0.05	NA	0.002	7.9	0.08	41	8.7	NA	19.2
Aupouri - Ahipara	105914	24	0.07	NA	0.25	6.4	0.025	35	6.7	NA	17.4
Aupouri - Houhora East	106736	52.4	0.16	0.001	0.001	7.8	0.092	42.9	15.4	NA	18.7
Aupouri - Houhora West	104890	30.5	0.005	NA	0.003	6.6	0.078	39	8.7	NA	17.7
Aupouri - Awanui	106737	68.4	0.54	0.001	0.001	7.7	0.296	34	0.7	NA	18.2
Bland Bay	105226	21.7	0.005	0.001	0.927	7.6	0.009	11.7	7.9	NA	18.1
Cable Bay	106694	120.5	0.04	0.004	0.006	7.0	0.028	66.6	29.6	NA	18.5
Coopers Beach	107034	40.4	0.04	0.001	0.001	7.4	0.063	93	18.8	NA	20.1
Glenbervie	105916	12.4	0.005	NA	NA	7.3	0.011	25	10.6	NA	18.2
Kaikohe	101920	11.7	0.005	NA	3	6.6	0.075	40.5	2.9	NA	17.9
Kerikeri	106728	10.5	0.009	0.004	0.963	5.7	0.004	10.6	2.5	NA	17.9
Mangawhai - South	103138	345	0.3	0.001	0.002	8.0	0.167	21.7	8.3	NA	17.7
Mangawhai Heads	103192	62.1	0.08	0.001	0.002	7.3	0.062	75.4	6.4	NA	17.4
Matapouri	106697	48.4	0.01	0.026	1.372	7.6	0.038	12.4	45.4	NA	17.5
Maunu	106742	15	0.005	0.001	4.16	6.7	0.029	39.3	3	118	17.4
Ngunguru	106698	35.3	0.016	0.001	0.013	7.4	0.051	26.2	18.6	NA	17.7
Oakura	108361	38.7	NA	NA	NA	7.6	NA	NA	NA	NA	17.5
Oakura Foreshore	106696	64.3	0.005	0.001	3.18	7.6	0.143	19.6	44.2	NA	17.7
Pataua North	108263	201	0.005	NA	9.49	7.4	0.018	10	36.5	NA	18.5
Ruatangata	106741	14.5	0.005	0.001	5.08	5.5	0.004	10	1.6	71	17.2
Sandy Bay	108262	79.4	0.04	NA	1.23	5.1	0.017	38	54.1	NA	17.4
Taiharuru	108261	59.8	0.005	NA	1.32	6.3	0.014	15.4	54.1	NA	17.1
Tara	104886	12.6	0.005	NA	2.4	6.4	0.06	22	2.8	NA	16.8
Maungakaramea	108590	23.8	0.005	0.001	9.81	6.7	0.008	NA	5.8	NA	18.2
Taupo Bay	108333	22.9	0.005	NA	4.96	7.7	0.046	15.5	9.8	NA	18.4
Tauranga Bay	108326	20.4	0.005	NA	5.78	7.3	0.088	8.15	18.8	NA	17.9
Te Ngaire Bay	108341	55.7	0.005	NA	4.64	7.4	NA	NA	18.3	NA	17.3
Three Mile Bush	106739	11.7	0.005	0.001	2.77	6.4	0.018	29.6	6.2	111	17.6
Tutukaka	106545	90	0.005	NA	2	6.8	NA	33	26	NA	17.3
Whananaki North	108260	58.1	0.05	0.003	0.002	6.6	0.064	60.6	20.5	NA	19.3
Whangaumu	106695	156	0.005	0.001	0.172	7.1	0.395	33.8	55.3	NA	17.7
Whatitiri	106740	19.2	0.005	0.001	7.28	6.9	0.059	45.1	2.2	147	16.6

Table 14: Medians for all data for sites of the Ruawai aquifer investigation (NA = No result available)

Site name	Site number	Bromine (mg/L)	Calcium (mg/L)	Chlorine (mg/L)	Cond (uS/cm)	Fluorine (mg/L)	Iron (mg/L)	Hydrogen carbonate (mg/L)	Potassium (mg/L)	E. coli (n/100mL)	Magnesium (mg/L)	Manganese (mg/L)
Ruawai	102110	0.29	33.7	91	562	0.08	0.21	142	3.49	<1	6.77	0.121
Ruawai - East	105206	4.51	225.5	1215	4399	0.03	69.60	115	19.9	<10	81.7	2.2
Ruawai - South East	106920	0.27	35	94.3	573	0.15	3.22	151	2.82	<1	7.44	0.131
Ruawai - Central	106693	0.40	48	145	1207	0.07	3.54	427	5.07	<1	17.5	0.037

