Targeted groundwater quality investigations in the Wairarapa

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Targeted groundwater quality investigations in the Wairarapa

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Executive summary

This report summarises six targeted groundwater quality studies conducted in the Wairarapa from 2004 to 2008. These studies investigated the extent of nitrate-nitrogen contamination in selected intensive farming areas in Te Ore Ore, Carterton and South Featherston, expanding coastal settlements (Riversdale and Flat Point) and an area of increasing rural/residential subdivision serviced by on-site wastewater treatment systems (Norfolk Road).

Groundwater samples from selected bores were tested for one or more dissolved nutrients and faecal indicator bacteria. Not all variables were tested in each targeted study. Results were compared against the New Zealand National Drinking Water Standards (DWSNZ 2005). These standards apply to water used for human consumption and set a maximum acceptable value (MAV).

The investigations found that nitrate-nitrogen contamination exists to various degrees in all six areas studied. The greatest nitrate-nitrogen contamination is present in shallow groundwater in the Carterton (Mangatarere) and Te Ore Ore areas; the DWSNZ (2005) MAV of 11.3 mg/L was exceeded on five occasions in these areas and a number of bores also recorded nitrate-nitrogen concentrations of at least half the MAV.

Dissolved reactive phosphorus concentrations were generally low with only five occasions where concentrations were above 0.1 mg/L in South Featherston and Carterton. Ammoniacal nitrogen and nitrite-nitrogen concentrations were also low.

Bacterial contamination was present in a number of shallow bores, with counts of *E. coli* and faecal coliforms above the DWSNZ (2005) MAV in a number of bores used for domestic supply. The highest faecal count recorded was 1,800 cfu/100mL.

Elevated groundwater nitrate-nitrogen concentrations can be linked to intensive agricultural land use, with the shallow aquifers in Carterton, Te Ore Ore and South Featherston study areas showing the greatest level of contamination. In contrast, bores in the Norfolk Road, Riversdale and Flat Point study areas – where land use is either residential or is changing from pastoral to residential development – recorded significantly lower nitrate-nitrogen concentrations. Nonetheless, some groundwater contamination is present in these areas, particularly at Riversdale where there have been occasional guideline exceedances for nitrate nitrogen, nitrite nitrogen and faecal bacteria.

Higher nitrate-nitrogen concentrations – along with higher *E. coli* and faecal coliform counts – were generally seen in winter when rainfall was greater, soils more saturated and groundwater levels higher. However, groundwater contamination was not limited to shallow aquifers; a number of bores located in the deep confined or semi-confined aquifers in the South Featherston, Carterton and Te Ore Ore study areas recorded elevated concentrations that in some cases exceeded the DWSNZ (2005) MAV for nitrate-nitrogen. This suggests a degree of connectivity between the shallow and deep aquifers and that contamination is possibly migrating into deeper aquifers. As the deeper aquifers generally contain older groundwater that is less affected by contamination, the full effects of recent land use intensification are probably yet to be seen in these aquifers.

Piezometric surveying in many of the study areas suggests that groundwater discharges into adjacent or downgradient surface water bodies. Therefore, it is highly likely that elevated nitrate-nitrogen concentrations in shallow groundwater are contributing to the poor water quality identified in a number of surface water bodies monitored by Greater Wellington, including the Enaki Stream, Mangatarere Stream and Lake Wairarapa. This highlights the need for an integrated approach to managing the region's soil and water resources, particularly when assessing resource consent applications for wastewater discharges to land. Soil nutrient loadings and wastewater application rates must be assessed carefully, particularly in areas of intensive land use.

Recommendations

1. Inform bore owners with groundwater nitrate-nitrogen concentrations and faecal bacteria counts above the DWSNZ (2005) MAV that the water in their bore is unsafe for human consumption.

2. Repeat targeted groundwater quality sampling in the South Featherston study area, incorporating additional shallow bores in close proximity to Lake Wairarapa to help gauge the effect of groundwater on lake water quality.

3. Repeat targeted groundwater quality sampling of a selection of bores in the Te Ore Ore study area, including the six bores sampled only once in 2005.

4. Undertake further investigations in the Carterton study area, focusing on the likely contamination of the Mangatarere Stream and its tributaries by shallow groundwater.

5. Reduce bi-monthly sampling of groundwater quality in five bores at Riversdale to quarterly sampling in one bore that is incorporated into Greater Wellington's Groundwater State of the Environment (GSoE) monitoring programme.

6. Cease bi-monthly sampling in the Norfolk Road subdivision area and utilise data from quarterly sampling of the nearby GSoE monitoring bore to track temporal changes in groundwater quality in this area.

7. Consider in future groundwater quality investigations:

   - better consistency in the water quality variables analysed (i.e., testing all samples for *E. coli*, faecal coliforms, dissolved reactive phosphorus and ammoniacal nitrogen as well as nitrate-nitrogen and nitrite-nitrogen);
   - incorporating available groundwater age data to help determine whether contamination in aquifers is due to past or present land use;
   - using faecal sterol analysis or other testing methods to determine the origin of faecal contamination (human vs animal) in shallow groundwater; and
   - exploring the interaction between surface water and groundwater to help establish the contamination contribution made by groundwater to surface water and vice versa.

8. Consider establishing dedicated groundwater protection zones when Greater Wellington's Regional Freshwater Plan is next reviewed, with greater controls on discharges to land within these zones.

Contents

1. Introduction

Over the last decade there has been a major shift in the management of agricultural and municipal wastewater discharges in the Wellington region, with wastewater discharges directed away from surface water bodies and onto land wherever practicable. As a result, there are no longer any authorised (consented) agricultural discharges to rivers, streams or lakes in the Wellington region. While discharges to land have been promoted to help reduce the impacts on surface water quality and ecology, discharging waste onto land has potential implications for soil and groundwater quality. For example, high application rates of wastewater to land may induce leaching of nutrients, pathogens and other contaminants to groundwater, especially in shallow aquifers in winter when soil moisture levels are high. This can be a cause for concern where the groundwater is used for potable or stock water supply, or if the groundwater enters nearby surface water systems.

Routine Groundwater State of the Environment (GSoE) groundwater quality monitoring in the Wellington region has highlighted elevated nitrate concentrations (>3 mg/L as nitrate-nitrogen) in some areas, including the Hautere, Coastal, Otaki, Te Ore Ore, Upper Plain, Carterton, Parkvale, East Taratahi, Moroa, Matarawa and South Featherston groundwater zones (Jones & Baker 2005). As elevated nitrate concentrations in groundwater are potentially hazardous to human health and can impact on surface water quality, the Greater Wellington Regional Council (Greater Wellington) has undertaken targeted groundwater quality studies to investigate the extent of nitrate contamination in selected "at-risk" areas. This report summarises the results of six such studies undertaken in the Wairarapa during 2004 to 2008. These studies targeted intensive farming areas in Te Ore Ore, Carterton and South Featherston, expanding coastal settlements (Riversdale and Flat Point) and an area where there are an increasing number of rural/residential subdivisions serviced by on-site wastewater treatment systems (Norfolk Road).

In furthering our understanding of the extent and likely causes of poor groundwater quality in the region, the targeted studies provide important information that is needed in order to fulfil Objectives 4.1.4 and 4.1.6 of Greater Wellington's Regional Plan for Discharges to Land (WRC 1999). These objectives seek a significant reduction of contamination of surface water, groundwater and coastal water from discharges of human effluent to land (Objective 4.14), and a significant reduction of non-point source pollution of surface water and groundwater from agricultural activities (Objective 4.16).

1.1 Report outline

This report comprises nine sections. Section two provides a brief overview of the study areas and outlines sample site selection, methods and analysis. Findings from the six study areas are then reported individually in sections three to eight. Overall conclusions and recommendations are presented in section nine.

1.2 Nomenclature

In this report the dissolved nutrients nitrate-nitrogen, nitrite-nitrogen, ammoniacal nitrogen and dissolved reactive phosphorus, are referred to as nitrate, nitrite, ammonia and DRP respectively.

2. Study sites and methods

This section provides an overview of the study sites and sampling and analytical methods.

2.1 Study sites

A number of individual bores sampled quarterly in Greater Wellington's Groundwater State of the Environment (GSoE) monitoring programme have indicated the presence of elevated nitrate concentrations in the groundwater. The locations of these bores were used to determine the areas requiring targeted groundwater quality assessments. The resulting study areas incorporated two key land-uses with potential to impact on groundwater quality: intensive agricultural land use (Te Ore Ore, Carterton, South Featherston) and residential developments incorporating on-site wastewater discharges (Riversdale, Flat Point and Norfolk Road in Carterton) (Figure 2.1).

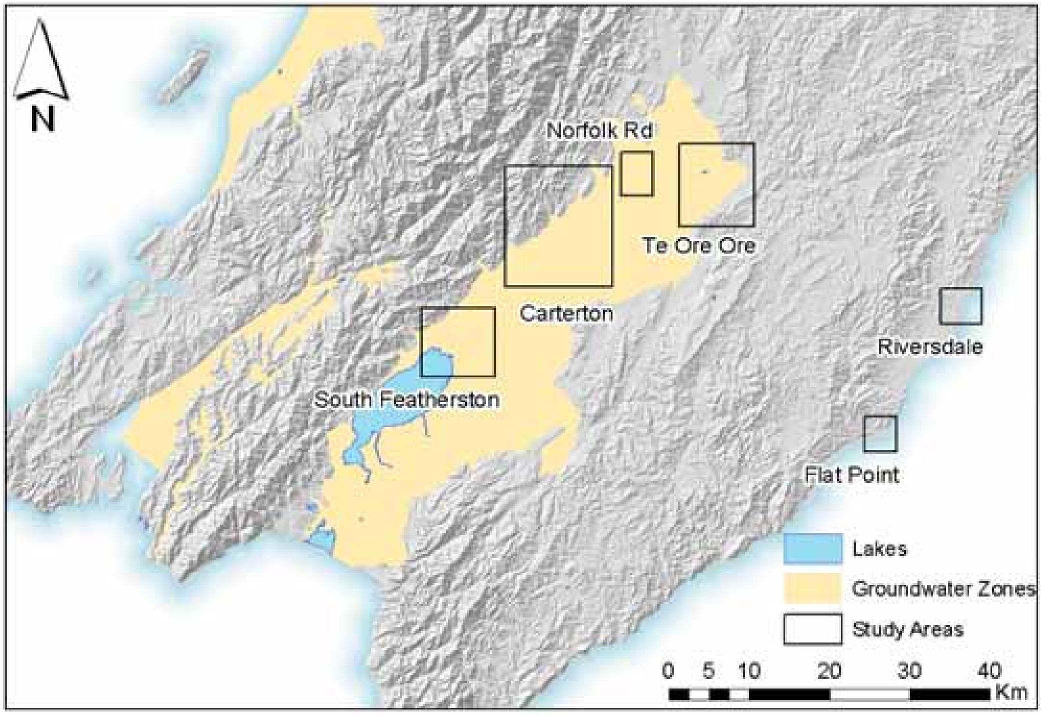

Figure 2.1: Location of the six study areas in the Wairarapa selected for targeted groundwater quality sampling on one or more occasions during 2004 and 2008.

2.2 Bore selection

A bore search of the GSoE network was conducted within areas requiring targeted groundwater quality assessments to locate existing bores that could be sampled. Sampling bores were selected taking into account spatial coverage, depth (bores within both shallow and deeper aquifers were targeted), usage and direction of groundwater flow. Sampling of the selected bores was then subject to land/bore owner approval. Refer to Appendix 1 for sampling bore details.

At Flat Point and Riversdale new bores were installed by Greater Wellington in order to assess groundwater quality.

2.3 Sampling methods and sample analysis

Groundwater samples were collected by trained Greater Wellington staff using nationally accepted protocols (Ministry for the Environment 2006). This involved purging the bore for a predetermined amount of time to remove any standing water and monitoring the pumped water continuously for parameter stabilisation. These practices were employed to make sure that the water sampled was representative of the aquifer. Care was also taken to ensure that the water sampled was not contaminated by other sources through mishandling of sampling equipment, containers or by other water sources.

Water samples were stored on ice upon collection and transported to Greater Wellington's contracted laboratories for analysis (Appendix 2) within 24 hours of sampling. Field measurements (temperature, conductivity, pH and dissolved oxygen) were taken using a YSI-556 or equivalent field meter and flow cell. Field meters were calibrated on the day of sampling.

Water samples were tested for one or more dissolved nutrients (nitrate, nitrite, ammonia and DRP) as well as faecal indicator bacteria (*Escherichia coli (E. coli)* and faecal coliforms). Not all variables were tested in each targeted study.

2.4 Data interpretation and presentation

Groundwater sample results were compared against the New Zealand National Drinking Water Standards (DWSNZ 2005). These standards apply to water used for human consumption and set a maximum acceptable value (MAV) of:

- 50 mg/L nitrate (NO_3) or an equivalent of 11.3 mg/L as nitrate-nitrogen (NO_3-N);
- 0.2 mg/L for nitrite (NO_2)[1] or an equivalent of 0.06 mg/L as nitrite-nitrogen (NO_2-N); and
- <1 cfu/100 mL for *E. coli* and faecal coliforms.

There are no MAVs for ammonia or DRP.

Groundwater nitrate concentrations were also evaluated in terms of likely human influence. Groundwater in New Zealand rarely demonstrates concentrations above 1 mg/L naturally (Close et al. 2001), therefore a threshold of 3 mg/L has been adopted as a means of defining nitrate contamination from anthropogenic sources (Close et al. 2001). This threshold follows the findings of a US study of nitrates (Madison & Brunett 1985) that concluded concentrations of nitrate in groundwater above 3 mg/L were due to human influence. Therefore, in this report, reference to elevated nitrate concentrations indicates the concentrations are above 3 mg/L.

[1] Provisional MAV for long-term exposure.

This report uses GIS plots for a spatial representation of the groundwater quality results as well as simple x-y plots to display nutrient concentrations against groundwater depth or rainfall. Interpretation of the results has been made taking into account land use, groundwater depth and rainfall. As most of the studies reported here only involved one-off sampling, temporal changes in groundwater quality are inferred from nearby GSoE monitoring bores. GSoE monitoring bores are sampled at three-monthly intervals, with data records going as far back as the early 1990s in some of the study areas. Note that no formal trend analysis was performed on GSoE monitoring data.

3. South Featherston groundwater quality study

3.1 Overview of the study area

The South Featherston study area is located south of Featherston Township, flanked on the western side by the Rimutaka Ranges and on the eastern side by the Tauherenikau River (Figure 3.1). The groundwater bores selected for sampling span over three different groundwater zones: Tauherenikau, South Featherston, and Lower Valley. In general the aquifers consist of gravels and sands from alluvial fans deposited by rivers in the area, with layers of marine silt and clays. Groundwater flow is expected to be in the general direction of Lake Wairarapa. The hydraulic conductivity of groundwater improves with distance from the Rimutaka Ranges and Tauherenikau River. Groundwater recharge is primarily by rainfall and runoff from side valleys, with some contributions from river sources (Butcher 1996).

Land use in the study area is predominantly agriculture with 55% of the land used for dairy faming, 12% for beef farming and 5% for pig farming (Appendix 3). Therefore, the main demands on groundwater supplies are for stock and irrigation water. There are also some domestic groundwater takes (Appendix 1).

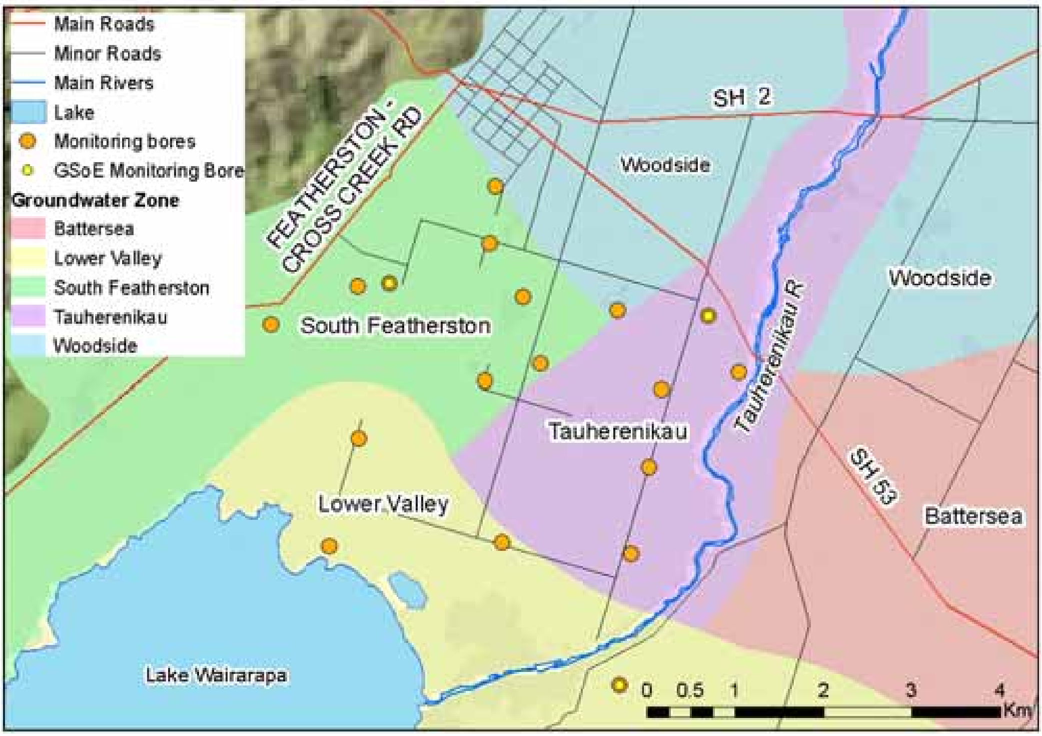

Figure 3.1: The location of the 18 South Featherston groundwater bores sampled on one occasion during November/December 2006 and the three GSoE bores sampled quarterly since 2004.

3.2 Groundwater sampling dates and variables

During November and December 2006 groundwater from 18 bores was sampled for concentrations of nitrate, nitrite, DRP and faecal and *E. coli* bacteria (refer Figure 3.1).

Results from the December 2006 Groundwater State of the Environment (GSoE) sampling programme from bores S27/0009, S27/0070 and S27/0299 were also used in the South Featherston study (Figure 3.1), with historic results from these bores used to investigate long term nitrate trends in the area.

3.3 Results

None of the 18 South Featherston bores sampled in late 2006 exceeded the DWSNZ (2005) MAV for nitrate. Concentrations ranged from 0.001 mg/L to 7.44 mg/L, with an overall mean concentration of 2.65 mg/L (refer Appendix 4 for the complete analytical results). However, seven bores recorded elevated nitrate concentrations (Figure 3.2). These bores appear to be clustered in the centre of the study area where land use is predominantly dairy farming with a piggery located about bores S27/0008 and S27/0009 (Figure 3.2).

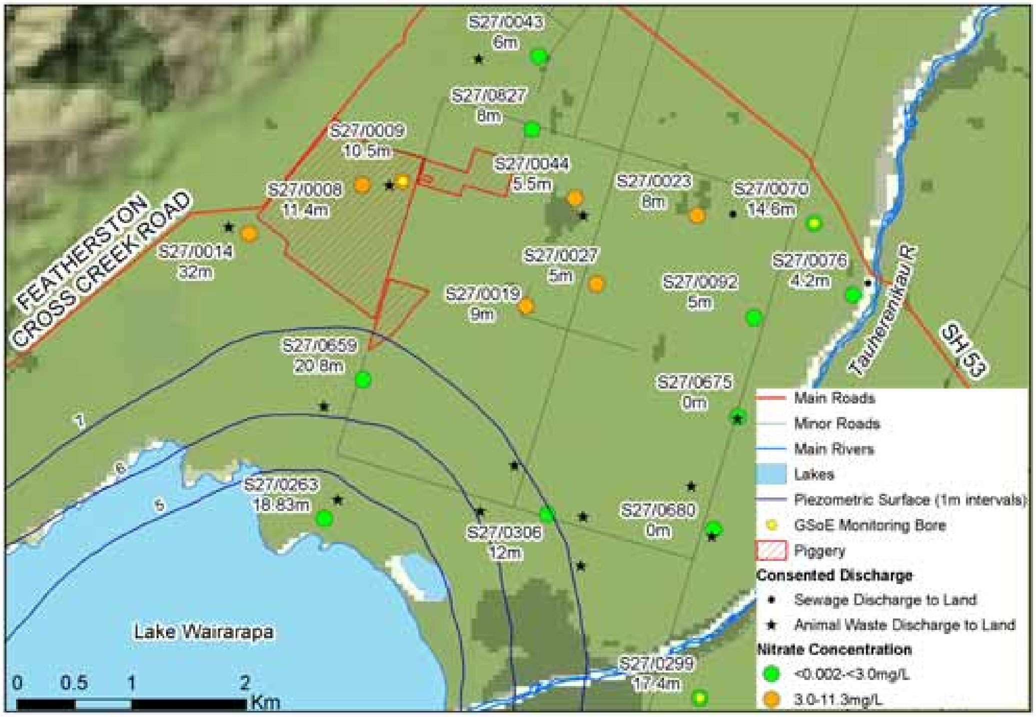

Figure 3.2: Nitrate concentrations recorded in South Featherston monitoring bores during November/December 2006. Consented discharges to land are also shown. Piezometric surveying is limited to the three contours shown in this figure.