Table 14 continued: Medians for all data for sites of the Ruawai aquifer investigation (NA = No result available)

Site name	Site number	Sodium (mg/L)	Ammoniacal nitrogen (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	pH	Phosphate (mg/L)	Silica (mg/L)	Sulphate (mg/L)	Total dissolved solids (mg/L)	Temp (DegC)
Ruawai	102110	61.6	0.1	0.001	0.002	7.7	0.054	44.9	7	284	18.1
Ruawai - East	105206	357	5.18	0.033	0.003	6.7	0.015	32.9	0.3	2645	17.1
Ruawai - South East	106920	70.1	0.155	0.001	0.001	7.3	0.014	49.4	2.5	322	18.3
Ruawai - Central	106693	184	0.7	0.001	0.001	7.2	0.021	71.2	6.2	651	17.6

Table 15: Medians for all data for sites of the Russell aquifer investigation (NA = No result available)

Site name	Site number	Bromine (mg/L)	Calcium (mg/L)	Chlorine (mg/L)	Cond (uS/cm)	Fluorine (mg/L)	Iron (mg/L)	Hydrogen carbonate (mg/L)	Potassium (mg/L)	E. coli (n/100mL)	Magnesium (mg/L)	Manganese (mg/L)
Russell - North	108360	NA	14.6	63.8	342	NA	4.65	88	NA	<1	4.97	0.513
Russell - Foreshore Central	104744	NA	NA	77	399	NA	5.31	NA	NA	1	NA	0.966
Russell - Foreshore North	104745	NA	NA	46	357	NA	42.60	NA	NA	0.15	NA	1.62
Russell - Tapeka Point	108335	0.67	7.3	103	514	0.11	NA	39.5	NA	1	7.93	NA
Matauwhi Bay - Foreshore	102368	NA	1.8	98.3	554	0.18	0.03	NA	NA	1	NA	0.023
Matauwhi Bay - North	102367	0.21	4	60	461	0.25	0.01	NA	NA	0.36	1.42	0.008

Table 15 continued: Medians for all data for sites of the Russell aquifer investigation (NA = No result available)

Site name	Site number	Sodium (mg/L)	Ammoniacal nitrogen (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	pH	Phosphate (mg/L)	Silica (mg/L)	Sulphate (mg/L)	Total dissolved solids (mg/L)	Temp (DegC)
Russell - North	108360	41.9	0.005	NA	0.007	6.5	NA	68.8	2.8	NA	18.2
Russell - Foreshore Central	104744	NA	0.004	NA	NA	6.4	NA	NA	NA	NA	19.8
Russell - Foreshore North	104745	NA	1.41	NA	NA	6.2	NA	NA	NA	NA	17.8
Russell - Tapeka Point	108335	87.1	NA	NA	0.075	5.9	0.006	54.6	20.7	NA	18.5
Matauwhi Bay - Foreshore	102368	108.5	0.065	NA	NA	6.7	NA	NA	NA	NA	18.4
Matauwhi Bay - North	102367	NA	<0.0001	NA	0.589	6.5	0.121	49.7	34.2	NA	18.5

Table 16: Medians for all data for sites of the Taipa aquifer investigation (NA = No result available)

Site name	Site number	Bromine (mg/L)	Calcium (mg/L)	Chlorine (mg/L)	Cond (uS/cm)	Fluorine (mg/L)	Iron (mg/L)	Hydrogen carbonate (mg/L)	Potassium (mg/L)	E. coli (n/100mL)	Magnesium (mg/L)	Manganese (mg/L)
Taipa - North	104650	NA	NA	27.1	526	NA	0.1	NA	NA	1	NA	0.003
Taipa - Northwest	104653	NA	NA	32.7	410	NA	NA	258.3	NA	<1	5.8	0.036
Taipa - West	107790	NA	NA	34.2	523	NA	NA	NA	NA	7	NA	NA
Taipa - Central	101759	0.05	78.3	29	565	0.24	0.01	284	2.23	<1	19.8	0.002
Taipa - NW Foreshore	102332	NA	79.1	46	534	NA	0.63	332.1	NA	<1	7.83	0.056

Table 16 continued: Medians for all data for sites of the Taipa aquifer investigation (NA = No result available)

Site name	Site number	Sodium (mg/L)	Ammoniacal nitrogen (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	pH	Phosphate (mg/L)	Silica (mg/L)	Sulphate (mg/L)	Total dissolved solids (mg/L)	Temp (DegC)
Taipa - North	104650	NA	0.005	0.005	4.87	7.7	NA	NA	NA	NA	18.0
Taipa - Northwest	104653	22	0.06	0.006	1.6	7.5	NA	NA	10	NA	17.9
Taipa - West	107790	NA	0.12	NA	0.015	7.7	NA	NA	NA	NA	17.0
Taipa - Central	101759	20.9	0.005	0.005	6.28	7.7	0.014	10.3	16.7	NA	18.8
Taipa - NW Foreshore	102332	26	0.125	0.008	0.132	7.5	NA	NA	NA	NA	17.9

11.10 Appendix C: Significant trends detected using seasonal Mann Kendall test

Table 17: Significant trends at a 95% confidence interval for State of the Environment monitoring sites (NA = No result available, N = No significant trend)

Site name	Site number	Bromine (mg/L)	Calcium (mg/L)	Chlorine (mg/L)	Cond (uS/cm)	Fluorine (mg/L)	Iron (mg/L)	Hydrogen carbonate (mg/L)	Potassium (mg/L)	E. coli (n/100mL)	Magnesium (mg/L)	Manganese (mg/L)
Aupouri - Waipapakauri	101820	N	-0.6156	N	N	N	NA	N	N	N	N	-0.0061
Aupouri - Paparore	102039	N	-1.0069	-0.1427	N	N	N	N	N	NA	N	N
Aupouri - Ahipara	105914	-0.0092	-0.2219	N	N	N	N	N	N	NA	-0.1943	N
Aupouri - Houhora East	106736	N	N	N	N	N	N	N	N	N	N	N
Aupouri - Houhora West	104890	-0.0076	N	1.7279	4.2378	N	N	N	0.0501	NA	0.0403	N
Aupouri - Awanui	106737	N	N	N	N	N	N	N	N	N	N	N
Bland Bay	105226	N	N	-1.0898	N	N	NA	N	N	N	N	NA
Cable Bay	106694	0.2628	N	N	N	NA	N	15.5078	N	N	N	N
Coopers Beach	107034	NA	N	N	N	NA	N	N	N	N	N	N
Glenbervie	105916	-0.0018	N	N	N	N	NA	N	N	NA	N	NA
Kaikohe	101920	N	N	N	N	N	NA	N	N	NA	N	NA
Kerikeri	106728	N	N	N	N	NA	N	N	N	N	N	N
Mangawhai - South	103138	N	N	N	N	N	N	N	N	N	N	N
Mangawhai Heads	103192	0.0902	N	N	N	N	N	N	N	N	N	N
Matapouri	106697	N	N	N	N	N	NA	-6.4020	N	78.6067	N	N
Maunu	106742	NA	N	-2.1743	-17.457	NA	NA	N	N	N	N	0.0004
Ngunguru	106698	N	N	N	-6.6821	N	N	N	N	N	N	N
Oakura	108361	NA	NA	N	N	NA	NA	N	NA	NA	NA	NA
Oakura Foreshore	106696	N	N	-26.931	N	N	NA	N	N	N	N	N
Pataua North	108263	N	N	N	N	N	NA	N	NA	NA	N	N
Ruatangata	106741	N	N	N	N	NA	N	N	N	N	N	N
Sandy Bay	108262	N	N	N	N	NA	NA	N	NA	N	N	N
Taiharuru	108261	N	N	N	N	N	NA	N	NA	N	N	N
Tara	104886	-0.0059	-0.2558	-0.1307	NA	N	N	N	N	N	N	N
Maungakaramea	108590	NA	N	N	N	NA	NA	N	N	N	NA	NA
Taupo Bay	108333	N	N	N	N	N	NA	N	NA	-1.2041	NA	NA
Tauranga Bay	108326	NA	N	N	N	N	NA	N	NA	N	N	N
Te Ngaire Bay	108341	N	NA	N	N	N	NA	N	NA	N	N	NA
Three Mile Bush	106739	NA	N	N	N	NA	NA	N	N	N	0.2725	N
Tutukaka	106545	-0.1126	N	N	N	-0.0395	NA	NA	N	NA	N	N
Whananaki North	108260	N	N	N	N	N	N	N	NA	NA	N	N
Whangaumu	106695	N	N	-5.0172	-10.965	N	NA	N	N	N	N	NA
Whatitiri	106740	0.0605	0.3930	N	N	NA	N	N	N	N	0.4197	N