An assessment of nitrate concentrations against bore depth indicates concentrations are higher in bores located within the shallow aquifers (Figure 3.3). Of the eleven bores that had recorded nitrate concentrations below 3 mg/L, four were at depths of 12m or greater. There was one elevated nitrate concentration of 5.74 mg/L recorded in bore (S27/0014) which is located in the deeper aquifer (32 m deep). Shallow bores with concentrations of nitrate less than 3 mg/L were situated alongside the Tauherenikau River just out of Featherston Township (Figure 3.3). It is possible that hydraulic conductivity is higher in this area due to losses from the Tauherenikau River, possibly resulting in dilution of nitrate concentrations in the groundwater.

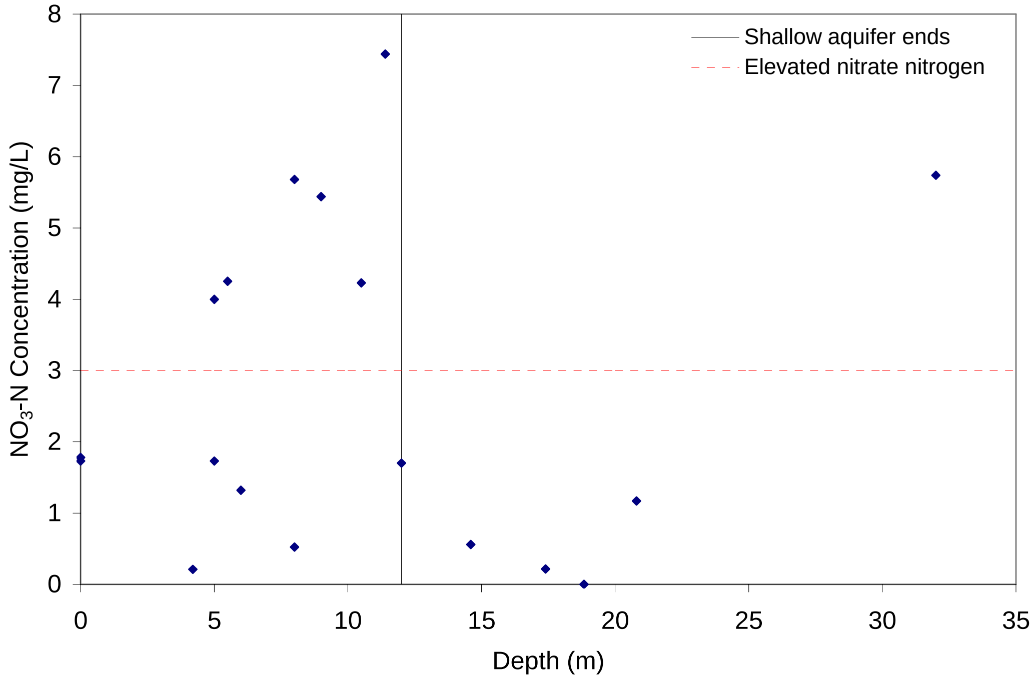

Figure 3.3: Bore depth compared against nitrate concentrations recorded in the South Featherston area during November/December 2006.

The only elevated DRP result (relative to the other bores) was from bore S27/0263 (0.407 mg/L) near the edge of Lake Wairarapa. The other 17 bores had DRP concentrations below 0.1 mg/L (Appendix 4).

All nitrite and faecal bacteria results were below their respective DWSNZ (2005) MAVs (Appendix 4), although faecal coliform and *E. coli* counts were only tested in samples from three bores.

3.4 Discussion

Sampling in the South Featherston area has highlighted that nitrate concentrations are low to elevated, with no bores exceeding the DWSNZ (2005) MAV for any variables tested. Elevated concentrations of nitrate are more evident in the shallower aquifer and are probably due to the farming practices undertaken in the area; the majority of the land is used for intensive dairy farming. There is also a piggery and some beef farming. In all, 13 of the 15 authorised (i.e., consented) discharges to land in the area are for animal waste (refer Figure 3.2).

Although seasonal and temporal variation in groundwater quality was not assessed in this study, records from the GSoE bores S27/0009, S27/0070 and S27/0299 (Appendix 5) indicate that nitrate concentrations vary with rainfall and season. Concentrations generally increase over the winter months or in months of greater rainfall (Figure 3.4). Monitoring results from bores S27/0009 and S27/0070 indicated that nitrate concentrations have not exceeded 3 mg/L to date. Both these bores are deeper than 15 m. Monitoring in the shallow bore S27/0009 shows nitrate concentrations are regularly above 3 mg/L. This is to be expected as most land use interaction occurs nearer the surface therefore groundwater in this zone is subject to infiltration from surface waters affected by fertilisers, effluent and other discharges to land.

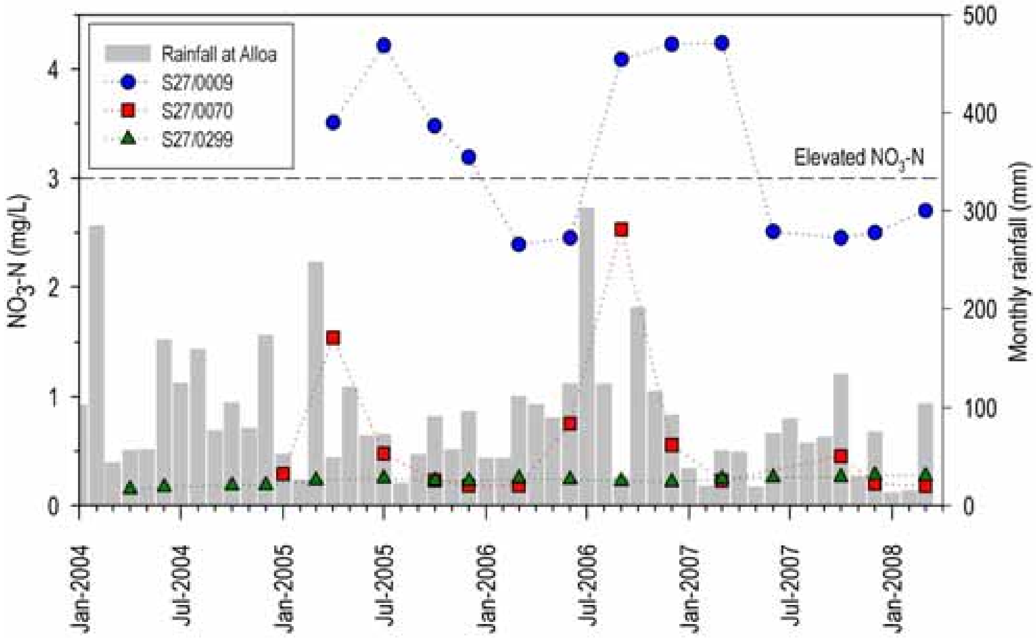

Figure 3.4: Nitrate concentrations recorded in South Featherston GSoE monitoring bores compared against total monthly rainfall from Tauherenikau at Alloa rain gauge (4 km N of South Featherston) over 2005 to 2008.

The elevated nitrate concentration recorded in the 32m deep bore S27/0014 is of concern. The reason for this result is unknown; it may indicate a degree of connectivity between the upper and lower aquifer in the area with contamination of the lower aquifer occurring as groundwater flows between the two aquifers. The elevated nitrate concentration in this bore may also be due to point source contamination directly to the bore, poor bore construction or a sampling error. Re-sampling of this bore is therefore recommended. Re-sampling of bore S27/0623 is also recommended as the DRP concentration recorded in this bore was unusually high.

Any future groundwater sampling in the South Featherston area should also include shallow bores in close proximity to Lake Wairarapa as limited piezometric surveying around Lake Wairarapa suggests that groundwater is flowing towards the lake (refer Figure 3.2). Greater Wellington lake water quality monitoring results indicate the lake is highly eutrophic (Perrie 2005), with elevated groundwater nutrient inputs likely to be a significant contributing factor.

4. Carterton groundwater quality study

4.1 Overview of the study area

The Carterton study area is located between the Mangatarere Stream and Waiohine River. The area is flanked on the western side by the Tararua Ranges.

The groundwater bores sampled span over the Carterton, Greytown, Parkvale, Hodders, Matarawa and Mangatarere groundwater zones (Figure 4.1). The area comprises an alluvial fan formed at the base of the Tararua Ranges consisting of poorly sorted sediments (cobbles, gravel, sand, silt and clay). Sediments become more well-sorted with increased distance towards Carterton. A low yielding unconfined aquifer is present over much of the alluvial fan area; the degree of confinement in this area may increase with depth. The unconfined aquifer gradually separates down gradient around Carterton to a low to medium yielding layered leaky aquifer system, which has increasing confinement with depth.

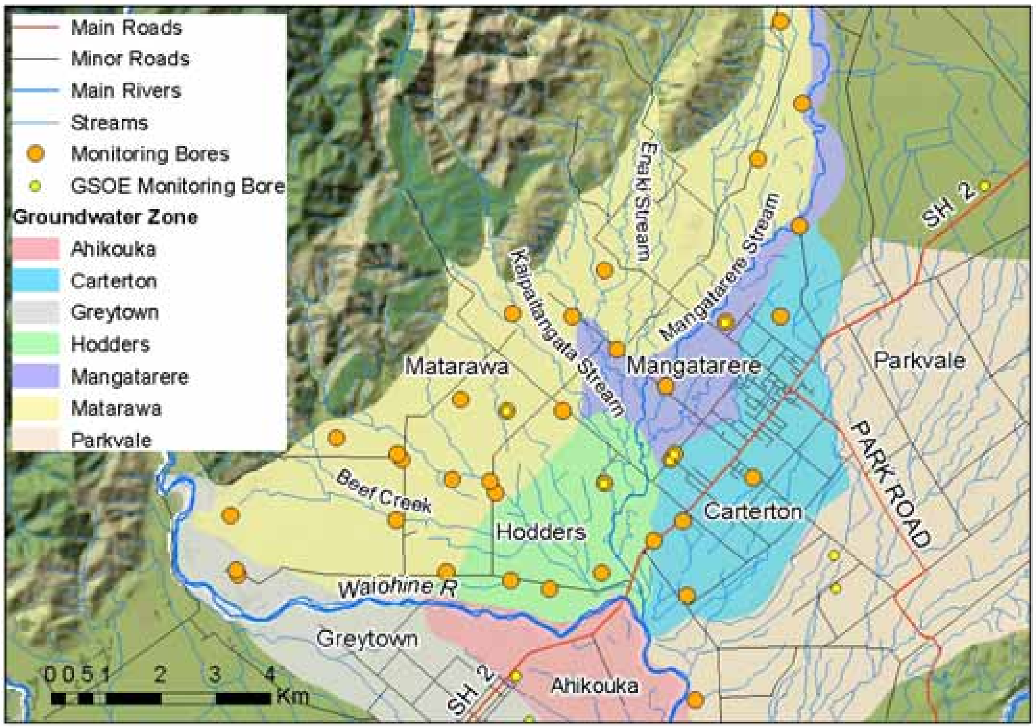

Figure 4.1: The location of the 36 Carterton groundwater bores sampled on one occasion during November/December 2006 and the five GSoE bores sampled quarterly since 2004.

Piezometric surveying in the area suggests that groundwater moves from the hill country and discharges as base flow to the spring-fed Beef Creek and Enaki and Kaipaitangata streams, the Mangatarere Stream south of Andersons Line and the Waiohine River. Hydraulic conductivity is low in the area from the Tararua Ranges to the Mangatarere Stream but improves from the Mangatarere Stream to the Parkvale and Carterton groundwater zones. Recharge is thought to come from primarily rainfall and run-off from side valleys, and leakage from the Mangatarere Stream above Andersons Line.

Land use in the Carterton study area comprises around 57% dairy farming, 9.5% sheep and beef farming and 2% pig farming (Appendix 3). Groundwater is abstracted for a mixture of rural domestic, stock, horticultural, irrigation and municipal water supplies (Appendix 1).

4.2 Groundwater sampling dates and variables

During November and December 2006 groundwater from 36 bores was sampled for concentrations of nitrate, nitrite, DRP and faecal and *E. coli* bacteria (refer Figure 4.1).

Results from the December 2006 Groundwater State of the Environment (GSoE) sampling programme from bores S26/0705, S26/0824, S26/0117, S26/0439 and S26/0467 were also used in the Carterton study (refer Figure 4.1), with historic results from these bores used to investigate long term nitrate trends in the area.

4.3 Results

The 36 bores sampled in the Carterton area during 2006 had nitrate concentrations ranging from 0.001 mg/L to 16.1 mg/L with an overall mean concentration of 4.01 mg/L. A complete list of analytical results can be found in Appendix 4.

Nitrate concentrations in two bores exceeded the DWSNZ (2005) MAV (Figure 4.2). Both of these bores (S26/0097 and S26/0877) are less than 12m deep and are located to the north west of Carterton township. There were 16 bores that had nitrate concentrations in the elevated status while the remaining 18 bores had concentrations below 3 mg/L (Appendix 4). Bores with elevated nitrate concentrations are situated in the centre of the monitoring area and around the upper reaches of the Mangatarere Stream (Figure 4.2).

An assessment of nitrate concentrations against bore depth indicates that nitrate concentrations appear to be higher in bores located in the shallow and unconfined aquifer (Figure 4.3). Two deep bores S26/0824 (20.6m deep) and S26/0705 (27.4m deep) also had nitrate concentrations in the elevated range. These bores are located next to each other to the east of the lower reaches of the Mangatarere Stream and form part of the public water supply for the Carterton District.

Nitrite concentrations were below the DWSNZ (2005) MAV in all but one bore on one occasion (Appendix 4). DRP concentrations were generally low with only four sites (S26/0345, S26/0362, S26/0449 and S26/0666) recording concentrations above 0.1 mg/L (Appendix 4).

Samples from six bores were analysed for faecal bacteria. Two of the six bores (S26/0117 and S26/0169) recorded bacteria counts above the detection limit with one very high faecal and *E. coli* result (700 cfu/100mL) recorded in bore S26/0169 (Appendix 4). This bore is 7.65m deep and located on a pig farm (Figure 4.2).

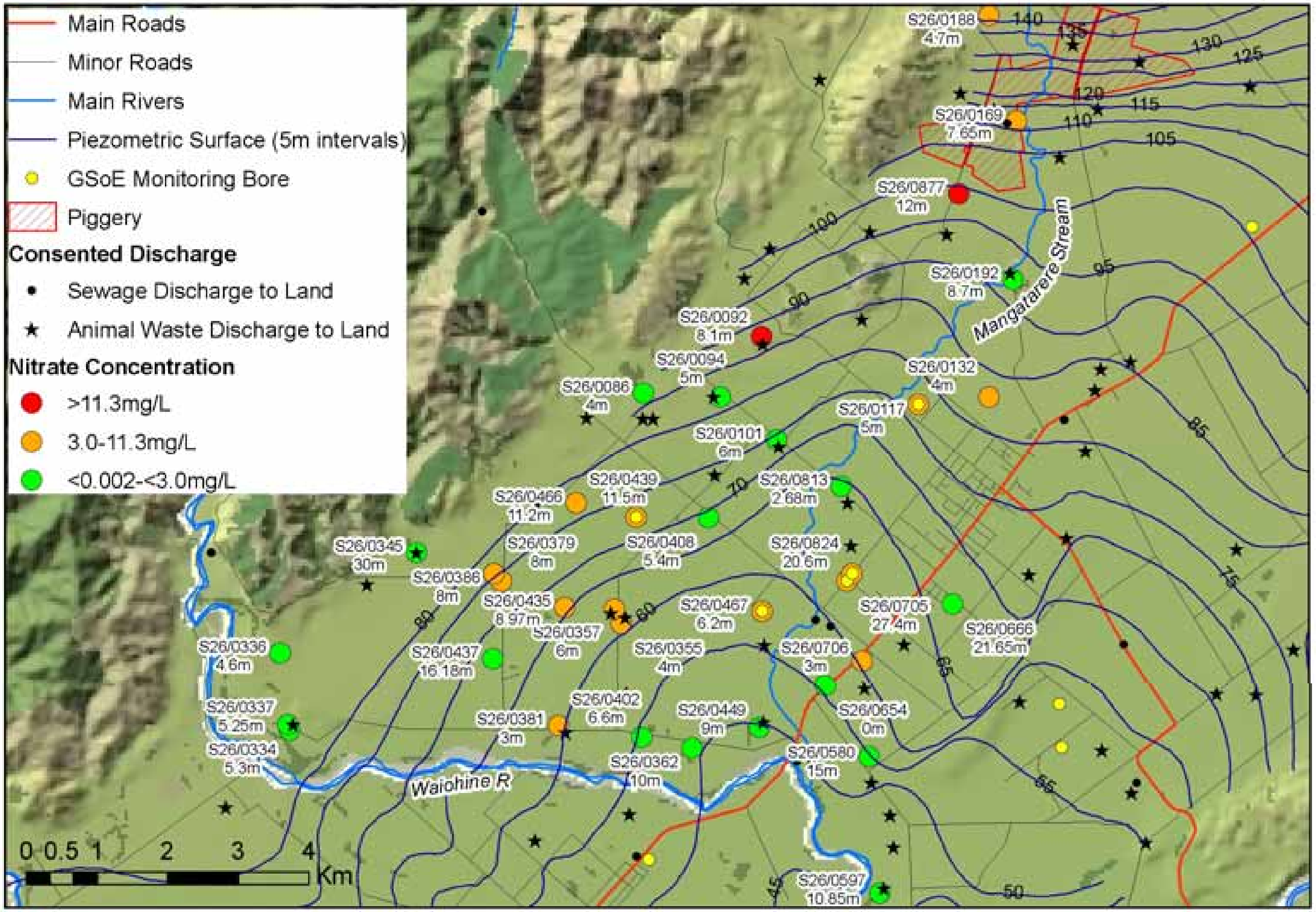

Figure 4.2: Nitrate concentrations recorded in Carterton monitoring bores during November/December 2006. Key consented discharges to land are also shown.

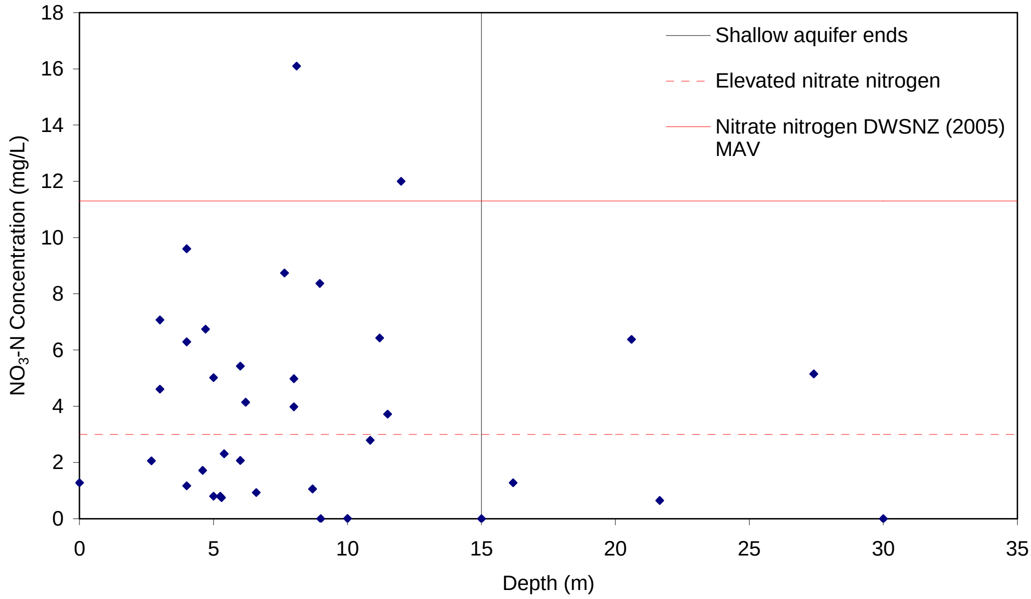

Figure 4.3: Bore depth compared against nitrate concentrations recorded in the Carterton area during November/December 2006.

4.4 Discussion

Sampling in 2006 in the Carterton area has highlighted that nitrate concentrations are elevated in many bores and in two bores, S26/0092 and S26/0877, exceed the DWSNZ (2005) MAV. Bore S27/0877 is situated downgradient of a large piggery (Figure 4.2) while bore S26/0092 is surrounded by dairy farming. Both bores supply groundwater for domestic supply (Appendix 1) and are in an area where recharge infiltrates into a large aquifer system. There are at least five other bores with nitrate concentrations in the upper elevated range that also supply groundwater for domestic supply (Appendix 1).