Table 17 continued: Significant trends at a 95% confidence interval for SOE monitoring sites (NA = No result available, N = No significant trend)

Site name	Site number	Sodium (mg/L)	Ammoniacal nitrogen (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	pH	Phosphate (mg/L)	Silica (mg/L)	Sulphate (mg/L)	Total dissolved solids (mg/L)	Temp (DegC)
Aupouri - Waipapakauri	101820	N	NA	NA	0.0161	N	-0.0098	N	N	NA	N
Aupouri - Paparore	102039	-0.4606	N	NA	N	N	N	-0.9395	-0.0596	NA	N
Aupouri - Ahipara	105914	-0.2153	0.0078	NA	0.0259	N	NA	N	-0.1780	NA	N
Aupouri - Houhora East	106736	N	N	NA	NA	N	N	N	N	NA	N
Aupouri - Houhora West	104890	N	NA	NA	-0.0013	N	N	N	-0.3654	NA	N
Aupouri - Awanui	106737	N	N	NA	NA	N	N	N	N	NA	N
Bland Bay	105226	N	NA	NA	N	N	N	-0.2369	N	NA	N
Cable Bay	106694	N	N	N	N	N	N	N	N	NA	N
Coopers Beach	107034	N	N	NA	NA	N	0.0136	N	N	NA	N
Glenbervie	105916	-0.4001	NA	NA	NA	-0.1006	-0.0143	N	N	NA	N
Kaikohe	101920	N	NA	NA	-0.1328	N	N	N	-0.0582	NA	N
Kerikeri	106728	N	0.0101	N	N	N	N	N	N	NA	N
Mangawhai - South	103138	N	N	NA	N	N	N	N	N	NA	N
Mangawhai Heads	103192	N	N	NA	N	N	0.0240	N	N	NA	N
Matapouri	106697	N	N	N	N	N	N	N	N	NA	N
Maunu	106742	-1.0970	NA	NA	N	N	N	N	N	N	N
Ngunguru	106698	N	N	NA	N	0.1152	N	N	N	NA	N
Oakura	108361	N	NA	NA	NA	N	NA	NA	NA	NA	N
Oakura Foreshore	106696	N	NA	NA	N	N	N	N	N	NA	N
Pataua North	108263	N	NA	NA	N	N	N	N	N	NA	N
Ruatangata	106741	N	NA	NA	N	N	N	N	N	N	N
Sandy Bay	108262	N	N	NA	N	-0.4014	N	N	N	NA	N
Taiharuru	108261	N	NA	NA	N	N	N	N	N	NA	N
Tara	104886	-0.3954	NA	NA	N	N	N	N	N	NA	N
Maungakaramea	108590	N	NA	NA	N	N	N	NA	N	NA	N
Taupo Bay	108333	N	NA	NA	N	N	N	N	N	NA	N
Tauranga Bay	108326	N	NA	NA	N	N	N	N	N	NA	N
Te Ngaire Bay	108341	N	NA	NA	N	N	NA	NA	N	NA	N
Three Mile Bush	106739	N	NA	NA	N	N	N	-0.5935	N	N	N
Tutukaka	106545	N	NA	NA	-0.3339	N	NA	N	N	NA	N
Whananaki North	108260	N	N	N	N	N	N	N	N	NA	N
Whangaumu	106695	N	NA	NA	-0.0102	N	N	N	N	NA	N
Whatitiri	106740	N	NA	NA	N	N	N	N	N	N	N

Table 18: Significant trends at a 95% confidence interval for sites of the Ruawai aquifer investigation (NA = No result available, N = No significant trend)

Site name	Site number	Bromine (mg/L)	Calcium (mg/L)	Chlorine (mg/L)	Cond (uS/cm)	Fluorine (mg/L)	Iron (mg/L)	Hydrogen carbonate (mg/L)	Potassium (mg/L)	E. coli (n/100mL)	Magnesium (mg/L)	Manganese (mg/L)
Ruawai	102110	N	N	-1.8198	-16.895	N	N	N	N	NA	N	0.0041
Ruawai - East	105206	N	N	N	N	NA	N	N	N	N	N	N
Ruawai - South East	106920	N	1.0404	N	N	N	N	N	N	N	N	-0.0199
Ruawai - Central	106693	N	N	N	N	N	N	N	N	N	N	N

Table 18 continued: Significant trends at a 95% confidence interval for sites of the Ruawai aquifer investigation (NA = No result available, N = No significant trend)

Site name	Site number	Sodium (mg/L)	Ammoniacal nitrogen (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	pH	Phosphate (mg/L)	Silica (mg/L)	Sulphate (mg/L)	Total dissolved solids (mg/L)	Temp (DegC)
Ruawai	102110	N	N	NA	N	N	N	N	N	N	N
Ruawai - East	105206	-48.039	N	N	N	N	N	N	NA	N	N
Ruawai - South East	106920	N	N	N	NA	N	N	N	N	N	N
Ruawai - Central	106693	N	N	NA	NA	N	N	N	-1.197	N	N

Table 19: Significant trends at a 95% confidence interval for sites of the Russell aquifer investigation (NA = No result available, N = No significant trend)

Site name	Site number	Bromine (mg/L)	Calcium (mg/L)	Chlorine (mg/L)	Cond (uS/cm)	Fluorine (mg/L)	Iron (mg/L)	Hydrogen carbonate (mg/L)	Potassium (mg/L)	E. coli (n/100mL)	Magnesium (mg/L)	Manganese (mg/L)
Russell - north	108360	NA	N	N	N	NA	N	N	NA	N	N	N
Russell - foreshore central	104744	NA	NA	N	-12.795	NA	-0.624	NA	NA	N	NA	N
Russell - foreshore north	104745	NA	NA	0.8315	N	NA	-2.170	NA	NA	N	NA	-0.0979
Russell - Tapeka Point	108335	N	N	N	N	N	NA	N	NA	N	N	NA
Matauwhi Bay - foreshore	102368	NA	N	N	N	N	N	N	NA	-3.942	NA	N
Matauwhi Bay - north	102367	N	N	1.0527	-20.551	-0.1184	NA	N	NA	391.962	N	-0.0016

Table 19 continued: Significant trends at a 95% confidence interval for sites of the Russell aquifer investigation (NA = No result available, N = No significant trend)

Site name	Site number	Sodium (mg/L)	Ammoniacal nitrogen (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	pH	Phosphate (mg/L)	Silica (mg/L)	Sulphate (mg/L)	Total dissolved solids (mg/L)	Temp (DegC)
Russell - North	108360	N	NA	NA	N	N	NA	N	N	NA	N
Russell - Foreshore Central	104744	NA	-0.0035	NA	NA	N	NA	NA	NA	NA	N
Russell - Foreshore North	104745	NA	N	NA	NA	N	NA	NA	NA	NA	-0.2701
Russell - Tapeka Point	108335	N	NA	NA	N	N	N	N	N	NA	-1.0007
Matauwhi Bay - Foreshore	102368	N	N	NA	NA	0.1462	NA	NA	NA	NA	N
Matauwhi Bay - North	102367	NA	-0.0049	NA	N	0.0803	N	N	N	NA	N

Table 20: Significant trends at a 95% confidence interval for sites of the Taipa aquifer investigation (NA = No result available, N = No significant trend)

Site name	Site number	Bromine (mg/L)	Calcium (mg/L)	Chlorine (mg/L)	Cond (uS/cm)	Fluorine (mg/L)	Iron (mg/L)	Hydrogen carbonate (mg/L)	Potassium (mg/L)	E. coli (n/100mL)	Magnesium (mg/L)	Manganese (mg/L)
Taipa - North	104650	NA	NA	1.1877	N	NA	N	NA	NA	N	NA	N
Taipa - Northwest	104653	NA	NA	-4.7023	7.1914	NA	NA	NA	NA	N	N	N
Taipa - West	107790	NA	NA	N	N	NA	NA	NA	NA	N	NA	NA
Taipa - Central	101759	N	2.3838	N	5.4043	N	0.0116	N	N	N	N	N
Taipa - NW Foreshore	102332	NA	N	-1.6219	N	NA	N	NA	NA	N	N	0.0027

Table 20 continued: Significant trends at a 95% confidence interval for sites of the Taipa aquifer investigation (NA = No result available, N = No significant trend)