The presence of elevated nitrate concentrations in the shallow groundwater – and the elevated faecal coliform result in bore S26/0169 – are attributed to the intensive farming practices undertaken in the study area; there are 35 consented animal waste discharges to land. Most are dairyshed effluent discharges with the exception of a large piggery. There are also three consented sewage discharges in the area including the discharge from the Carterton Wastewater Treatment Plant (refer Figure 4.2).

Elevated nitrate concentrations are also seen in several deep bores. This is not surprising as it is suspected that the deeper aquifer is only semi–confined, indicating that shallow groundwater affected by land use may be reaching deeper aquifers. Given piezometric surveying information suggests that groundwater flows into the Mangatarere Stream and its tributaries, it is very likely that contamination in the shallow aquifer is contributing to the degraded surface water quality in the catchment reported by Perrie (2007, 2008)[2].

[2] The Mangatarere Stream at SH 2 consistently exceeds national (ANZECC 2000) water quality guidelines for dissolved and total nutrients.

All five GSoE monitoring bores (S26/0705, S26/0824, S26/0117, S26/0439 and S26/0467) indicate nitrate concentrations in central Carterton have been above 3 mg/L since groundwater quality monitoring commenced in 1998 (Figure 4.4, Appendix 5). Nitrate concentrations appear to increase seasonally in the winter months or in months of greater total monthly rainfall (Figure 4.4)[3]. Concentrations are more stable in the deeper bores (S26/0705 and S26/0824) than in the shallow bores (S26/0117, S26/0439 and S26/0467) which are more responsive to rainfall. Monitoring in both the deep and shallow GSoE bores indicates a slight decrease in nitrate concentrations from 1998 to present. The reason for this decrease has yet to be investigated. There is only a limited amount of groundwater level data so no trend between groundwater level and rainfall can be made.

Further investigation of both surface water and groundwater quality in the Mangatarere catchment is required. Future studies would require the installation of an additional rain gauge to accurately measure the amount of rainfall the Carterton area receives. This has been recognised in a Greater Wellington hydrological monitoring network review carried out in 2006 (Watts 2006).

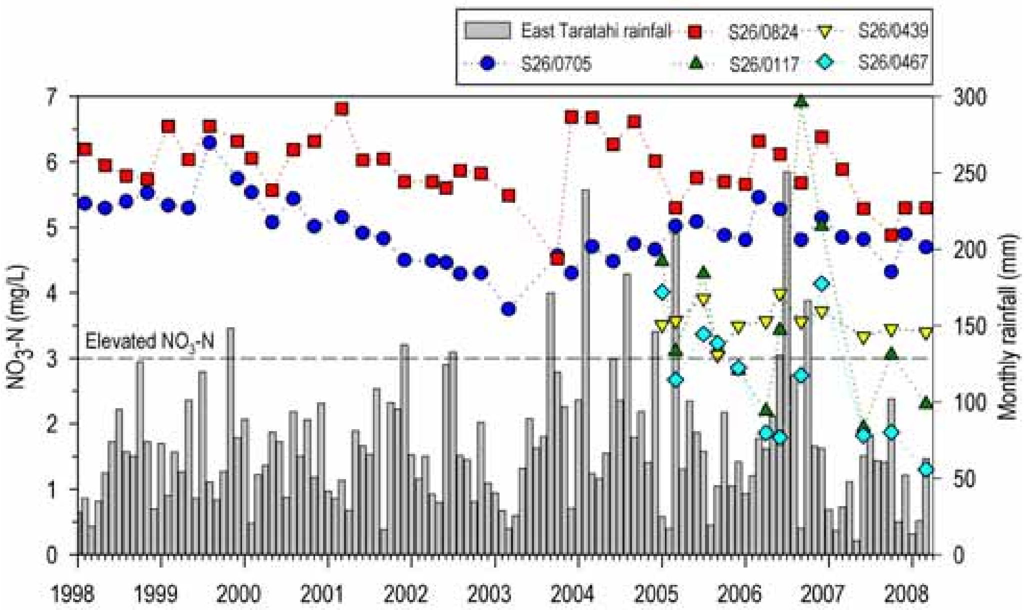

Figure 4.4: Nitrate concentrations recorded in the Carterton GSoE monitoring bores compared against total monthly rainfall from the East Taratahi meteorological station rain gauge over 1998 to 2008.

[3] There is no rain gauge in the Carterton study area therefore information from a MetService site at East Taratahi meteorological station (located 13 km East of the Carterton study area) was used to compare NO_3-N concentrations against monthly rainfall.

5. Te Ore Ore groundwater quality study

5.1 Overview of the study area

The Te Ore Ore study area is situated east along the Masterton-Castlepoint Road on the outer edge of Masterton. Te Ore Ore geologically is situated in a basin which is contained in the north and east by Tertiary hill country and in the west by alluvial fan deposits from the Waingawa and Waipoua rivers. The Whangaehu River runs along the eastern basin boundary while the Ruamahanga River runs along the western boundary (Butcher 1997).

The area comprises alluvial sediments (sand and gravel) interlain with finer grained flood plain silts and clays. Sediments are generally well sorted and form a sequence of transmissive leaky connected aquifers. Hydraulic conductivity is generally good in the majority of the aquifers. Piezometric surveying suggests that groundwater moves in a southerly direction from the top of the monitoring area (Te Ore Ore-Bideford Road) towards the confluence of the Ruamahanga and Whangaehu rivers (Figure 5.1) and discharges to the spring-fed Poterau Steam running through central Te Ore Ore (Figure 5.1). Rainfall and river contributions from the Ruamahanga River are thought to provide groundwater recharge (Butcher 1997).

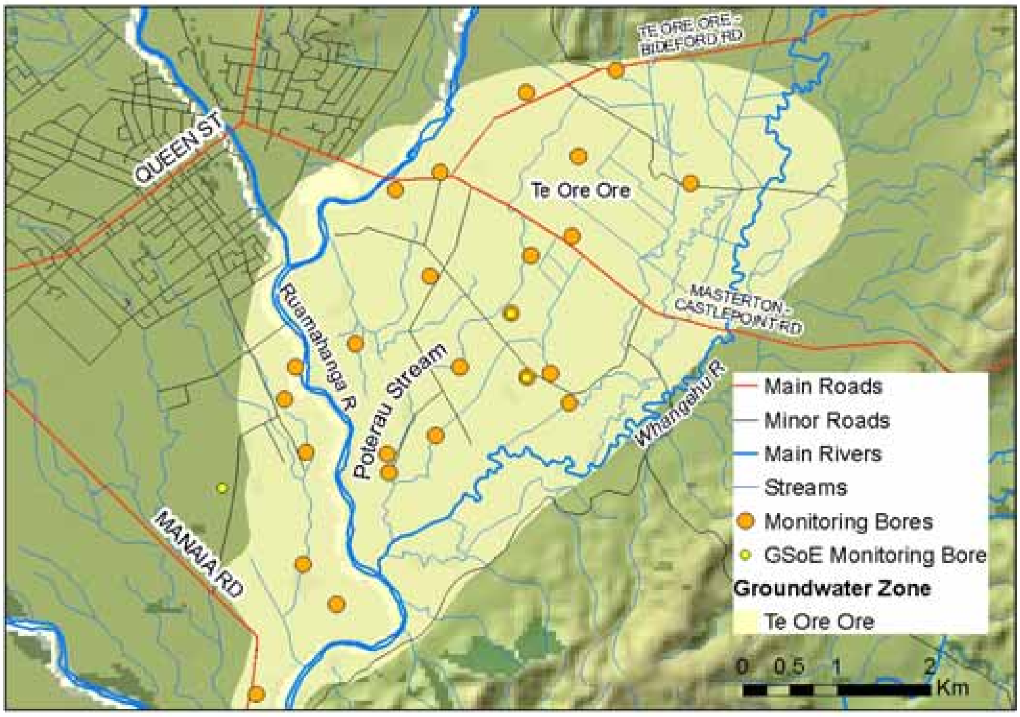

Figure 5.1: The location of the 24 Te Ore Ore groundwater bores sampled on two separate occasions, once during November/December 2005 and again during November/December 2007.

Land use comprises around 20% dairy farming, 10% beef farming, 16% sheep farming and 11% grazing (Appendix 3). Groundwater is mainly used for stock and irrigation purposes. However, with the area being increasingly been subdivided the land use is changing and there is a rising demand on the shallow groundwater aquifer for domestic supply.

5.2 Groundwater sampling dates and variables

Te Ore Ore bores were sampled on two occasions, once in 2005 and then again in 2007. Sampling occurred in the months of November or December in both years. Twenty-four bores were sampled in 2005 while 18 bores were sampled in 2007 (refer Figure 5.1). Bores were sampled for concentrations of nitrate and nitrite.

Results from the December 2005 and 2007 Groundwater State of the Environment (GSoE) sampling programme for bores T26/0489 and T26/0538 were also used in the Te Ore Ore study (Figure 5.1, with historic results from these bores used to investigate long term nitrate trends in the area.

5.3 Results

The 24 bores sampled in Te Ore Ore in late 2005 had nitrate concentrations ranging from 0.063 mg/L to 15.3 mg/L, with an overall mean concentration of 4.98 mg/L. A complete list of analytical results can be found in Appendix 4.

Bores T26/0557, T26/0541 and T26/0508 recorded nitrate concentrations above the DWSNZ (2005) MAV. A further two bores (T26/0489 and T26/0538) had nitrate concentrations very close to the MAV threshold. There were 11 bores with concentrations above 3 mg/L while the remaining 10 bores had concentrations below the elevated threshold (Figure 5.2).

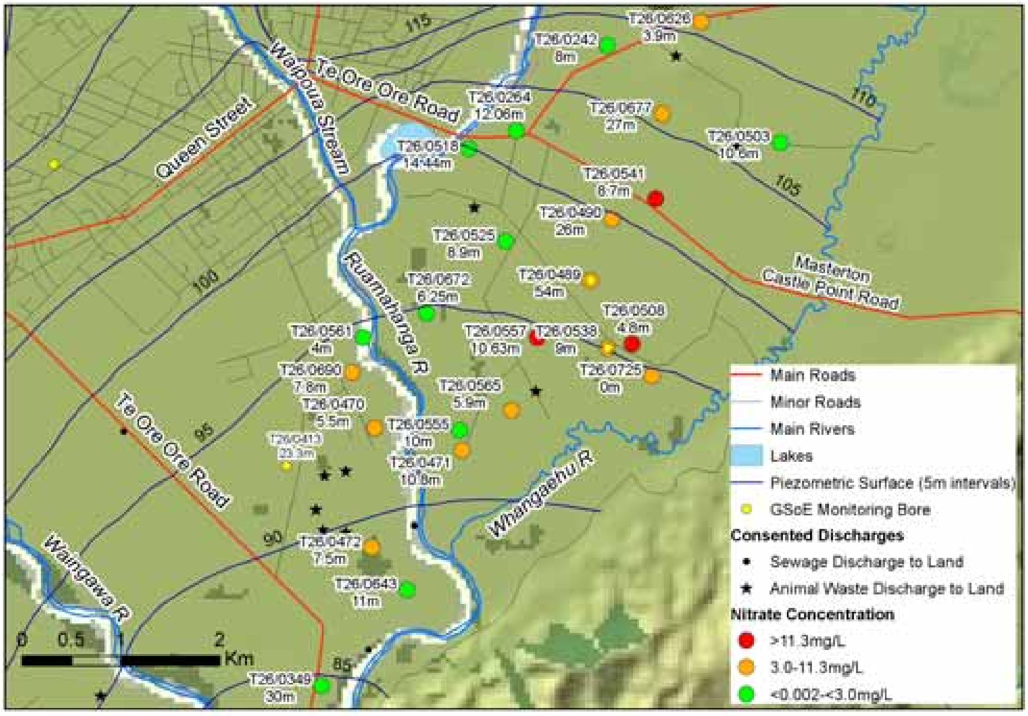

Figure 5.2: Mean nitrate concentrations recorded in Te Ore Ore monitoring bores during November/December 2005 and 2007. Key consented discharges to land are also shown.

Nitrate concentrations for the 18 bores re-sampled in 2007 ranged from 0.049 mg/L to 13.0 mg/L, with an overall mean concentration of 4.61 mg/L (Appendix 4). Monitoring in 2007 indicated that one deep bore (T26/0490) exceeded the DWSNZ (2005) MAV (Figure 5.3). Seven bores had nitrate concentrations above 3 mg/L while concentrations in the remaining 10 bores were below the elevated threshold.

It should be noted that six of the bores in the 2005 sampling round were not re-sampled in 2007. Nitrate concentrations in two of the bores (T26/0541 and T26/0508) sampled in 2005 but not in 2007 were above the DWSNZ (2005) MAV.

A comparison of the 2005 and 2007 results show that nitrate concentrations in 11 of the 18 bores re-sampled were lower, while concentrations in six of the bores were higher. Generally changes in nitrate concentrations were relatively minor, except in bore T26/0490 where the concentration was almost two times higher in 2007 (Figure 5.3).

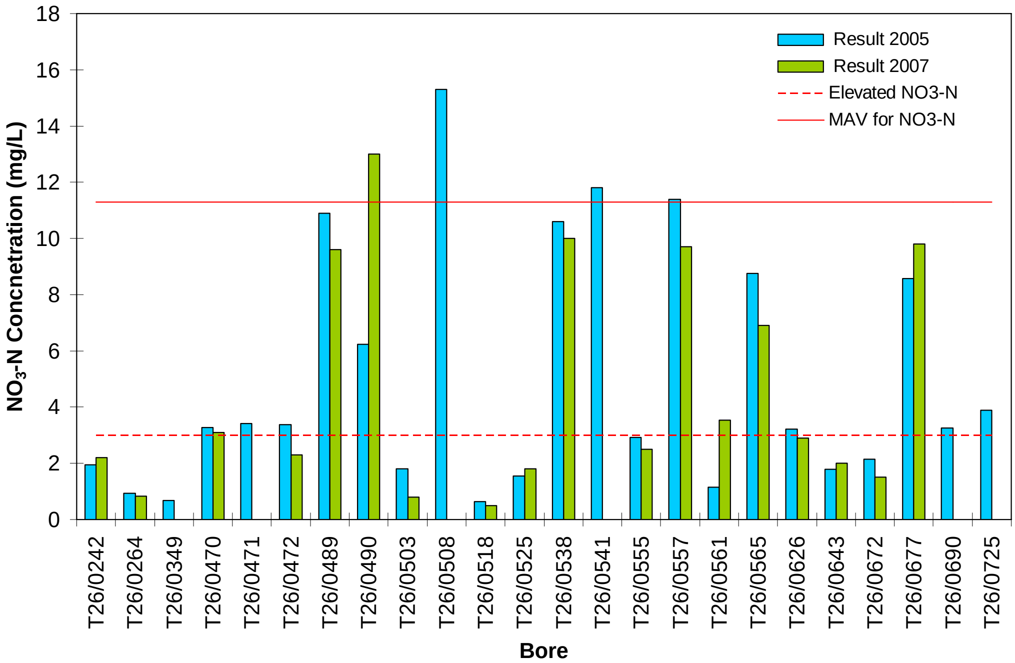

Figure 5.3: A comparison of nitrate concentrations recorded in the Te Ore Ore bores on two separate sampling occasions during late 2005 and 2007.

Elevated concentrations of nitrate are situated in the central region of the monitoring area where land use is a mixture of sheep and beef and dairy farming. An assessment of nitrate concentrations against bore depth shows that nitrate concentrations are generally greater in the shallow aquifer. There are two elevated results recorded in bores T26/0489 (54m deep) and T26/0667 (27m deep) suggesting that the deeper aquifers are connected with shallower groundwater zones and are also affected by land use (Figure 5.4).

All nitrite results in 2005 and 2007 were below the DWSNZ (2005) MAV (Appendix 4).

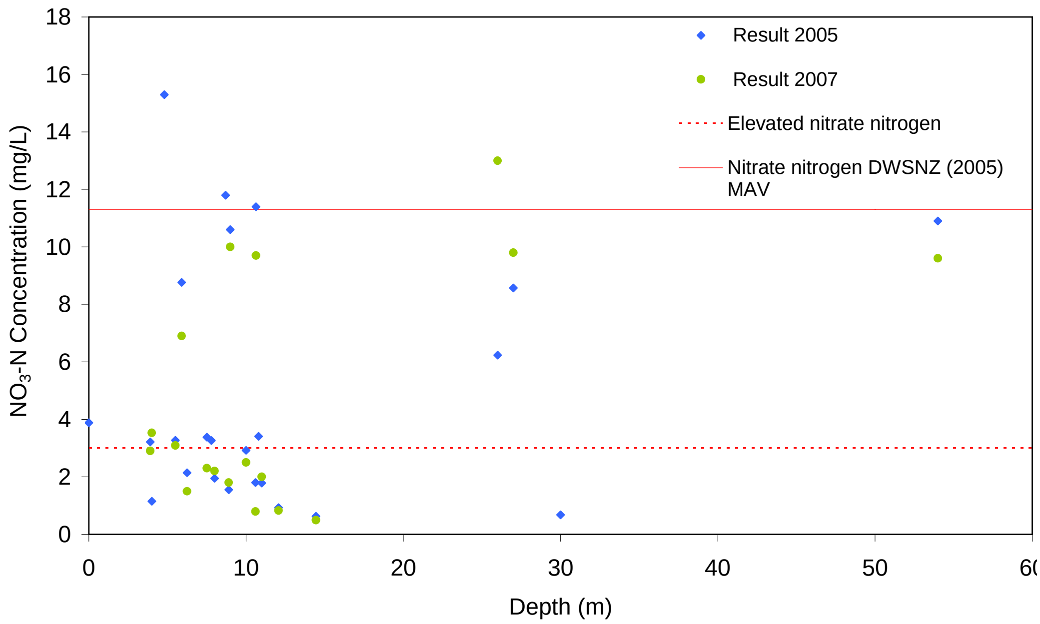

Figure 5.4: Bore depth compared against nitrate concentrations recorded at Te Ore Ore during late 2005 and 2007.

5.4 Discussion

Sampling in the Te Ore Ore area has highlighted a range of nitrate concentrations above and below elevated status with concentrations in three bores exceeding the DWSNZ (2005) MAV. Records of bore use show that two of the three bores are used for domestic purposes. A number of other bores with elevated nitrate concentrations are also used for domestic supply (Appendix 1).

Sampling was conducted once in 2005 and again in 2007 but as a number of bores identified with high nitrate concentrations in 2005 were not re-sampled in 2007 it was not possible to determine the significance of nitrate contamination at these bores.

Monitoring in GSoE bores T26/0489 and T26/0538 indicate nitrate concentrations in groundwater at Te Ore Ore have historically been above 11.3 mg/L (Appendix 5). Bore T26/0489 is 54m deep and nitrate concentrations follow an expected stable seasonal cycle; concentrations generally increase in winter or in months of greater rainfall (Figure 5.5). In contrast, bore T26/0538 is only 9m deep and concentrations of nitrate regularly exceed the DWSNZ (2005) MAV, with a maximum concentration of 15.8 mg/L recorded in June 2004. Nitrate concentrations also appear to be steadily increasing over time in bore T26/0538 and are often higher in the summer months (Figure 5.5).

Groundwater levels generally increase over winter or in months of greater rainfall totals but it can take up to a month for response to become evident. Groundwater levels also appear to be decreasing in the shallow bore T26/0538 (Figure 5.6).

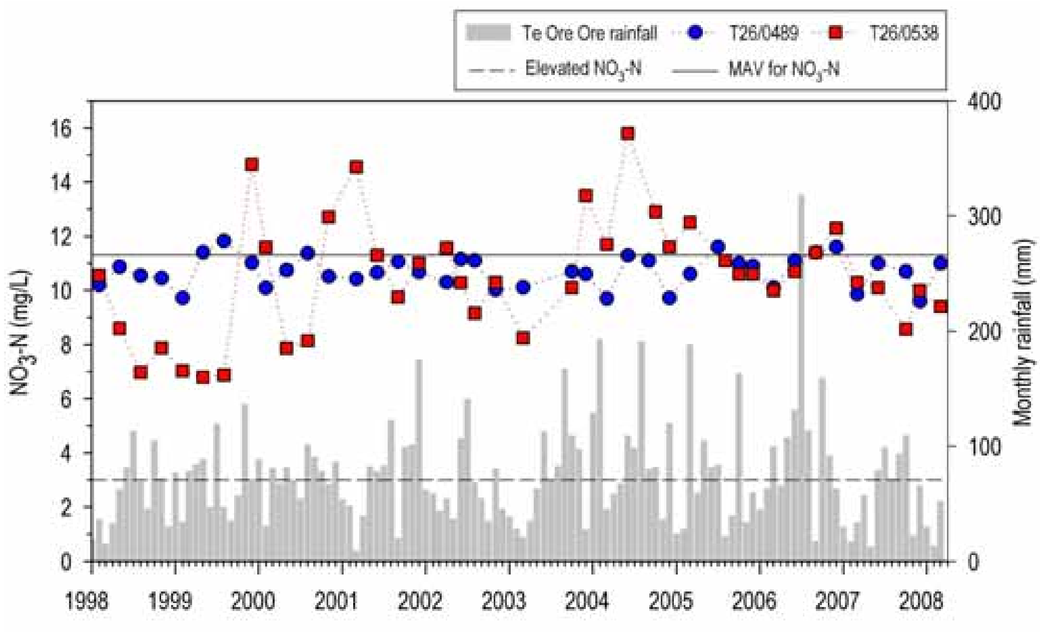

Figure 5.5: Nitrate concentrations in GSoE monitoring bores in Te Ore Ore from 1998 to present compared against total monthly rainfall recorded at the Te Ore Ore meteorological station.

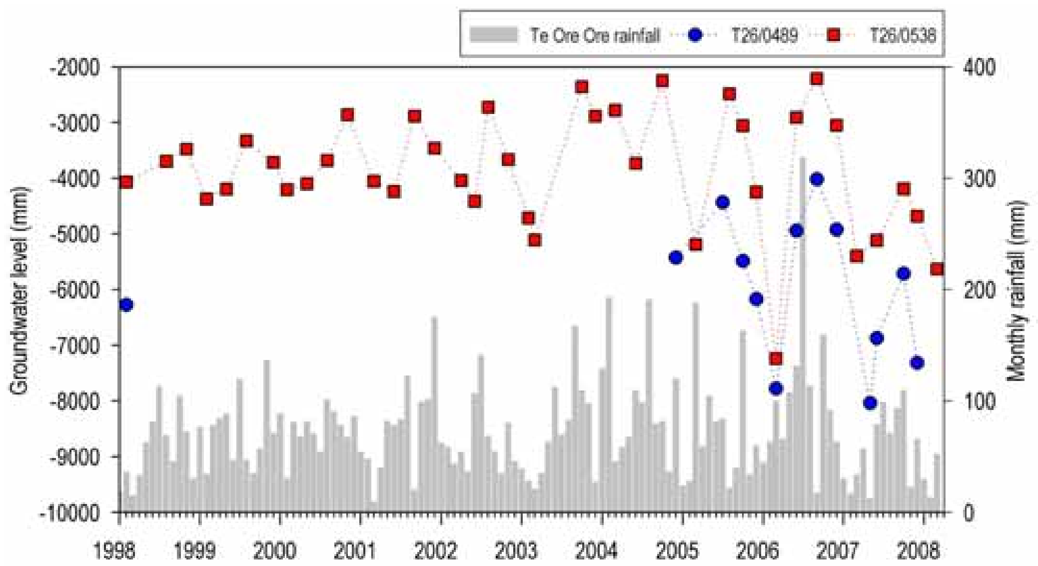

Figure 5.6: Groundwater levels recorded in GSoE monitoring bores in Te Ore Ore from 1998 to present compared against total monthly rainfall recorded at Te Ore Ore meteorological station.

There are nine consented animal waste discharges to land and three consented sewage discharges in the area (refer Figure 5.2). There are no consented discharges near the three bores (T26/0557, T26/0541 and T26/0508) that exceeded the DWSNZ (2005) MAV. These bores, along with other bores with elevated nitrate concentrations, are situated in the central region (Figure 5.2) of the monitoring area where land use is mainly a mixture of sheep, beef and dairy farming (Appendix 3).

It is possible that elevated nitrate concentrations in the shallow aquifer are impacting on water quality in the Poterau Stream; chemical analysis from a one-off surface water sample taken from the stream in March 2008 returned a nitrate concentration of 1.8 mg/L. This result is an order of magnitude above the Australian and New Zealand Environmental and Conservation Council (ANZECC 2000) guidelines for lowland streams (0.444 mg/L).

Nitrate contamination is not only limited to shallow bores; high concentrations were recorded in deeper bores. This suggests a degree of connectivity between the upper and lower aquifers in Te Ore Ore and that contamination in groundwater has reached an advanced and stable level in the deeper aquifers. Contamination in deeper aquifers could also be the result of poor bore construction.

Further groundwater investigations are needed in the Te Ore Ore area. This should include re-sampling the six bores that were not re-sampled in 2007. Age-dating of groundwater in the Te Ore Ore area has indicated that current nitrate contamination is due to past land use practices (van der Raaij 2000). Intensification of farming practices and development of housing in Te Ore Ore over recent years could mean the nutrient load in the aquifer has increased but concentrations are not yet evident in the bores currently sampled due to slow recharge rates (van der Raaij 2000). There is no reticulated sewage scheme or water supply in the Te Ore Ore area therefore water is expected to be increasingly abstracted as subdivision grows.

6. Norfolk Road groundwater quality study

6.1 Overview of the study area

The Norfolk Road study area is located south of Masterton off State Highway 2 in the West Taratahi groundwater zone (Figure 6.1). West Taratahi is in the floodplains of the Waingawa and Mangatarere rivers and due to close distance to the Tararua Ranges much of the material deposited in this area consists of poorly sorted sands and gravels with a high percentage of silts and clays (Butcher 1996). An unconfined aquifer exists to a depth of 25m but due to the presence of silts and clay the hydraulic conductivity is low (Butcher 1996). Shallow groundwater is thought to flow approximately parallel with Norfolk Road with rainfall the main source of recharge (Butcher 1996).

The Norfolk Road study area is located on the up-thrown side of the Masterton Fault. At the base of the Masterton Fault spring flow discharges into a QEII covenanted wetland behind the old Waingawa freezing works and a tributary of the Parkvale Stream forms from this wetland (Figure 6.1).

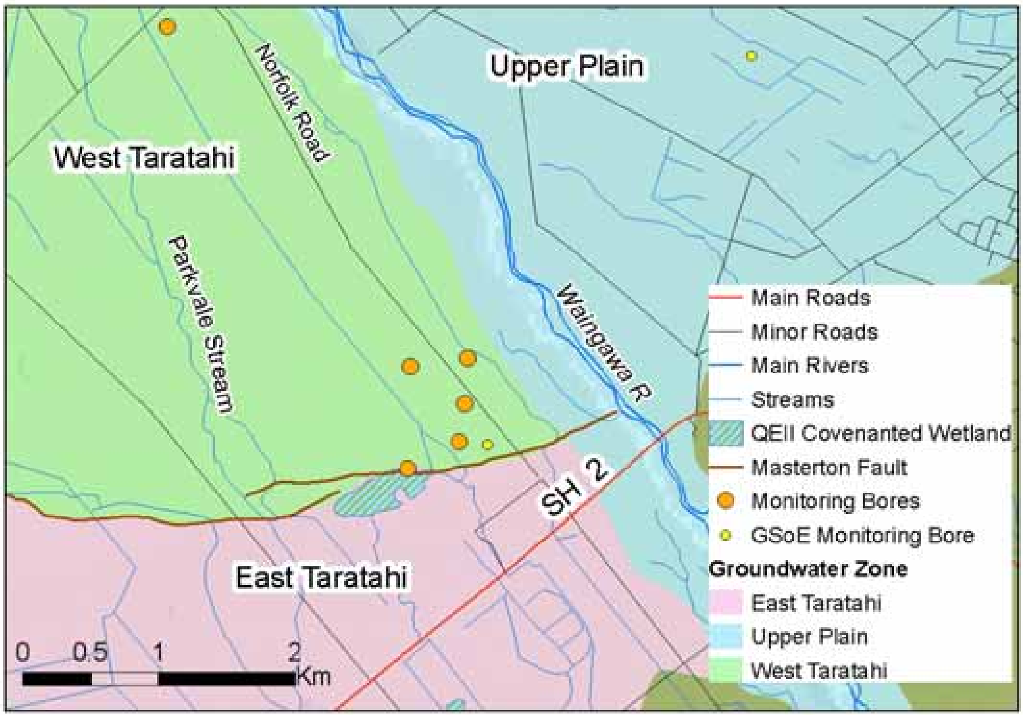

Figure 6.1: The location of the six groundwater bores sampled in the Norfolk Road study area from May 2007 to present.

With land use in the area comprising around 71% beef and sheep farming (Appendix 3), groundwater is largely abstracted for rural domestic and stock watering with some small pastoral and horticultural abstracts for irrigation (Appendix 1). Historical land use included a poultry farm and an abattoir (both no longer operating). Growing interest in rural/residential subdivision and development around Norfolk Road has increased the potential number of on-site wastewater systems installed in the area. This study was therefore conducted to establish an understanding of background nitrate concentrations in the area while the scale of development remained relatively small.

6.2 Groundwater sampling data and variables

Sampling of six bores (one a spring[4]) located in the shallow unconfined aquifer began in May 2007 (refer Figure 6.1). These bores were sampled bi-monthly for nitrate, nitrite, DRP and faecal and *E. coli* bacteria. There were a total of five sampling events during the reporting period (May 2007 to April 2008) but not all bores yielded a water sample on every sampling occasion.

Historic results from the quarterly Groundwater State of the Environment (GSoE) monitoring bore S26/0299 (Figure 6.1) were used to investigate long term nitrate trends in the area. This bore is sampled quarterly under the GSoE programme.

6.3 Results

Nitrate concentrations in the six bores sampled between May 2007 and April 2008 ranged from 0.117 mg/L to 3.99 mg/L, with overall mean and median concentrations of 1.89 mg/L and 1.79 mg/L respectively. A complete list of analytical results can be found in Appendix 4. None of the samples collected over the reporting period had nitrate concentrations above the DWSNZ (2005) MAV of 11.3 mg/L.

The highest nitrate concentration recorded was 3.99 mg/L from the spring S26/0244. Median nitrate concentrations for the reporting period were below the elevated threshold in all six bores (Figure 6.2).

Generally nitrate concentrations in all bores follow a relatively stable seasonal cycle with concentrations increasing over the winter months when rainfall is higher and decreasing during the summer months (Figure 6.3). Bore S26/0051 and the spring S26/0244 were particularly affected over the winter months. Nitrate concentrations in the spring S26/0244 sharply increase from 1.71 mg/L in May 2007 to 3.99 mg/L in August 2007 and slowly decrease to 1.4 mg/L in February 2008. Similarly in bore S26/0051, the nitrate concentration was 0.117 mg/L in May 2007 and increased to 1.95 mg/L in August 2007. Concentrations then decreased over summer (Figure 6.3).

E. coli and faecal coliform counts in bores S26/0256, S26/0244 and S26/0220 periodically exceeded the DWSNZ (2005) MAV of <1 cfu/100 mL. The highest *E. coli* and faecal coliform counts recorded were 410 and 450 cfu/100 mL respectively; both measurements were recorded in the spring S26/0244 during sampling in November 2007 (Appendix 4).

All nitrite concentrations were below the DWSNZ (2005) MAV on every sampling occasion while DRP concentrations did not reach levels of concern in any of the bores sampled (Appendix 4).

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[4] Bore S26/0244 is a spring that feeds into the Waingawa Wetland and samples are collected where groundwater discharges to the surface (refer Figure 6.1).

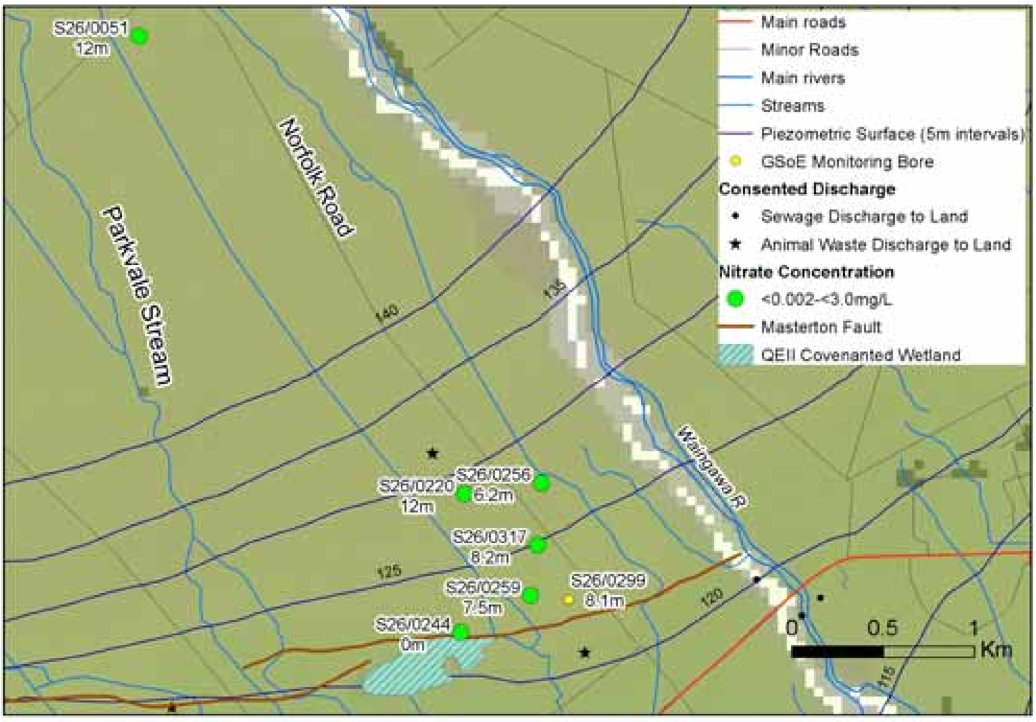

Figure 6.2: Median nitrate concentrations recorded in the Norfolk Road study area bores sampled bi-monthly, May 2007-April 2008. Key consented discharges to land are also shown.

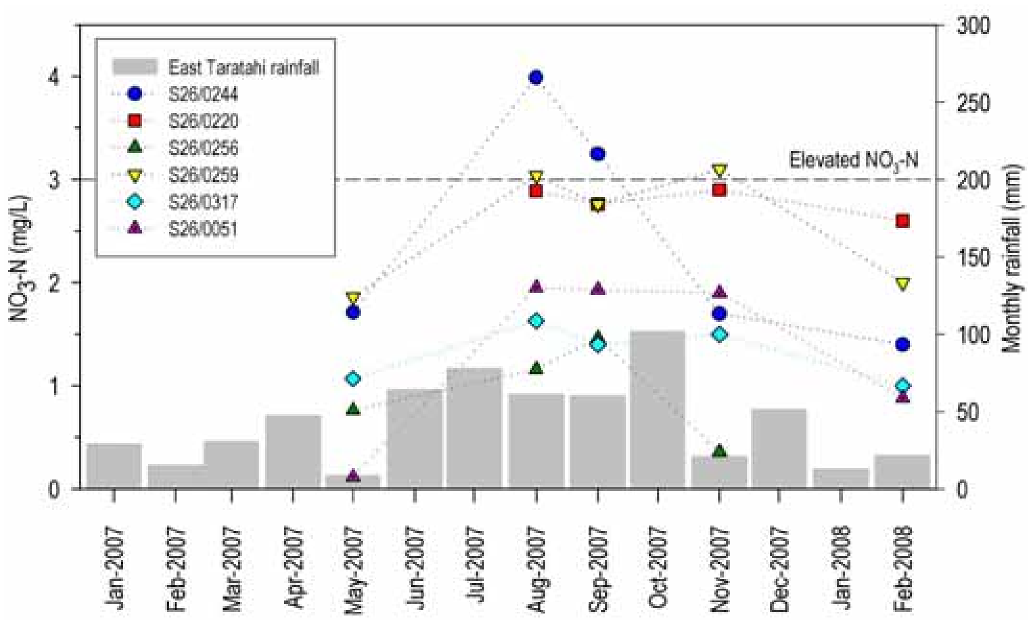

Figure 6.3: Nitrate concentrations recorded in the Norfolk Road study area bores during May 2007 and April 2008 compared against monthly rainfall totals recorded at the East Taratahi meteorological station.

6.4 Discussion

Although the sampling bores are located in the unconfined shallow aquifer where groundwater has the most interaction with land use, all median nitrate concentrations in the groundwater at Norfolk Road are below 3 mg/L and no individual result exceeded the DWSNZ (2005) MAV. Bores S26/0244 and S26/0259 have periodically had nitrate concentrations above 3 mg/L, but never above 4 mg/L. However, all nitrate concentrations in the groundwater discharge at the spring S26/0244 exceeded the ANZECC (2000) guideline for lowland streams of ≤ 0.444 mg/L; this is of concern as this water feeds into the (QEII covenanted) Waingawa wetland. The low nitrate concentrations overall probably reflect the relatively low intensity land use in the area.

Nitrate concentrations tend to correlate with rainfall, being higher in the months over winter when rainfall is higher and lower in the summer months when rainfall is less (Figure 6.3).

Monitoring results from GSoE bore S26/0299 indicate concentrations of nitrate have historically been above 3 mg/L and once exceeded the DWSNZ (2005) MAV in 2004 with a concentration of 11.9 mg/L (Appendix 5). However concentrations of nitrate at bore S26/0299 have decreased over time and now reflect the results seen in the bores sampled bi-monthly at Norfolk Road. Similarly, nitrate concentrations in this bore tend to fluctuate in response to the amount of rainfall, with peaks in nitrate concentrations generally coinciding with periods of high rainfall (Figure 6.4). *E. coli* and faecal coliform counts in bore S26/0299 have exceeded the DWSNZ (2005) MAV only once, in September 2007 (22 cfu/100 mL) (Appendix 4) but this is believed to be a result of bore contamination.

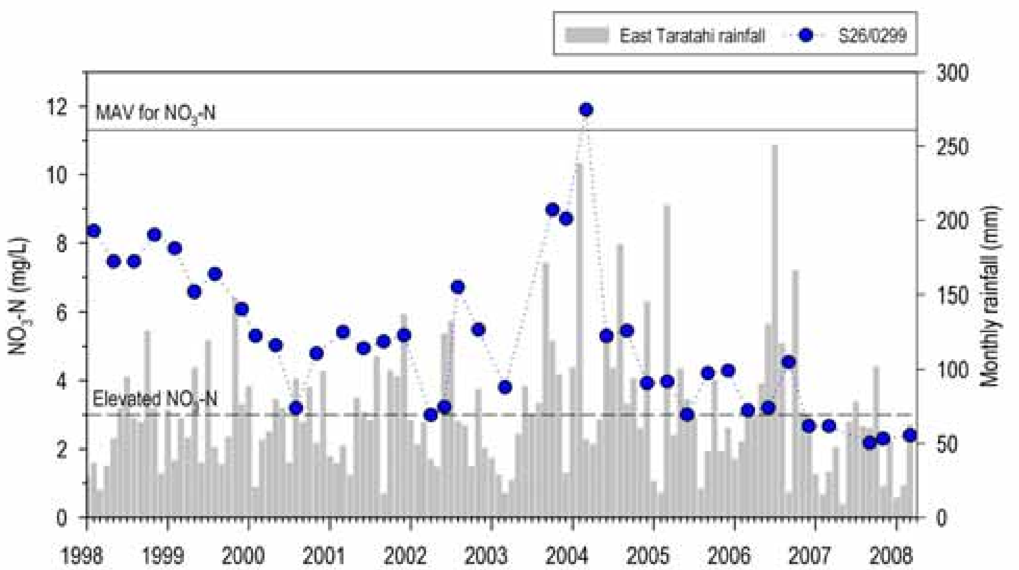

Figure 6.4: Nitrate concentrations recorded in GSoE bore S26/0299 from 1998 to present compared against monthly rainfall totals recorded at the East Taratahi meteorological station.

E. coli and faecal coliform counts in bores S26/0256, S26/0244 and S26/0220 periodically exceed the DWSNZ (2005) MAV. Elevated bacteria counts seen at site S26/0244 may be due to the spring not being fenced off from grazing stock. Of these three bores, S26/0256 is the only bore used solely for domestic supply (Appendix 1).

Bi-monthly sampling in the six Norfolk Road study area bores to date and quarterly monitoring of GSoE bore S26/0299 indicate nitrate concentrations are generally low. It is therefore considered that the existing two-monthly monitoring should cease; data from the nearby GSoE bore could be used to monitor any changes in groundwater quality over time. If there is a significant increase in contaminant concentrations in this bore, or in the number of dwellings reliant on on-site wastewater treatment systems in the Norfolk Road area, another targeted sampling investigation could be undertaken.

7. Riversdale groundwater quality study

7.1 Overview of the study area

The Riversdale beach settlement is located on the Wairarapa's east coast (Figure 7.1) and occupies a flat 200-250m wide coastal/beach terrace rising to about 2–6 metres above mean sea level (amsl). The terrace is underlain by a 2-3 metre thick layer of sand and sequential layers of siltstone/mudstone (papa) and calcareous sandstone belonging to the Whangai formation (Lee & Begg 2002, Phreatos 2004). West of the Riversdale settlement a higher terrace of bedrock papa overlain with older marine sands and gravels rises to about 35m amsl (Phreatos 2004). Alluvial material is derived from stream valleys incising the escarpment and carrying the load out to the beach (Phreatos 2004).