Site name	Site number	Sodium (mg/L)	Ammoniacal nitrogen (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	pH	Phosphate (mg/L)	Silica (mg/L)	Sulphate (mg/L)	Total dissolved solids (mg/L)	Temp (DegC)
Taipa - North	104650	NA	NA	-0.0010	-0.5317	0.0161	NA	NA	NA	NA	N
Taipa - Northwest	104653	N	N	N	N	N	NA	NA	N	NA	N
Taipa - West	107790	NA	N	NA	N	N	NA	NA	NA	NA	N
Taipa - Central	101759	N	NA	N	-1.3717	N	N	N	3.1999	NA	N
Taipa - Northwest Foreshore	102332	-0.6661	-0.0410	N	0.0761	N	NA	NA	NA	NA	-0.1065

11.11 Appendix D: Site categorisation

Table 21: Categories for State of the Environment monitoring sites

Site name	Site number	Calc TDS (mg/L)	CBE %	Median Category	Trend Category
Aupouri – Waipapakauri	101820	207.9	-0.2	2A	SiO2
Aupouri – Paparore	102039	333.0	-2.1	2A	WR1
Aupouri – Ahipara	105914	144.4	-0.7	2A	WR2
Aupouri - Houhora East	106736	337.1	0.9	2A	SiO2
Aupouri - Houhora West	104890	172.6	5.4	2A	WR2
Aupouri – Awanui	106737	369.8	2.7	2B	SiO2
Bland Bay	105226	423.9	-0.4	1A-1	WR2
Cable Bay	106694	536.7	5.7	2A	SiO2
Coopers Beach	107034	489.0	1.0	2A	WR1
Glenbervie	105916	265.5	-2.9	1A-1	SiO2
Kaikohe	101920	153.5	0.7	1A-2	SiO2
Kerikeri	106728	52.6	-4.1	1B-2	WR2
Mangawhai - South	103138	836.3	26.2	2A	D
Mangawhai Heads	103192	374.3	0.8	2A	WR1
Matapouri	106697	559.0	0.3	1A-1	P
Maunu	106742	150.6	0.9	1A-2	P
Ngunguru	106698	345.1	1.3	2A	D
Oakura	108361	529.3	0.6	1A-2	WR2
Oakura Foreshore	106696	621.9	-7.6	1A-2	D
Pataua North	108263	917.6	4.5	1A-2	I
Ruatangata	106741	59.0	-4.2	1B-2	WR1
Sandy Bay	108262	301.8	0.1	1A-2	I
Taiharuru	108261	308.0	2.0	1A-1	D
Tara	104886	95.4	-2.1	1B-2	WR1
Maungakaramea	108590	155.1	-2.6	1A-2	P
Taupo Bay	108333	437.6	2.2	1A-2	I
Tauranga Bay	108326	490.7	2.5	1A-2	P
Te Ngaire Bay	108341	566.4	1.8	1A-2	I
Three Mile Bush	106739	118.4	-0.2	1B-2	WR1
Tutukaka	106545	284.0	9.7	1A-2	P
Whananaki North	108260	389.9	1.0	2A	D
Whangaumu	106695	515.7	1.7	1A-2	D
Whatitiri	106740	160.8	-0.6	1A-2	WR1

Table 22: Categories for sites of the Ruawai aquifer investigation

Site name	Site number	Calc TDS (mg/L)	CBE %	Median Category	Trend Category
Ruawai	102110	391.2	-0.3	2A	WR1
Ruawai - East	105206	2129.2	1.0	2B	I
Ruawai - South East	106920	404.3	-1.2	2B	WR1
Ruawai - Central	106693	903.6	3.0	2B	P

Table 23: Categories for sites of the Russell aquifer investigation

Site name	Site number	Calc TDS (mg/L)	CBE %	Median Category	Trend Category
Russell - North	108360	295.3	-1.1	2A	I
Russell - Foreshore Central	104744	277.7	-6.0	2A	
Russell - Foreshore North	104745		2.8		
Russell - Tapeka Point	108335	327.9	11.2	2A	D
Matauwhi Bay - Foreshore	102368	365.1	3.9	2A	SiO2
Matauwhi Bay - North	102367	362.5	2.1	1A-2	P

Table 24: Categories for sites of the Taipa aquifer investigation

Site name	Site number	Calc TDS (mg/L)	CBE %	Median Category	Trend Category
Taipa - North	104650	407.1	3.7	1A-1	SiO2
Taipa - Northwest	104653	382.6	1.4	1A-1	D
Taipa - West	107790				
Taipa - Central	101759	467.6	1.6	1A-1	I
Taipa - Northwest Foreshore	102332	496.7	-8.0	2A	WR1