Figure 7.1: The Riversdale study area, including the location of the five groundwater bores sampled bi-monthly from April 2006 to present.

A 2-3 metre thick unconfined sand layer containing shallow groundwater is located above the impermeable Whangai formation bedrock. The water table depth ranges from one to two metres below the surface. Groundwater generally flows towards the beach except in the vicinity of streams and shallower bedrock where it is deflected towards these features. Recharge is primarily from rainfall infiltration and surface water runoff from the escarpment and streams when entering the lower costal terrace (Phreatos 2004).

The groundwater is mainly used for domestic water purposes such as garden irrigation, flushing toilets and clothes washing. It is not generally used for drinking due to its odour, taste and potential for bacteriological contamination although it can used to supplement the rainwater domestic supply if needed (Hurndell & Sevicke-Jones 2002).

The Masterton District Council is currently in the process of designing a community wastewater treatment system for the Riversdale area as it is undergoing rapid development and problems have already been experienced with some existing on-site wastewater treatment systems. The aim of this sampling was to gather some information on the temporal variability in groundwater quality under different climatic conditions.

7.2 Groundwater sampling data and variables

In April 2006 Greater Wellington installed five monitoring bores in the unconfined shallow aquifer along the inner coast line of the Riversdale settlement (Figure 7.1). Sampling of these bores was conducted on a bi-monthly basis from April 2006 to date, with samples analysed for nitrate, nitrite, ammonia, DRP and faecal and *E. coli* bacteria. There were a total of 12 sampling events during the reporting period (April 2006 to March 2008), although not all bores yielded water samples on every sampling occasion.

7.3 Results

Nitrate concentrations recorded in the six bores sampled bi-monthly over April 2006 to March 2008 at Riversdale ranged from <0.002 mg/L to 15 mg/L, with overall mean and median concentrations of 1.77 mg/L and 0.991 mg/L respectively. See Appendix 4 for a complete list of results.

The highest nitrate concentration was 15 mg/L recorded in bore T27/0062 in August 2006 (Figure 7.2). This result exceeds the DWSNZ (2005) MAV but was an isolated case; all of the other results for this bore were below 3 mg/L. Only one other bore (T27/0063) recorded nitrate concentrations above the elevated threshold (Appendix 4).

A comparison between nitrate concentrations and rainfall data from a manually-read rain gauge at Fernglen (7.5 km SW of Riversdale) shows increased concentrations of nitrate in the groundwater tend to coincide with periods of higher rainfall (Figure 7.3). In contrast, nitrate concentrations are lower in drier periods such as the summer months of 2006 and 2007 (in some cases bores ran dry during the summer months and were unable to be sampled). Bi-monthly measurements of groundwater levels indicated groundwater levels also fluctuate with changes in rainfall. Generally groundwater levels are higher in the winter months (Figure 7.4).

E. coli and faecal coliform counts were generally below the analytical detection limit except on 25 October 2006 where counts exceeded the DWSNZ (2005) MAV in samples from all five bores. The highest count was 32 cfu/100 mL in bore T27/0065; all other bores had counts between 5-9 cfu/100 mL. There were also six occasions where poor detection limits (<10 cfu/100 mL) mean that counts may potentially have exceeded the MAV (Appendix 4).

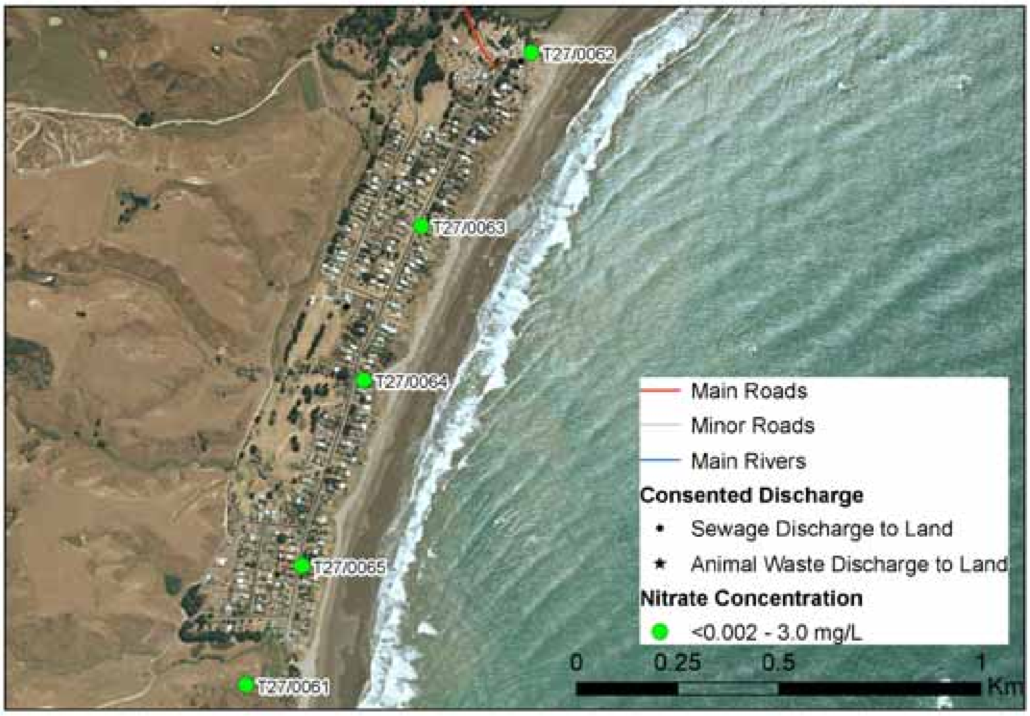

Figure 7.2: Median nitrate concentrations recorded in Riversdale monitoring bores, based on bi-monthly sampling from April 2006 to March 2008.

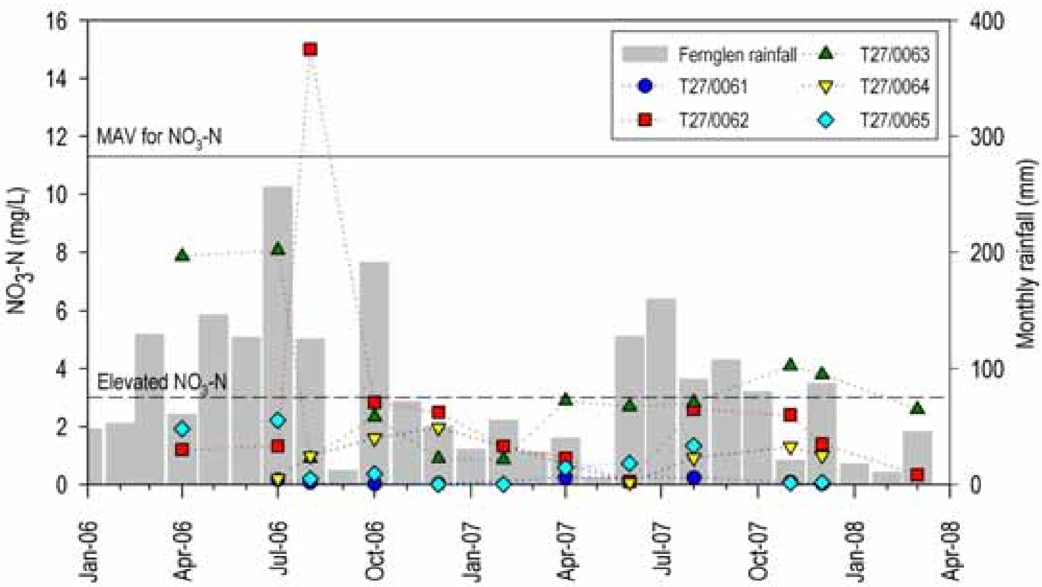

Figure 7.3: Nitrate concentrations recorded in Riversdale bores over April 2006 to March 2008 compared against monthly rainfall totals from the Fernglen rain gauge.

Nitrite concentrations were generally below the DWSNZ (2005) MAV, the exception being some samples from bores T27/0062 and T27/0065. Ammonia and DRP concentrations did not reach levels of concern in any of the bores sampled (Appendix 4).

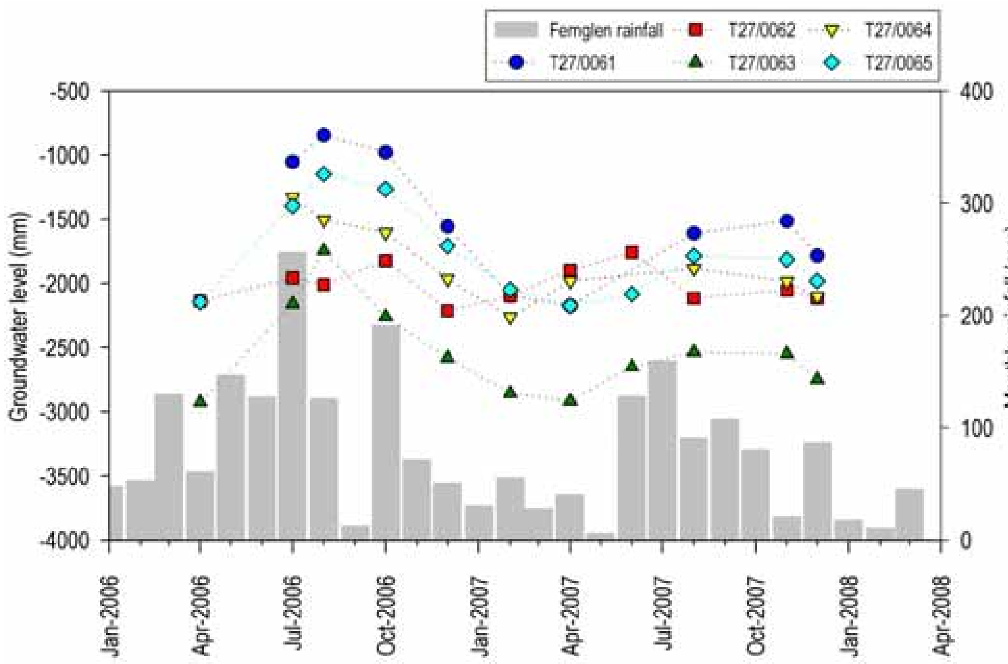

Figure 7.4: Groundwater levels recorded in the Riversdale study bores over April 2006 to March 2008 compared against monthly rainfall totals from the Fernglen rain gauge.

7.4 Discussion

Nitrate concentrations were generally low in all five bores sampled at Riversdale. There were only four occasions where nitrate concentrations were above 3 mg/L (all of which occurred in bore T27/0063) and one occasion where the DWSNZ (2005) MAV was exceeded (bore T27/0062).

Riversdale is effectively an urban environment and many of the bores sampled are near private dwellings. There is currently no reticulated sewage system, therefore all households use on-site wastewater treatment and disposal systems. Bore T27/0063 is located in an area downgradient of a number of houses and as piezometric surveying suggests that groundwater flows towards the sea, it is possible that water quality in this bore is impacted by septic tank discharges.

All monitoring bores are located in the unconfined shallow aquifer and it appears that groundwater levels and nitrate concentrations tend to respond to rainfall recharge. Seasonal variation was evident in both cases with increases in groundwater levels and nitrate concentrations observed in the winter months when monthly rainfall was higher (Figure 7.3 and Figure 7.4).

On 25 October 2006 faecal coliforms and *E. coli* counts exceeded the DWSNZ (2005) MAV in samples from all five bores. The reason for this is unclear, although both rainfall and groundwater levels were relatively high in October 2006 suggesting likely contamination from on-site wastewater treatment systems due to interception of effluent with high groundwater levels in the shallow aquifer. Previous studies conducted by Greater Wellington have confirmed that the type of bacteria present in the Riversdale area is predominantly human in origin (Hurndell & Sevicke-Jones 2002).

Although groundwater sampling conducted in Riversdale to date has not identified significant increasing trends in nitrate concentrations or faecal bacteria counts, nitrate concentrations have often been above background levels in bore T27/0063 and there have been occasional guideline exceedances for nitrate, nitrite and faecal bacteria. Given this, and the continuing residential development at Riversdale in the absence of a reticulated wastewater treatment system, some ongoing monitoring of nitrate and bacteria in the shallow aquifer is recommended. It is proposed that one of the five monitoring bores – ideally bore T27/0063 – is added to Greater Wellington's existing GSoE monitoring network and sampled quarterly.

8. Flat Point groundwater quality study

8.1 Overview of the study area

Flat Point is located approximately 42 km east of Martinborough on the Wairarapa's east coast. The stretch of coastline between Flat Point and Glenburn is a 500-700 m wide wave cut coastal/beach terrace rising to about 10m above mean sea level. The Flat Point subdivision and monitoring area is located on a terrace underlain by a 2-3 m thick layer of sand and sequential layers of siltstone/mudstone (papa) and calcareous sandstone belonging to the Whangai formation (Lee & Begg 2002, Phreatos 2004). A thin layer (averaging 0.3 m) of coarse sand and river gravels sits on top of the 'papa' formation. The Te Unu Unu Stream has cut through the beach sands and discharges to the coast just south of Flat Point (Figure 8.1).

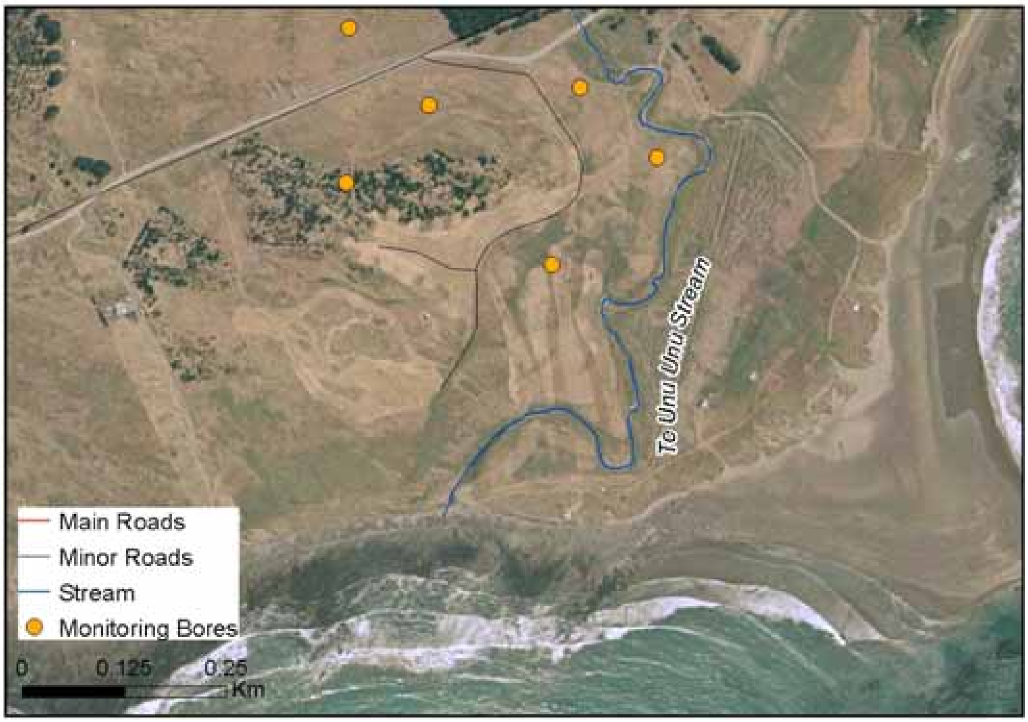

Figure 8.1: The location of the five Flat Point groundwater bores sampled bi-monthly from February 2004 to October 2006.

Groundwater is located beneath the terrace in 2-3 m of unconfined aquifer consisting of beach sands and river gravels above the relatively impermeable 'papa' formation. The water table in the lower lying areas of the subdivision is extremely shallow during the winter (0.15–0.4 m) and drops in summer to 1.0–2.0 m below ground level. Thus, during the summer only a very thin saturated zone is present. Groundwater generally flows in a southerly direction towards the coast except around the Te Unu Unu Stream where groundwater discharges to the stream (see Figure 8.2).

Prior to the recent subdivision there was no known groundwater use in the area. One property now has a large diameter well installed, thought to only be used for wash-down and cleaning purposes. All houses have rainwater tanks. With approximately a third of lots currently developed in the new Flat Point subdivision, there is potential for further groundwater use and subsequent groundwater contamination from on-site treatment systems that will be installed in the area.

Five monitoring bores were installed around the Flat Point subdivision in 1999 by New Zealand Environmental Technologies (NZET) to investigate the impact of a new type of wastewater treatment system on groundwater quality. These bores had to be replaced due to poor construction and subsequent deterioration. In 2004 Griffiths Drilling, under the direction of Greater Wellington, replaced all five bores[5] and drilled an additional bore to extend the monitoring network so that the impacts of on-site wastewater disposal in the developing subdivision could be assessed. This report only looks at the results from the groundwater monitoring bores and Te Unu Unu Stream.

8.2 Groundwater sampling data and variables

Groundwater from six bores located around the Flat Point subdivision were sampled bi-monthly between February 2004 to October 2006 for concentrations of nitrate, nitrite and faecal coliforms and *E. coli* bacteria (Figure 8.1). There were a total of 22 sampling events during the sampling period, although not all bore yielded water samples every sampling occasion.

Surface water from the Te Unu Unu Stream was also sampled on two separate occasions in March and December 2004 for nitrate, nitrite, faecal coliforms and *E. coli*. Samples were taken at the Flat Point Road Bridge and at locations upstream and downstream of the subdivision.

8.3 Results

Nitrate concentrations in the six bores sampled bi-monthly at Flat Point ranged from <0.002 mg/L to 10.5 mg/L, with overall mean and median concentrations of 1.61 mg/L and 0.145 mg/L respectively. The highest nitrate concentration was recorded in bore T27/0053 (10.5mg/L). A complete list of results is provided in Appendix 4.

Nitrate concentrations in five of the six bores were below 'background' concentrations (<1 mg/L) in the summer months and were significantly higher in the winter months in both years of the investigation (Figure 8.2). Concentrations in bore T27/0055 continued to increase from May 2005 to February 2006, and T27/0055 was the only bore T27/0055 with a mean nitrate concentration above the elevated threshold (i.e., >3 mg/L).

[5] The bore were replaced with a 50mm PVC pipe, a hand-cut slotted screen and a fibreglass filter sock. The bores were then backfilled with gravel, finished flush to the ground with a bentonite seal and capped with a cast iron well cap.

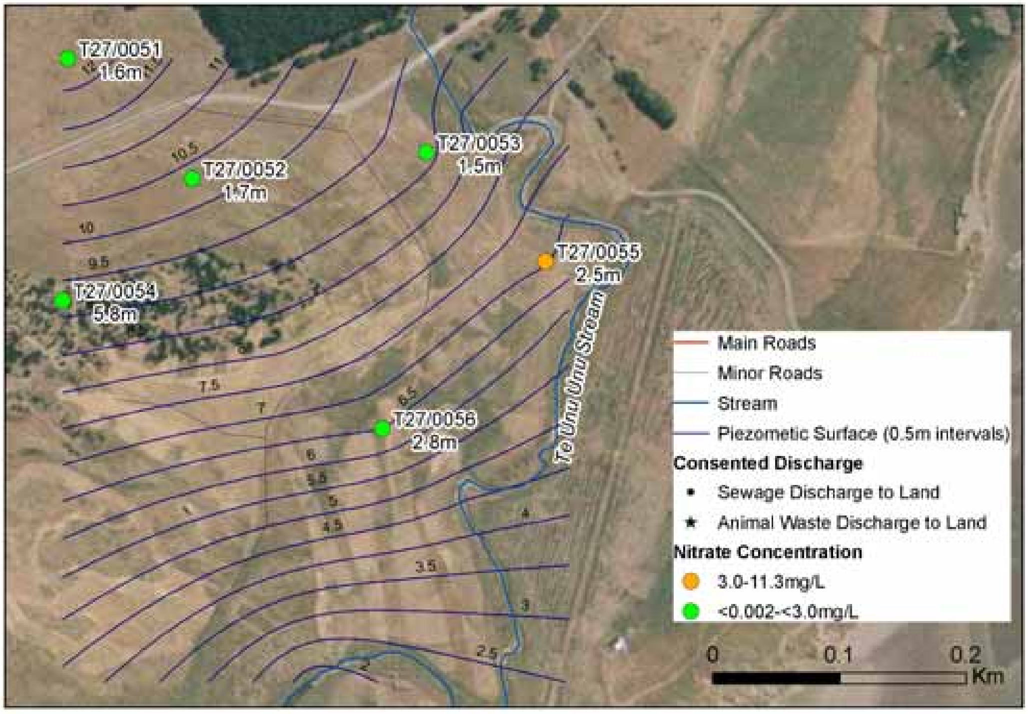

Figure 8.2: Median nitrate concentrations recorded in Flat Point monitoring bores, based on bi-monthly sampling from February 2004 to October 2006. Piezometric survey information is also shown.

An assessment of nitrate concentrations against monthly rainfall data from a manually-read rain gauge at Te Wharau Waimoana (6.7 km SW of Flat Point) shows a one to three month lag between increases in rainfall and increases in nitrate concentrations (Figure 8.3). This is also consistent with results from the bacteriological monitoring (Appendix 4).

Bores T27/0052, T27/0053, T27/0054, T27/0055 and T27/0056 displayed similar patterns of *E. coli* and faecal coliform counts, with positive results occuring in February 2004 and between April and June 2005 (Appendix 4). These positive results occur approximately one month after periods of heavy rainfall. Bacteriological contamination was most prevalent in the control bore T27/0051; this bore had positive *E. coli* and faecal coliform counts on over half of all sampling occasions (Appendix 4) and recorded the highest *E. coli* and faecal coliform counts (780 and 1,800 cfu/100mL respectively).

Water sampling results from the Te Unu Unu Stream indicated that nitrate concentrations were low (<0.002 to 0.004 mg/L) and generally below detection limits. However, *E. coli* and faecal coliform counts tested positive on most sampling occasions, ranging from <4 to 1,100 cfu/100 mL (Appendix 4).

Groundwater levels appear relatively stable with a seasonal trend seen during the summer when groundwater levels decrease and then increase during winter (Figure 8.4). Groundwater levels also appear to fluctuate around large changes in monthly rainfall totals, although it could take up to three months for a response to be evident (Figure 8.4). All bores were surveyed relative to mean sea level and groundwater levels are given in millimetres amsl.

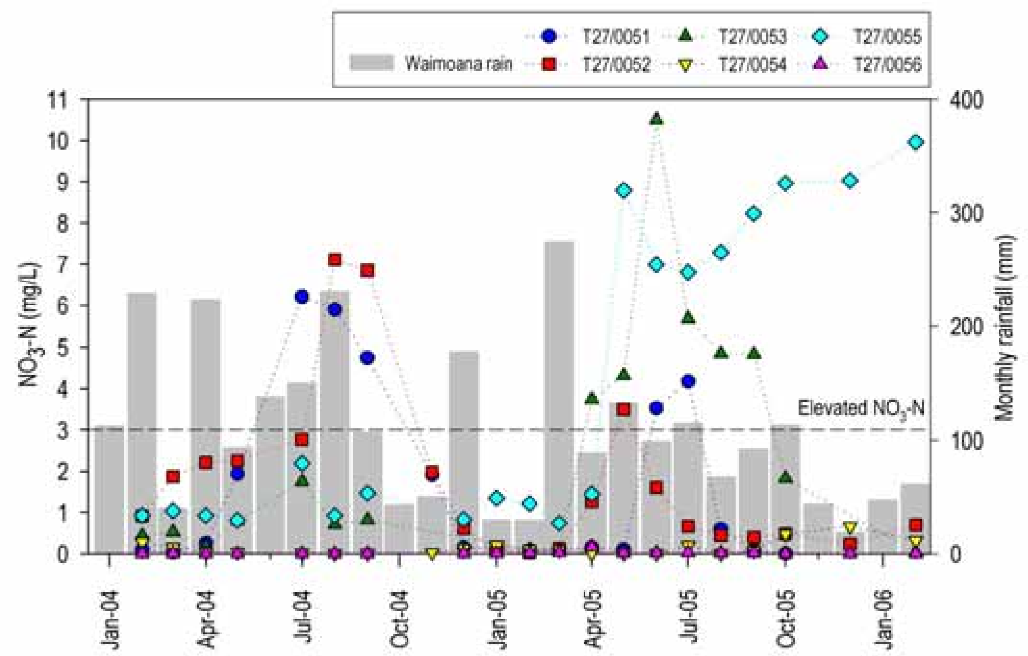

Figure 8.3: Nitrate concentrations recorded in the Flat Point groundwater bores, based on bi-monthly sampling from February 2004 to October 2006, compared against monthly rainfall totals from the Te Wharau Waimoana rain gauge.

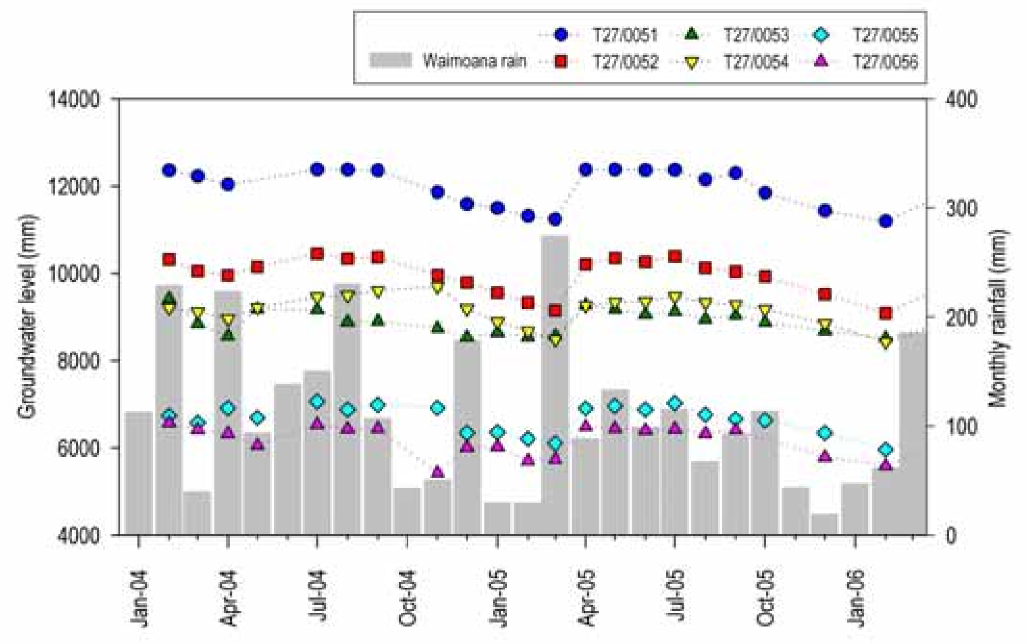

Figure 8.4: Groundwater levels recorded bi-monthly in the Flat Point groundwater bores from February 2004 to October 2006 compared against monthly rainfall totals from the Te Wharau Waimoana rain gauge.

Nitrite concentrations were generally below the DWSNZ (2005) MAV, the exception being some groundwater samples from bores T27/0054 and T27/0055 (Appendix 4).

8.4 Discussion

The original bore locations were selected by NZET based on their understanding of groundwater flow in the area. Greater Wellington redeveloped these bores in 2004 but only surveyed the bores relative to the mean high water mark at the conclusion of the Flat Point monitoring programme. When a piezometric surface was created it was found that groundwater flow was not in the direction originally theorised. Therefore groundwater quality results from bores T27/0053 and T27/0055 are unlikely to represent the impacts of wastewater disposal systems in the area. However, bores T27/0051, T27/0052, T27/0054 and T27/0056 can be considered relevant to this study.

The nitrate concentrations in all Flat Point monitoring bores are low to elevated; no concentrations exceed the DWSNZ (2005) MAV. Mean nitrate concentrations are low in all bores except T27/0055 where the mean concentration is above 3 mg/L.

Nitrate concentrations in all bores follow a seasonal trend, increasing in the winter months and decreasing over summer. Concentrations in all bores except T27/0055 appear to be stable. Since May 2005 nitrate concentrations in bore T27/0055 have begun to increase. Piezometric surveying suggests that groundwater does not flow from the subdivision to bore T27/0055 (refer Figure 8.2), therefore the nitrate contamination is probably not from wastewater treatment systems in the Flat Point subdivision. It is suspected that water quality in this bore is influenced by fertiliser application on the nearby golf course.

Nitrate concentrations reached elevated levels in bore T27/0051 during the winter months and bacteriological contamination occurred most often in this bore. Given its location upgradient of the subdivision, water quality in bore T27/0051 is possibly impacted by sheep or beef grazing in the surrounding paddock; this bore is located in a zone of increased risk for groundwater contamination as the aquifer is at its shallowest depth and the water table is closest to the surface. Therefore bore T27/0051 indicates that groundwater quality upgradient of the subdivision is already potentially degraded before it flows under the subdivision.

The presence of farming upstream makes it difficult to determine the impact of on-site wastewater disposal on groundwater quality; the contaminated groundwater from farming practices in the vicinity of the upgradient control bore flows under the subdivision. In addition, there is no long-term background monitoring data available and the possibility of nutrient increases at Flat Point due to natural processes (e.g., decay of plant organic matter) cannot be ruled out. The aquifer system appears to be controlled by the winter 'flushing' that occurs, so it is possible that nutrients build up in the soil and are flushed out after heavy rain. Given high evapotranspiration rates during summer, it is likely that there would be a build-up of nutrients in the soil over the summer months and nutrients from farming practices and wastewater treatment systems would contribute to that build up.

Although median nitrate concentrations in all six monitoring bores at Flat Point are low, increasing concentrations of nitrate in bore T27/0055 are of concern as concentrations approach the DWSNZ (2005) MAV. Some further sampling of this bore may be desirable.

9. Conclusions and recommendations

Targeted groundwater quality investigations in the Wairarapa undertaken over 2004 to 2008 indicate that nitrate contamination exists to various degrees in all six areas studied. The greatest nitrate contamination is present in shallow groundwater in the Carterton (Mangatarere) and Te Ore Ore areas; the DWSNZ (2005) MAV of 11.3 mg/L was exceeded on five occasions in these areas and a number of bores also recorded nitrate concentrations of at least half the MAV.

DRP concentrations were generally low with only five occasions where concentrations were above 0.1 mg/L in South Featherston and Carterton. Ammonia and nitrite concentrations were also low.

Bacterial contamination was present in a number of shallow bores, with counts of *E. coli* and faecal coliforms above the DWSNZ (2005) MAV in a number of bores used for domestic supply. The highest faecal count recorded was 1,800 cfu/100mL.

Elevated groundwater nitrate concentrations can be linked to land use; the shallow aquifers in the Carterton, Te Ore Ore and South Featherston study areas show the greatest level of contamination and there is intensive land use in these three areas. This is reflected in these areas having the greatest number of consented discharges to land, the majority of which are dairyshed effluent discharges. In contrast, bores in the Norfolk Road, Riversdale and Flat Point study areas – where land use is either residential or is changing from pastoral to residential development – recorded significantly lower nitrate concentrations. For example, long-term monitoring in GSoE bore S26/0299 at Norfolk Road has shown a steady decrease in nitrate concentrations since 2005. Nonetheless, some groundwater contamination is present in these areas of less intensive land-use, particularly at Riversdale where there have been occasional guideline exceedances for nitrate, nitrite and faecal bacteria.

Higher nitrate concentrations – along with higher *E. coli* and faecal coliform counts – were generally seen in winter when rainfall was greater, soils more saturated and groundwater levels higher. Under these conditions, there is a greater likelihood of the shallow groundwater intercepting leachate from animal or human waste disposed onto land. However, groundwater contamination was not limited to shallow aquifers; a number of bores located in the deep confined or semi-confined aquifers in the South Featherston, Carterton and Te Ore Ore study areas recorded elevated concentrations that in some cases exceeded the DWSNZ (2005) MAV. This suggests a degree of connectivity between the shallow and deep aquifers and that contamination is possibly migrating into deeper aquifers. As the deeper aquifers generally contain older groundwater that is less affected by contamination, the full effects of recent land use intensification are probably yet to be seen in these aquifers.

Piezometric surveying in many of the study areas suggests that groundwater discharges into adjacent or downgradient surface water bodies. Therefore, it is highly likely that elevated nitrate concentrations in shallow groundwater are contributing to the poor water quality identified in a number of surface water bodies monitored by Greater Wellington, including the Enaki Stream, Mangatarere Stream and Lake Wairarapa. This highlights the need for an integrated approach to managing the region's soil and water resources, particularly when assessing resource consent applications for wastewater discharges to land. Soil nutrient loadings and wastewater application rates must be assessed carefully, particularly in areas of intensive land use.

9.1 Recommendations

1. Inform bore owners with groundwater nitrate-nitrogen concentrations and faecal bacteria counts above the DWSNZ (2005) MAV that the water in their bore is unsafe for human consumption.

2. Repeat targeted groundwater quality sampling in the South Featherston study area, incorporating additional shallow bores in close proximity to Lake Wairarapa to help gauge the effect of groundwater on lake water quality.

3. Repeat targeted groundwater quality sampling of a selection of bores in the Te Ore Ore study area, including the six bores sampled only once in 2005.

4. Undertake further investigations in the Carterton study area, focusing on the likely contamination of the Mangatarere Stream and its tributaries by shallow groundwater.

5. Reduce bi-monthly sampling of groundwater quality in five bores at Riversdale to quarterly sampling in one bore that is incorporated into Greater Wellington's GSoE monitoring programme.

6. Cease bi-monthly sampling in the Norfolk Road subdivision area and utilise data from quarterly sampling of the nearby GSoE monitoring bore to track temporal changes in groundwater quality in this area.

7. Consider in future groundwater quality investigations:

   - better consistency in the water quality variables analysed (i.e., testing all samples for *E. coli*, faecal coliforms, DRP and ammoniacal nitrogen as well as nitrate-nitrogen and nitrite-nitrogen);

   - incorporating available groundwater age data to help determine whether contamination in aquifers is due to past or present land use;

   - using faecal sterol analysis or other testing methods to determine the origin of faecal contamination (human vs animal) in shallow groundwater; and

   - exploring the interaction between surface water and groundwater to help establish the contamination contribution made by groundwater to surface water and vice versa.

8. Consider establishing dedicated groundwater protection zones when Greater Wellington's Regional Freshwater Plan is next reviewed, with greater controls on discharges to land within these zones.

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A number of Greater Wellington Environmental Monitoring & Investigations staff assisted with this report, including Juliet Milne (guidance and peer review), Laura Watts (data presentation), Doug McAlister (peer review and interpretation of groundwater movement and aquifer structure), and Mike Gordon (hydrological data).

Appendix 1: Groundwater bore site location and details

South Featherston

Bore Number	Easting	Northing	Depth (m)	Well Type	Bore use: Primary use	Bore use: Secondary use
S27/0008	2703559	6005167	11.40	Bore	Dairy Use	Stock Supply
S27/0009 (GSoE)	2703916	6005200	10.50	Bore	Domestic Supply	Domestic Supply
S27/0014	2702570	6004740	32.00	Bore	Domestic Supply	Stock Supply
S27/0019	2705000	6004100	9.00		Domestic Supply	Stock Supply
S27/0023	2706500	6004900	8.00			
S27/0027	2705620	6004299	5.00	Bore		
S27/0043	2705110	6006300	6.00		Domestic Supply	Stock Supply
S27/0044	2705430	6005050	5.50		Irrigation	
S27/0070 (GSoE)	2707528	6004830	14.60	Bore	Public Supply	
S27/0076	2707870	6004200	4.20		Industrial	
S27/0092	2707000	6004000	5.00		Domestic Supply	
S27/0263	2703229	6002232	18.83	Bore	Domestic Supply	Stock Supply
S27/0299 (GSoE)	2706525	6000655	17.40	Bore	Irrigation	
S27/0306	2705190	6002270	12.00	Bore	Domestic Supply	Stock Supply
S27/0659	2703567	6003456	20.80	Bore	Dairy Use	Stock Supply
S27/0675	2706859	6003130	0.00	Bore		
S27/0680	2706647	6002138	0.00		Domestic Supply	Stock Supply
S27/0827	2705054	6005654	8.00	Bore		

Carterton

Bore Number	Easting	Northing	Depth (m)	Well Type	Bore use: Primary use	Bore use: Secondary use
S26/0086	2717608	6018657	4.00		Stock Supply	
S26/0092	2719280	6019455	8.10	Bore	Domestic Supply	Stock Supply
S26/0094	2718700	6018600	5.00		Domestic Supply	Stock Supply
S26/0101	2719500	6018000	6.00		Domestic Supply	
S26/0117 (GSoE)	2721500	6018500	5.00			
S26/0132	2722500	6018600	4.00		Domestic Supply	Stock Supply
S26/0169	2722884	6022504	7.65	Bore	Stock Supply	Domestic Supply
S26/0188	2722500	6024000	4.70			
S26/0192	2722834	6020266	8.70	Bore	Dairy Use	
S26/0334	2712600	6013885	5.30	Bore	Domestic Supply	
S26/0336	2712475	6014985	4.60	Bore	Domestic Supply	
S26/0337	2712580	6013970	5.25	Bore	Domestic Supply	
S26/0345	2714400	6016400	30.00		Stock Supply	
S26/0355	2717300	6015400	4.00		Domestic Supply	Stock Supply
S26/0357	2717200	6015600	6.00		Domestic Supply	Stock Supply
S26/0362	2718288	6013634	10.00	Bore	Domestic Supply	Stock Supply
S26/0379	2715600	6016000	8.00		Domestic Supply	Stock Supply
S26/0381	2716400	6013950	3.00		Domestic Supply	Stock Supply
S26/0386	2715500	6016100	8.00		Filled in (plugged)	Stock Supply
S26/0402	2717580	6013790	6.60	Bore	Stock Supply	
S26/0408	2718530	6016890	5.40	Well	Domestic Supply	Stock Supply
S26/0435	2716500	6015630	8.97	Bore	Domestic Supply	
S26/0437	2715480	6014900	16.18	Bore	Domestic Supply	

Bore Number	Easting	Northing	Depth (m)	Well Type	Bore use: Primary use	Bore use: Secondary use
S26/0439 (GSoE)	2717510	6016900	11.50	Bore	Domestic Supply	
S26/0449	2719240	6013925	9.00	Bore	Domestic Supply	Stock Supply
S26/0466	2716660	6017100	11.20	Bore	Domestic Supply	Stock Supply
S26/0467 (GSoE)	2719290	6015570	6.20		Domestic Supply	
S26/0580	2720788	6013515	15.00	Bore	Domestic Supply	Stock Supply
S26/0597	2720940	6011590	10.85	Bore	Domestic Supply	
S26/0654	2720175	6014520	0.00	Bore	Domestic Supply	
S26/0666	2721985	6015675	21.65	Bore	Industrial	
S26/0705 (GSoE)	2720489	6015999	27.40	Bore	Public Supply	
S26/0706	2720712	6014868	3.00		Domestic Supply	
S26/0813	2720413	6017337	2.68		Domestic Supply	Stock Supply
S26/0824 (GSoE)	2720564	6016101	20.60	Bore	Public Supply	
S26/0877	2722074	6021486	12.00	Bore	Domestic Supply	Stock Supply

Te Ore Ore

Bore Number	Easting	Northing	Depth (m)	Well Type	Bore use: Primary use	Bore use: Secondary use
T26/0242	2737750	6025950	8.00	Well	Domestic Supply	Stock Supply
T26/0264	2736830	6025090	12.06	Bore	Domestic Supply	
T26/0349	2734860	6019480	30.00	Bore	Domestic Supply	
T26/0470	2735395	6022085	5.50	Bore	Domestic Supply	
T26/0471	2736280	6021860	10.80	Bore	Irrigation	
T26/0472	2735365	6020876	7.50	Bore	Irrigation	
T26/0489 (GSoE)	2737585	6023576	54.00	Bore	Irrigation	
T26/0490	2737800	6024200	26.00	Bore	Irrigation	
T26/0503	2739501	6024971	10.60	Bore	Domestic Supply	Stock Supply
T26/0508	2738002	6022933	4.80	Bore	Stock Supply	
T26/0518	2736352	6024908	14.44	Bore	Industrial	
T26/0525	2736723	6023972	8.90	Bore	Domestic Supply	Stock Supply
T26/0538 (GSoE)	2737752	6022891	9.00	Bore	Domestic Supply	Stock Supply
T26/0541	2738239	6024402	8.70	Bore	Domestic Supply	
T26/0555	2736256	6022061	10.00		Domestic Supply	Irrigation
T26/0557	2737040	6023000	10.63	Bore	Domestic Supply	Stock Supply
T26/0561	2735280	6023000	4.00		Foundation/Investigation Bore	
T26/0565	2736780	6022265	5.90	Bore	Domestic Supply	Stock Supply
T26/0626	2738700	6026191	3.90	Well	Domestic Supply	
T26/0643	2735724	6020448	11.00	Bore	Foundation/Investigation Bore	Groundwater Remediation
T26/0672	2735919	6023247	6.25	Bore	Irrigation	
T26/0677	2738310	6025259	27.00	Bore	Irrigation	
T26/0690	2735166	6022647	7.80	Bore	Domestic Supply	Irrigation
T26/0725	2738206	6022611	0.00	Bore		

Norfolk Rd

Bore Number	Easting	Northing	Depth (m)	Well Type	Bore use: Primary use	Bore use: Secondary use
S26/0051	2726018	6026682	12.00	Bore	Domestic Supply	Stock Supply
S26/0220	2727800	6024170	12.00	Bore	Stock Supply	
S26/0244	2727780	6023410	0.00	Spring	Not Used	
S26/0256	2728220	6024230	6.20		Domestic Supply	
S26/0259	2728161	6023611	7.50	Bore	Domestic Supply	Irrigation
S26/0317	2728200	6023890	8.10	Bore	Domestic Supply	
S26/0299 (GSoE)	2728370	6023590	8.20	Bore	Domestic Supply	Stock Supply

Riversdale

Bore Number	Easting	Northing	Depth (m)	Well Type	Bore use: Primary use	Bore use: Secondary use
T27/0061	2767602	6007227	2.00	Bore	Groundwater Quality Sampling	
T27/0062	2768307	6008791	4.42	Bore	Groundwater Quality Sampling	
T27/0063	2768035	6008362	3.59	Bore	Groundwater Quality Sampling	
T27/0064	2767893	6007981	2.33	Bore	Groundwater Quality Sampling	
T27/0065	2767740	6007522	3.35	Bore	Groundwater Quality Sampling	

Flat Point

Bore Number	Easting	Northing	Depth (m)	Well Type	Bore use: Primary use	Bore use: Secondary use
T27/0051	2757647	5992053	1.60	Bore	Groundwater Quality Sampling	
T27/0052	2757745	5991958	1.70	Bore	Groundwater Quality Sampling	
T27/0053	2757930	5991979	1.50	Bore	Groundwater Quality Sampling	
T27/0054	2757643	5991862	5.80	Bore	Groundwater Quality Sampling	
T27/0055	2758024	5991893	2.50	Bore	Groundwater Quality Sampling	
T27/0056	2757895	5991761	2.80	Bore	Groundwater Quality Sampling	
Te Unu Unu Stream @ Bridge	2758006	5991937	0.00		Surfacewater Quality Sampling	
Te Unu Unu Stream @ Downstream	2757930	5991574	0.00		Surfacewater Quality Sampling	
Te Unu Unu Stream @ Upstream	2757848	5992277	0.00		Surfacewater Quality Sampling	

Appendix 2: Groundwater quality variables and analytical methods

Laboratory	Variable	Method Used	Detection Limit
N/A	Temperature	Field meter –YSI 550A Meters and WTW Multi-line P4 meter	0.01 ˚C
N/A	Conductivity	Field meter – YSI 550A Meters and WTW Multi-line P4 meter	0.1 µS/cm
Hills	Total Ammoniacal-N	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH4-N = NH4+-N + NH3-N) APHA 4500-NH3 F (modified from manual analysis) 21st ed. 2005.	0.01 mg/L
Hills	Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO3 - I (modified) 21sted. 2005.	0.002 mg/L
Hills	Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 mg/L
Hills	Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO3 - I (modified) 21st ed. 2005.	0.002 mg/L
Hills	Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st ed. 2005.	0.004 mg/L
ELS	Faecal coliforms	APHA 21st Ed. Method 9222 D	1 cfu/100 mL
ELS	*Escherichia coli*	APHA 21st Ed. Method 9222 G	1 cfu/100 mL

Appendix 3: Land cover information (calculated from the AgriQuality 2000 database)

Farm Type	South Featherston		Carterton		Te Ore Ore		Norfolk Road	
	Hectares (Ha)	Percentage	Hectares (Ha)	Percentage	Hectares (Ha)	Percentage	Hectares (Ha)	Percentage
Arable cropping or seed production			47.56	0.69	47.70	2.49		
Beef cattle farming	382.50	11.90	600.04	8.67	194.18	10.13	318.34	41.84
Dairy cattle farming	1736.20	54.00	3959.00	57.17	381.03	19.89		
Deer Farming			121.56	1.76	0.00	0.00	14.20	1.87
Dairy dry stock	71.40	2.22	14.08	0.20	0.73	0.04		
Forestry			15.50	0.22	78.34	4.09		
Fruit	10.20	0.32			2.22	0.12	2.58	0.34
Grazing other peoples stock			105.25	1.52	212.06	11.07		
Horse farming and breeding	16.80	0.52	14.32	0.21	15.60	0.81	13.83	1.82
Lifestyle block	3.30	0.10	105.25	1.52			20.85	2.74
New record unconfirmed farm type			2.40	0.03				
Not farmed (i.e. idle land or non-farm use)							5.15	0.68
Other livestock			0.82	0.01				
Other planted			0.28	0.00				
Other enterprises not covered	42.70	1.33	26.67	0.39	8.32	0.43	19.27	2.53
Pig Farming	159.20	4.95	154.12	2.23				
Plant Nurseries					4.53	0.24		
Poultry	3.90	0.12						
Sheep farming	4.90	0.15	165.41	2.39	306.23	15.98	104.69	13.76
Sheep and Beef farming			68.63	0.99	61.42	3.21	119.61	15.72
Unspecified	693.80	21.58	1523.79	22.01	602.86	4.83	142.36	18.71
Vegetable					4.20	0.22		
Total Area	3214.90		6924.70		1915.99		760.86	

*Land use at Riversdale is classified as 100% urban and Flat Point was 100% sheep farming.

Data provided by AgriQuality New Zealand 2000

Appendix 4: Raw data from the targeted investigations

South Featherston 2006

Bore Number	Date and time	Water Temperature (ºC)	Nitrite-N (mg/L)	Nitrate-N (mg/L)	NNN (mg/L)	DRP (mg/L)	*E. coli* (cfu/100mL)	Faecal coliforms (cfu/100mL)	Field Conductivity (µS/cm)
S27/0008	30/11/2006 12:12		<0.002	7.44	7.44	0.012			196
S27/0009	14/12/2006 13:11	13.99	<0.002	4.23	4.23	0.011	<1	<1	181
S27/0014	01/12/2006 08:51		<0.002	5.74	5.74	0.054			210
S27/0019	01/12/2006 09:56		<0.002	5.44	5.44	0.018			173
S27/0023	01/12/2006 08:58		<0.002	5.68	5.68	0.021			159
S27/0027	30/11/2006 11:28		<0.002	4.00	4.00	0.012			160
S27/0043	01/12/2006 10:54		<0.002	1.32	1.32	0.013			139
S27/0044	01/12/2006 09:54		<0.002	4.25	4.25	0.013			164
S27/0070	11/12/2006 12:35	12.33	<0.002	0.557	0.558	0.002	<1	<1	84
S27/0076	30/11/2006 10:10		<0.002	0.21	0.21	0.029			64
S27/0092	30/11/2006 09:35		<0.002	1.73	1.73	0.006			116
S27/0263	30/11/2006 13:28		<0.002	<0.002	<0.002	0.407			170
S27/0299	07/12/2006 11:55	13.91	<0.002	0.215	0.216	0.004	<1	<1	99
S27/0306	30/11/2006 11:02		<0.002	1.70	1.71	0.005			129
S27/0659	01/12/2006 09:24		<0.002	1.17	1.17	0.022			123
S27/0675	01/12/2006 10:14		<0.002	1.73	1.73	0.009			126
S27/0680	30/11/2006 10:35		<0.002	1.78	1.78	0.021			115
S27/0827	01/12/2006 09:26		<0.002	0.523	0.523	0.032			109

Carterton 2006

Bore Number	Date and time	Water Temperature (ºC)	Nitrite-N (mg/L)	Nitrate-N (mg/L)	NNN (mg/L)	DRP (mg/L)	*E. coli* (cfu/100mL)	Faecal coliforms (cfu/100mL)	Field Conductivity (µS/cm)
S26/0086	27/11/2006 13:59		<0.002	1.17	1.17	0.007			108
S26/0092	29/11/2006 12:05		<0.002	16.1	16.1	0.021			258
S26/0094	29/11/2006 10:35		0.009	0.802	0.811	0.007			164
S26/0101	29/11/2006 09:45		<0.002	2.07	2.07	0.010			135
S26/0117	12/12/2006 13:47	13.39	<0.002	5.02	5.02	0.012	3	3	157
S26/0132	29/11/2006 13:56		<0.002	9.60	9.60	0.008			195
S26/0169	17/11/2006 16:30		0.104	8.74	8.84		700		
S26/0188	30/11/2006 11:07	14.72	<0.002	6.74	6.74	0.005			85
S26/0192	30/11/2006 13:52	13.43	<0.002	1.06	1.06	0.017			98
S26/0334	27/11/2006 09:04		<0.002	0.75	0.751	0.008			88
S26/0336	30/11/2006 08:45		<0.002	1.72	1.72	0.009			105
S26/0337	27/11/2006 09:28		<0.002	0.799	0.80	0.007			88
S26/0345	27/11/2006 11:07		<0.002	<0.002	0.002	0.200			318
S26/0355	29/11/2006 13:02		<0.002	6.29	6.29	0.026			192
S26/0357	30/11/2006 09:21		<0.002	5.43	5.43	0.018			194
S26/0362	27/11/2006 10:10		<0.002	0.004	0.005	0.199			70
S26/0379	27/11/2006 10:44		<0.002	3.98	3.98	0.013			134
S26/0381	29/11/2006 12:04		<0.002	4.61	4.61	0.018			137
S26/0386	27/11/2006 10:15		<0.002	4.98	4.98	0.030			213
S26/0402	29/11/2006 10:38		<0.002	0.934	0.936	0.022			83
S26/0408	27/11/2006 12:45		<0.002	2.31	2.31	0.015			130
S26/0435	01/12/2006 11:51		0.004	8.37	8.38	0.022			174
S26/0437	12/12/2006 13:19		<0.002	1.28	1.28	<0.004			155
S26/0439	12/12/2006 12:42	14.27	<0.010	3.72	3.72	0.024	<1	<1	169
S26/0449	30/11/2006 12:50		0.004	0.003	0.007	1.660			242
S26/0466	27/11/2006 14:20		<0.002	6.43	6.43	0.022			180
S26/0467	12/12/2006 12:07	13.86	<0.010	4.14	4.14	0.021	<1	<1	148
S26/0580	30/11/2006 13:23		<0.002	<0.002	<0.002	0.072			203
S26/0597	29/11/2006 11:36		<0.002	2.79	2.79	0.012			116

S26/0654	29/11/2006 09:45		0.009	1.28	1.29	0.009			151
S26/0666	29/11/2006 13:05		0.003	0.647	0.65	0.112			176
S26/0705	07/12/2006 08:42	13.62	<0.002	5.15	5.15	0.027	<1	<1	168
S26/0706	30/11/2006 12:07		<0.002	7.07	7.07	0.014			177
S26/0813	29/11/2006 10:15		<0.002	2.06	2.06	0.071			134
S26/0824	07/12/2006 08:13	14.04	<0.002	6.38	6.38	0.014	<1	<1	174
S26/0877	30/11/2006 10:02		<0.002	12.0	12.0	0.007			214

Te Ore Ore 2005

Bore Number	Date and time	Water Temperature (ºC)	Nitrite-N (mg/L)	Nitrate-N (mg/L)	NNN (mg/L)	Field Conductivity (µS/cm)
T26/0242	22/11/2005 08:18	14.38	<0.002	1.95	1.95	131
T26/0264	21/11/2005 12:42	12.66	<0.002	0.927	0.928	309
T26/0349	23/11/2005 14:03	13.02	0.011	0.675	0.687	347
T26/0470	21/11/2005 14:20	14.62	<0.002	3.27	3.27	133
T26/0471	22/11/2005 13:32	12.95	<0.002	3.41	3.41	237
T26/0472	24/11/2005 13:55	13.22	<0.002	3.38	3.38	155
T26/0489	19/12/2005 08:07	13.07	0.003	10.9	10.9	238
T26/0490	22/11/2005 08:52	15.10	<0.002	6.23	6.23	143
T26/0503	21/11/2005 08:45	13.20	0.017	1.80	1.82	180
T26/0508	23/11/2005 11:54	13.75	<0.002	15.3	15.3	288
T26/0518	21/11/2005 12:18	13.45	<0.002	0.627	0.628	255
T26/0525	21/11/2005 10:43	14.42	<0.002	1.55	1.55	606
T26/0538	16/12/2005 14:10	13.47	<0.002	10.6	10.6	295
T26/0541	23/11/2005 10:55	13.60	<0.002	11.8	11.8	252
T26/0555	21/11/2005 09:43	13.31	<0.002	2.92	2.92	252
T26/0557	21/11/2005 10:10	13.76	<0.002	11.4	11.4	265
T26/0561	24/11/2005 12:28	12.65	0.024	1.15	1.17	126
T26/0565	21/11/2005 09:15	12.92	<0.002	8.76	8.77	204
T26/0626	23/11/2005 10:25	13.42	0.009	3.21	3.22	165
T26/0643	24/11/2005 13:25	12.48	<0.002	1.78	1.78	121
T26/0672	22/11/2005 12:55	13.66	<0.002	2.14	2.14	162
T26/0677	23/11/2005 09:00	13.05	0.012	8.57	8.59	290
T26/0690	21/11/2005 13:57	12.76	<0.002	3.26	3.26	339
T26/0725	23/11/2005 12:34	13.28	<0.002	3.88	3.88	204

Te Ore Ore 2007

Bore Number	Date and time	Water Temperature (ºC)	Nitrite-N (mg/L)	Nitrate-N (mg/L)	NNN (mg/L)	Field Conductivity (µS/cm)
T26/0242	23/11/2007 14:43	14.58	<0.002	2.20	2.20	303
T26/0264	22/11/2007 12:27	13.94	<0.002	0.83	0.83	159
T26/0470	10/10/2007 12:00		<0.002	3.09		
T26/0472	10/10/2007 12:00		<0.002	2.30	2.30	
T26/0489	19/12/2007 13:54	12.98	0.003	9.60	9.60	275
T26/0490	12/12/2007 11:02	13.55	0.002	13.0	13.0	358
T26/0503	12/12/2007 12:45	13.80	0.004	0.79	0.80	340
T26/0518	22/11/2007 14:35	19.56	<0.002	0.49	0.49	141
T26/0525	22/11/2007 14:12	14.02	<0.002	1.80	1.80	178
T26/0538	12/12/2007 13:18	13.17	<0.002	10.0	10.0	351
T26/0555	23/11/2007 13:26	13.45	<0.002	2.50	2.50	237
T26/0557	23/11/2007 12:35	14.43	<0.002	9.70	9.70	296
T26/0561	05/12/2007 12:00		0.020	3.53		
T26/0565	23/11/2007 13:02	13.56	<0.002	6.90	6.90	375
T26/0626	22/11/2007 12:58	14.85	0.028	2.90	3.00	316
T26/0643	05/12/2007 12:00		<0.002	2.00	2.00	
T26/0672	23/11/2007 12:08	13.26	<0.002	1.50	1.50	178
T26/0677	22/11/2007 13:36	17.65	<0.002	9.80	9.80	331

Norfolk Road 2007-2008

Bore Number	Date and time	Water Temperature (ºC)	Nitrite-N (mg/L)	Nitrate-N (mg/L)	NNN (mg/L)	DRP (mg/L)	*E. coli* (cfu/100mL)	Faecal coliforms (cfu/100mL)	Field Conductivity (µS/cm)
S26/0051	02/05/2007 06:55		<0.002	0.117	0.118	0.008	<1	<1	
	10/08/2007 08:00		<0.002	1.95	1.95	0.021	<1	<1	
	24/09/2007 07:20		0.002	1.93	1.93	<0.004	<1	<1	
	30/11/2007 15:30		<0.002	1.90	1.90	<0.004	<1	<1	
	04/02/2008 12:15		<0.002	0.88	0.88	<0.004	<1	<1	
	17/04/2008 12:10		0.008	1.10	1.10	<0.004	<1	<1	
S26/0220	09/08/2007 13:23	13.85	<0.002	2.89	2.89	0.014	<1	<1	98
	21/09/2007 12:45	13.99	<0.002	2.76	2.76	0.009	<1	<1	97
	30/11/2007 13:41	13.63	<0.002	2.90	2.90	0.009	<1	<1	111
	01/02/2008 12:27	15.86	<0.002	2.60	2.60	0.009	<1	<1	105
	18/04/2008 13:16	14.98	<0.002	3.10	3.10	0.008	4	4	90
S26/0244	01/05/2007 14:10	14.58	<0.002	1.71	1.71	0.011	8	8	94
	09/08/2007 13:55	12.35	<0.002	3.99	3.99	0.012	<1	<1	103
	21/09/2007 13:10	11.92	<0.002	3.25	3.25	0.011	<1	<1	104
	30/11/2007 14:05	13.52	<0.002	1.70	1.70	0.012	410	450	79
	01/02/2008 12:58	15.49	<0.002	1.40	1.40	0.016	390	390	80
	01/04/2008 10:08	15.87	0.002	2.20	2.20	0.013	<1	<1	96
S26/0256	01/05/2007 13:00	14.77	<0.002	0.763	0.764	0.022	<1	<1	72
	09/08/2007 13:01	13.46	<0.002	1.16	1.16	0.022	7	7	72
	21/09/2007 12:21	13.04	<0.002	1.46	1.46	0.017	<1	<1	78
	30/11/2007 13:18	13.16	<0.002	0.36	0.36	0.020	14	14	61
	01/04/2008 12:58	15.46	<0.002	0.68	0.68	0.024	<1	<1	74
S26/0259	01/05/2007 12:15	15.47	<0.002	1.86	1.86	0.021	<1	<1	96
	09/08/2007 12:15	13.10	<0.002	3.04	3.04	0.021	<1	<1	100
	21/09/2007 11:45	13.39	<0.002	2.76	2.76	0.017	<1	<1	104
	30/11/2007 12:42	13.78	<0.002	3.10	3.10	0.038	<1	<1	102
	01/02/2008 11:44	16.40	<0.002	2.00	2.00	0.023	<1	<1	96
	01/04/2008 11:12	16.97	<0.002	1.50	1.50	0.023	<1	<1	85

S26/0317	01/05/2007 12:37	15.23	<0.002	1.07	1.08	0.021	<1	<1	80
	09/08/2007 12:45	13.57	<0.002	1.63	1.63	0.019	<1	<1	80
	21/09/2007 12:05	13.46	<0.002	1.40	1.40	0.017	<1	<1	77
	30/11/2007 13:00	13.50	<0.002	1.50	1.50	0.020	<1	<1	82
	01/02/2008 11:58	14.49	<0.002	1.00	1.00	0.022	<1	<1	79
	01/04/2008 12:19	15.16	<0.002	1.30	1.30	0.018	<1	<1	80

Riversdale 2006-2008

Bore Number	Date and time	Water Temperature (ºC)	Water Level (m) amsl	Nitrite-N (mg/L)	Nitrate-N (mg/L)	NNN (mg/L)	Ammonia-N (mg/L)	DRP (mg/L)	*E. coli* (cfu/100mL)	Faecal coliforms (cfu/100mL)	Field Conductivity (µS/cm)
T27/0061	03/07/2006 14:01	10.10	-1053	<0.002	0.164	0.164	0.010	0.070	<1	<1	628
	28/08/2006 13:52	13.42	-844	<0.002	0.060	0.060	<0.010	0.078	<1	<1	600
	25/10/2006 12:35	14.68	-980	<0.002	0.016	0.016	<0.010	0.073	5	5	547
	18/12/2006 13:58	18.94	-1557	<0.002	0.015	0.015	<0.010	0.074	<1	<1	512
	21/02/2007 13:45		-2097								
	30/04/2007 13:25		-2175								
	24/08/2007 13:46	13.76	-1610	<0.002	0.238	0.239	0.030	0.066	<10	<10	507
	01/11/2007 12:48	14.85	-1515	<0.002	0.074	0.074	<0.010	0.068	<1	<1	549
	21/12/2007 12:07	17.66	-1784	<0.002	0.012	0.014	<0.010	0.064	<1	<1	571
T27/0062	20/04/2006 09:50	17.29	-2138	0.030	1.20	1.23	<0.010	0.030	<1	<1	6,050
	03/07/2006 12:01	11.40	-1958	0.039	1.33	1.37	0.020	0.026	<1	<1	8,160
	28/08/2006 12:10	14.54	-2011	0.045	15.0	15.0	<0.010	0.026	<1	<1	2,120
	25/10/2006 11:02	14.61	-1823	0.030	2.83	2.86	<0.010	0.028	<1	<1	1,486
	18/12/2006 12:22	16.14	-2213	0.036	2.49	2.53	<0.010	0.027	<1	<1	1,180
	21/02/2007 12:54	18.86	-2100	0.037	1.32	1.36	<0.010	0.025	<1	<1	1,607
	30/04/2007 12:30	16.93	-1896	0.048	0.903	0.951	0.070	0.023	<1	<1	7,104
	27/06/2007 12:10	15.45	-1760	0.028	0.093	0.122	0.030	0.034	<1	<1	25,710
	24/08/2007 12:20	14.34	-2116	0.077	2.60	2.68	0.010	0.031	<1	<1	16,827
	01/11/2007 11:17	14.78	-2054	0.061	2.40	2.40	<0.010	0.035	<1	<1	8,964
	21/12/2007 10:47	15.75	-2116	0.059	1.40	1.50	<0.010	0.025	<1	<1	11,680
	27/03/2008 09:14	17.68		0.045	0.330	0.380	<0.010	0.030	<1	<1	21,032
T27/0063	20/04/2006 10:35	17.59	-2926	<0.002	7.85	7.85	<0.010	0.083	<1	<1	723
	03/07/2006 12:30	11.00	-2160	<0.002	8.06	8.06	0.010	0.079	<1	<1	836
	28/08/2006 12:36	12.66	-1745	<0.002	0.907	0.907	<0.010	0.069	<1	<1	594

	25/10/2006 11:20	13.53	-2260	<0.002	2.33	2.33	<0.010	0.074	5	5	706
	18/12/2006 12:44	16.04	-2581	<0.002	0.900	0.900	0.020	0.073	<1	<1	658
	21/02/2007 13:12	17.04	-2856	<0.002	0.857	0.857	<0.010	0.065	<1	<1	628
	30/04/2007 12:42	16.54	-2917	<0.002	2.89	2.89	0.100	0.082	<1	<1	647
	27/06/2007 12:38	15.27	-2649	<0.002	2.69	2.69	<0.010	0.085	<1	<1	643
	24/08/2007 12:40	14.66	-2535	<0.002	2.83	2.83	<0.010	0.069	<10	<10	632
	01/11/2007 11:46	14.44	-2550	0.006	4.10	4.10	<0.010	0.068	<10	<10	660
	21/12/2007 11:06	15.99	-2749	<0.002	3.80	3.80	<0.010	0.068	<1	<1	655
	27/03/2008 09:41	17.67	-2830	<0.002	2.60	2.60	<0.010	0.063	<1	<1	723
T27/0064	03/07/2006 12:57	11.00	-1330	<0.002	0.197	0.198	<0.010	0.006	<1	<1	2,750
	28/08/2006 12:58	13.6	-1507	<0.002	0.982	0.983	<0.010	0.005	<1	<1	803
	25/10/2006 11:43	15.28	-1605	<0.002	1.60	1.60	<0.010	0.006	8	9	854
	18/12/2006 13:04	16.22	-1966	0.004	1.96	1.97	<0.010	0.007	<1	<1	1,033
	21/02/2007 13:20		-2261								
	27/06/2007 12:59	14.11	-1983	0.002	0.064	0.066	<0.010	0.006	<1	<1	1,876
	24/08/2007 12:55	14.34	-1885	<0.002	0.917	0.918	<0.010	0.010	<10	<10	1,159
	01/11/2007 12:05	14.55	-1986	<0.002	1.30	1.30	<0.010	0.006	<1	<1	886
	21/12/2007 11:17		-2104	<0.002	1.00	1.00	<0.010	0.007	<1	<1	881
	27/03/2008 10:00		-2320								
T27/0065	20/04/2006 11:00	18.55	-2145	0.032	1.93	1.96	<0.010	0.139	<1	<1	662
	03/07/2006 13:33	13.50	-1394	0.016	2.22	2.24	<0.010	0.108	<1	<1	904
	28/08/2006 13:24	13.49	-1149	<0.002	0.199	0.201	<0.010	0.083	<1	<1	974
	25/10/2006 12:05	14.80	-1266	<0.002	0.370	0.370	<0.010	0.095	27	32	1,327
	18/12/2006 13:26	16.98	-1707	<0.002	0.003	0.005	<0.010	0.105	<1	<1	940
	21/02/2007 13:38	18.94	-2050	<0.002	<0.002	<0.002	<0.010	0.137	<1	<1	855
	30/04/2007 13:18	18.02	-2173	0.009	0.582	0.591	0.070	0.149	<1	<1	700
	27/06/2007 13:43	15.62	-2084	0.040	0.732	0.771	0.010	0.145	<1	<1	675
	24/08/2007 13:23	14.70	-1784	0.020	1.34	1.36	0.010	0.127	<10	<10	728
	01/11/2007 12:25	14.91	-1814	0.003	0.055	0.058	0.012	0.067	<10	<10	922
	21/12/2007 11:40	17.62	-1983	<0.002	0.063	0.065	<0.010	0.200	<1	<1	963

Flat Point 2004-2006

Bore Number	Date and tme	Water Temperature (ºC)	Water Level (m) amsl	Nitrite-N (mg/L)	Nitrate-N (mg/L)	NNN (mg/L)	*E. coli* (cfu/100mL)	Faecal coliforms (cfu/100mL)	Field Conductivity (µS/cm)
T27/0051	20/02/2004 14:50	18.30	12361	0.017	0.101	0.118	60	60	1,094
	18/03/2004 10:00	18.80	12225	0.003	0.031	0.035	9	10	1,351
	21/04/2004 12:30	17.00	12031	0.006	0.254	0.260	<1	<1	1,356
	21/05/2004 10:15	13.90		0.033	1.94	1.97	<1	<1	1,149
	02/07/2004 09:55	10.80	12380	0.036	6.21	6.24	<1	<1	1,180
	03/08/2004 10:50	9.76	12377	0.047	5.90	5.94	2	2	1,177
	07/09/2004 10:25	9.92	12360	0.021	4.75	4.77	<1	<1	968
	02/11/2004 09:10	16.30	11858	0.026	1.91	1.94	<1	<1	1,490
	02/12/2004 09:00	20.20	11590	0.005	0.147	0.152	<1	<1	1,551
	17/01/2005 09:30	21.40	11493	0.008	0.097	0.105	780	1,800	1,602
	17/02/2005 09:10	20.20	11315	0.005	0.080	0.085	45	45	1,587
	21/03/2005 10:20	18.30	11240	0.008	0.101	0.109	4	4	1,811
	26/04/2005 10:30	13.80	12376	0.003	0.146	0.149	410	600	1,162
	24/05/2005 10:30	14.00	12377	<0.002	0.102	0.104	64	69	1,069
	21/06/2005 10:15	10.90	12367	0.013	3.53	3.54	13	14	1,110
	25/07/2005 10:30	10.50	12369	0.021	4.18	4.20	90	90	1,006
	22/08/2005 10:20	11.90	12150	0.004	0.597	0.601	17	23	1,105
	26/09/2005 10:49	12.88	12293	0.008	0.082	0.090	400	400	1,025
	31/10/2005 09:55	16.55	11845	0.002	0.003	0.005	400	400	1,006
	08/12/2005 09:45		11435						
	15/02/2006 09:13		11195						
	27/06/2006 12:00		12404						
T27/0052	20/02/2004 12:00	18.00	10315	<0.002	0.911	0.913	8	8	980
	18/03/2004 10:30	17.20	10048	<0.002	1.87	1.87	<1	<1	990
	21/04/2004 10:15	14.70	9950	<0.002	2.21	2.21	<1	<1	1,000
	21/05/2004 10:40	14.40	10150	0.002	2.25	2.25	<1	<1	920
	02/07/2004 10:25	12.60	10450	0.003	2.77	2.77	<1	<1	983
	03/08/2004 11:15	11.30	10335	0.059	7.11	7.17	12	12	1,038
	07/09/2004 10:45	11.04	10372	0.105	6.85	6.96	<1	<1	893

	02/11/2004 09:30	13.50	9958	0.033	1.98	2.010	<1	<1	871
	02/12/2004 09:30	15.20	9788	0.037	0.605	0.643	<1	<1	850
	17/01/2005 09:50	16.70	9560	0.007	0.100	0.107	<1	<1	896
	17/02/2005 09:25	18.70	9330	0.003	0.021	0.024	<1	<1	841
	21/03/2005 10:45	17.00	9144	<0.002	0.129	0.129	<1	<1	860
	26/04/2005 10:55	15.00	10204	<0.002	1.26	1.26	<1	<1	847
	24/05/2005 11:00	14.10	10352	<0.002	3.50	3.50	<1	<1	795
	21/06/2005 11:40	12.50	10257	<0.002	1.60	1.60	<1	<1	817
	25/07/2005 10:55	11.90	10393	<0.002	0.665	0.665	<1	<1	829
	22/08/2005 10:40	13.10	10125	<0.002	0.442	0.443	<1	<1	853
	26/09/2005 11:19	12.74	10034	<0.002	0.397	0.397	<1	<1	863
	31/10/2005 10:25	14.48	9928	<0.002	0.475	0.477	<1	<1	768
	08/12/2005 10:08	15.93	9524	0.016	0.232	0.248	<1	<1	750
	15/02/2006 09:34	17.42	9084	<0.002	0.696	0.696	<1	<1	843
	27/06/2006 12:00		10313						
T27/0053	20/02/2004 14:00	18.50	9421	0.035	0.433	0.468	2	2	1,256
	18/03/2004 12:00	21.40	8841	0.032	0.527	0.559	<1	<1	727
	21/04/2004 10:45	15.90	8560	0.002	0.175	0.177	<1	<1	1,792
	21/05/2004 12:00	14.80	9182	<0.002	0.790	0.791	<1	<1	1,875
	02/07/2004 11:00	12.00	9165	0.011	1.75	1.76	<1	<1	1,777
	03/08/2004 12:45	10.80	8885	0.007	0.709	0.716	<1	<1	1,744
	07/09/2004 11:40	11.18	8900	0.002	0.819	0.821	<1	<1	1,330
	02/11/2004 10:10		8742						
	02/12/2004 09:55	14.80	8540						1,080
	17/01/2005 10:35		8640						
	17/02/2005 09:55	19.50	8540	0.010	0.098	0.108	<1	<1	1,529
	21/03/2005 11:10	17.50	8561	0.009	0.081	0.090	<1	<1	1,466
	26/04/2005 11:55	14.80	9275	0.014	3.74	3.75	3	3	1,831
	24/05/2005 11:50	14.40	9174	0.004	4.32	4.33	3	4	1,919
	21/06/2005 10:45	11.60	9058	0.004	10.5	10.5	<1	<1	1,511
	25/07/2005 11:45	12.10	9124	<0.002	5.68	5.68	<1	<1	903
	22/08/2005 11:30	14.30	8950	0.002	4.85	4.85	<1	<1	840
	26/09/2005 12:45	13.07	9043	0.002	4.84	4.84	<1	<1	985

	31/10/2005 11:20	16.25	8879	0.024	1.83	1.85	<1	<1	1,106
	08/12/2005 11:00		8680						
	15/02/2006 10:19		8518	<0.002	0.031	0.031	<1	<1	
	27/06/2006 12:00		9204						
T27/0054	26/02/2004 11:30	16.30	9207	0.005	0.283	0.288	<20	<20	930
	18/03/2004 11:00	17.10	9115	0.003	0.148	0.151	<1	<1	1,623
	21/04/2004 12:00	17.00	8955	<0.002	0.037	0.039	<1	<1	1,309
	21/05/2004 11:00	15.20	9206	<0.002	0.031	0.032	<1	<1	1,581
	02/07/2004 10:40	13.20	9462	0.002	0.013	0.015	<1	<1	1,052
	03/08/2004 11:25	11.89	9493	0.003	0.002	0.005	<1	<1	1,065
	07/09/2004 11:00	11.41	9603	<0.002	0.005	0.005	<1	<1	865
	02/11/2004 10:10	13.90	9696	0.006	0.022	0.029	<1	<1	1,195
	02/12/2004 10:15		9185	0.017	0.128	0.145	<1	<1	
	17/01/2005 10:10	16.50	8889	0.053	0.207	0.261	<1	<1	1,183
	17/02/2005 10:25	16.70	8675	<0.002	0.106	0.107	<1	<1	1,096
	21/03/2005 10:55	17.10	8483	<0.002	0.091	0.091	<1	<1	1,049
	26/04/2005 11:30	15.70	9259	<0.002	0.017	0.017	2	2	1,189
	24/05/2005 11:25	14.50	9340	<0.002	0.004	0.005	86	88	1,036
	21/06/2005 12:10	13.30	9354	<0.002	<0.002	<0.002	<1	<1	965
	25/07/2005 11:15	12.40	9473	0.060	0.199	0.259	<1	<1	930
	22/08/2005 11:05	13.20	9330	<0.002	<0.002	<0.002	<1	<1	857
	26/09/2005 11:29	12.75	9278	0.008	0.071	0.079	<1	<1	948
	31/10/2005 10:52	14.06	9173	0.003	0.478	0.481	<1	<1	915
	08/12/2005 10:47	17.33	8849	0.033	0.661	0.695	1.00	1.00	985
	15/02/2006 10:06	18.06	8426	0.024	0.318	0.342	<1	<1	1,073
	27/06/2006 12:00		9225						
T27/0055	26/02/2004 12:00	19.90	6736	0.091	0.930	1.02	220	220	1,132
	18/03/2004 12:50	19.70	6577	0.091	1.04	1.13	1.00	1.00	1,260
	21/04/2004 11:40	16.10	6915	0.063	0.930	0.993	1.00	1.00	1,367
	21/05/2004 12:30	15.50	6690	0.034	0.810	0.844	<1	<1	1,285
	02/07/2004 11:20	13.00	7065	0.032	2.19	2.22	<1	<1	1,,313
	03/08/2004 13:00	12.44	6875	0.016	0.927	0.943	<1	<1	1,279
	07/09/2004 11:55	11.54	6988	0.040	1.47	1.51	<1	<1	1,103

	02/11/2004 09:50	13.40	6920				<1	<1	976
	02/12/2004 10:30	17.70	6342	<0.002	0.832	0.832	<1	<1	1,142
	17/01/2005 10:45	16.90	6360	0.049	1.35	1.40	<1	<1	1,168
	17/02/2005 10:10	17.80	6212	0.017	1.21	1.22	<1	<1	1,128
	21/03/2005 11:20	16.60	6108	0.063	0.741	0.803	<1	<1	1,089
	26/04/2005 12:25	15.80	6907	0.02	1.450	1.47	7	8	1,121
	24/05/2005 12:20	14.70	6962	0.051	8.79	8.84	2	3	1,115
	21/06/2005 11:15	13.20	6881	0.027	6.99	7.01	10	10	995
	25/07/2005 12:05	13.20	7030	0.021	6.81	6.83	<1	<1	959
	22/08/2005 12:45	13.20	6762	0.046	7.29	7.34	<1	<1	1,010
	26/09/2005 12:10	13.90	6665	0.069	8.23	8.30	<1	<1	1,068
	31/10/2005 11:49	15.11	6635	0.12	8.96	9.08	<1	<1	968
	08/12/2005 11:29	16.85	6345	0.151	9.03	9.18	<1	<1	1,005
	15/02/2006 10:49	17.20	5960	0.252	9.96	10.2	<1	<1	1,204
	27/06/2006 12:00		7075						
T27/0056	20/02/2004 13:10	17.80	6570	<0.002	<0.002	0.003	4	4	1,603
	18/03/2004 11:40	17.30	6415	<0.002	<0.002	<0.002	<1	<1	1,418
	21/04/2004 11:10	15.00	6325	0.003	<0.002	0.003	<1	<1	1,387
	21/05/2004 11:30	14.50	6060	<0.002	0.002	0.003	<1	<1	1,512
	02/07/2004 11:35	12.60	6530	<0.002	<0.002	<0.002	<1	<1	1,414
	03/08/2004 12:00	11.19	6437	0.002	<0.002	<0.002	<1	<1	1,509
	07/09/2004 11:20	11.12	6444	<0.002	<0.002	0.003	<1	<1	1,264
	02/11/2004 10:40	14.70	5420				<1	<1	1,148
	02/12/2004 10:00	14.60	6005	0.002	0.003	0.005	<1	<1	1,177
	17/01/2005 10:30	16.10	6022	<0.002	0.004	0.004	1	1	1,161
	17/02/2005 09:45	17.70	5698	<0.002	0.016	0.017	2	2	1,033
	21/03/2005 11:35	17.20	5735	<0.002	0.034	0.034	7	8	948
	26/04/2005 13:00	14.80	6487	0.009	0.164	0.173	7	7	1,367
	24/05/2005 12:55	14.40	6446	0.002	0.014	0.017	<1	<1	1,361
	21/06/2005 12:35	12.80	6400	<0.002	0.021	0.023	<1	<1	1,073
	25/07/2005 12:35	12.00	6432	0.018	0.024	0.042	<1	<1	1,165
	22/08/2005 12:00	12.70	6325	<0.002	0.017	0.017	<1	<1	1,170
	26/09/2005 13:13	12.67	6415	<0.002	0.013	0.014	<1	<1	1,126

	31/10/2005 12:13	15.37		<0.002	<0.002	<0.002	<1	<1	919
	08/12/2005 12:02	16.00	5788	<0.002	<0.002	<0.002	<1	<1	929
	15/02/2006 11:12	17.36	5591	<0.002	0.003	0.003	<1	<1	990
	27/06/2006 12:00		6520						
Te Unu Unu Stream @ Bridge	18/03/2004 14:00	19.20		<0.002	<0.002	<0.002	240	240	695
	02/12/2004 12:00	20.20		<0.002	<0.002	0.002	<4	<4	671
Te Unu Unu Stream @ Downstream	18/03/2004 13:45	18.80		<0.002	<0.002	<0.002	100	120	711
	02/12/2004 12:00	17.00		<0.002	0.004	0.004	1100	1100	797
Te Unu Unu Stream @ Upstream	18/03/2004 13:30	19.70		<0.002	<0.002	<0.002	180	180	659
	02/12/2004 12:00	18.20		<0.002	0.002	0.002	780	780	770

Appendix 5: GSoE water quality summary statistics

	Water Level (m)				NO_2-N (mg/L)			
Bore No.	Median	Minimum	Maximum	*n*	Median	Minimum	Maximum	*n*
S27/0009	-3119	-4226	4700	12	<0.002	<0.002	<0.002	14
S270070					<0.002	<0.002	<0.002	14
S27/0299	-1224	-1695	-992	22	<0.002	<0.002	0.003	30
S26/0117					<0.002	<0.002	0.007	15
S26/0439	-4515	-9670	3356	14	<0.002	<0.002	<0.002	16
S26/0467	-2910	-3642	2640	12	<0.002	<0.002	<0.002	15
S26/0705					<0.002	<0.002	0.033	41
S26/0824					<0.002	<0.002	0.051	41
T26/0538	-3738	-7243	-2216	39	<0.002	<0.002	<0.002	40
T26/0489	-5720	-8035	-4019	13	<0.002	<0.002	0.005	41
S26/0299	-4149	-5220	-3038	38	<0.002	<0.002	0.009	40

	NO_3-N (mg/L)				DRP (mg/L)			
Bore Number	Median	Minimum	Maximum	*n*	Median	Minimum	Maximum	*n*
S27/0009	2.95	2.39	4.24	14	0.010	0.010	0.030	14
S270070	0.37	0.18	2.53	14	0.005	<0.004	0.012	14
S27/0299	0.19	<0.002	0.28	30	0.008	0.004	0.016	30
S26/0117	3.40	1.94	6.91	15	0.016	0.012	0.032	15
S26/0439	3.70	3.05	8.29	22	0.026	0.009	0.030	16
S26/0467	2.27	1.20	4.14	15	0.020	0.017	0.025	15
S26/0705	4.88	3.75	6.30	41	0.026	0.019	0.035	41
S26/0824	5.89	4.52	6.82	41	0.020	0.013	0.029	41
T26/0538	10.30	6.80	15.80	41	0.009	<0.004	0.110	40
T26/0489	10.72	9.60	12.40	42	0.016	0.011	0.160	41
S26/0299	4.99	2.18	11.90	40	0.021	0.004	0.040	40

	E. coli (cfu/100mL)				Faecal coliforms (cfu/100mL)			
Bore Number	Median	Minimum	Maximum	*n*	Median	Minimum	Maximum	*n*
S27/0009	<1	<1	<1	14	<1	<1	<1	14
S270070	<1	<1	<1	14	<1	<1	<1	14
S27/0299	<1	<1	<1	16	<1	<1	<1	16
S26/0117	<1	<1	80	14	<1	<1	80	14
S26/0439	<1	<1	840	14	<1	<1	840	14
S26/0467	<1	<1	2	14	<1	<1	3	14
S26/0705	<1	<1	<1	17	<1	<1	<1	38
S26/0824	<1	<1	<1	18	<1	<1	<1	39
T26/0538	<1	<1	<1	19	<1	<1	<1	40
T26/0489	<1	<1	<1	12	<1	<1	<1	33

	NH_4-N (mg/L)				Field Conductivity (µS/cm)			
Bore Number	Median	Minimum	Maximum	*n*	Median	Minimum	Maximum	*n*
S27/0009	0.010	0.010	0.030	14	161	103	181	14
S270070	<0.01	<0.01	0.020	14	75	61	140	14
S27/0299	<0.01	<0.005	0.030	30	89	73	100	29
S26/0117					128	99	170	15
S26/0439	<0.01	<0.005	0.015	16	161	117	174	16
S26/0467	<0.01	0.006	0.031	15	128	94	148	15
S26/0705	<0.01	<0.005	0.160	41	165	127	174	41
S26/0824	<0.01	<0.005	0.150	41	174	130	184	41
T26/0538	0.008	0.005	0.040	40	294	223	354	40
T26/0489	<0.01	<0.005	0.040	41	273	218	298	41
S26/0299	<0.01	<0.005	0.050	40	124	80	164	39

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Sheree Tidswell taking a groundwater level measurement

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