Groundwater Quality Survey Results for Lower Waiau Nitrate Survey

February 2012

Dr Clint Rissmann
Environmental Scientist, Groundwater, Environment Southland

File Reference 218/02/04

Introduction

A groundwater quality survey was carried out on the 13 – 19thth of December 2011 in the Waiau area following two dairy compliance monitoring bores (D45/0111 and D45/0118) regularly measuring nitrate concentrations in excess of 80% of the Maximum Allowable Value (MAV) for drinking water (Ministry of Health, 2005). The purpose of this survey was to determine the severity and extent of high nitrate concentrations in the Papatotara (Southern Waiau), Clifden and Otahu areas of the Lower Waiau Groundwater Zone and if possible, identify the source of nitrate (Figure 1.).

Environmental Setting

The Waiau Groundwater Zone follows the course of the Waiau River, from its headwaters in the Te Anau region, to its river mouth in the south where it discharges into Te Waewae Bay (Figure. 1). The area of focus includes the lower half of the Waiau Groundwater Zone from north of Otahu Flat to Te Waewae Bay in the south. Within this region, the Waiau Groundwater Zone is hosted by a structurally controlled fault depression known as the Waiau Basin. The Waiau Basin is bounded in the west by the massif of the Fiordland Mountains and in the East by the Takitimu and Longwood Mountains (Fitzharris et al., 1992). The Waiau Basin has existed since middle Cenozoic time (~35 million years ago), and is controlled by subsidence along the northeast trending Moonlight Fault System (Turnball and Allibone, 2003). The Waiau Basin was in filled with Cenozoic sedimentary rocks within which sandstone and limestone units form prominent strike ridges. Extensive flights of Quaternary (last 2.6 million years) terraces, deposited by the Waiau River that drained the former Te Anau- Manapouri piedmont glacier and other Fiordland glaciers, overly the Cenozoic sedimentary sequence (Turnball and Allibone, 2003). Moraines are not extensively preserved within the Waiau Basin but extensive alluvial fans extend west from the Takitimu Mountains into the basin.

Soils

Topoclimate South (1998) soil mapping shows a predominance of shallow, rapidly draining brown to recent soils with subordinate allophonic soils. Minor pockets of melanic and organic soils also occur. Due to the characteristics of the major soil types, this area is assessed as having a very severe nitrate leaching risk (Crops of Southland, 2002). Because of the free draining soils and underlying gravels, a good deal of the rainfall that falls onto the land surface will drain into the aquifer. Due to the water holding capacity of the soils, they are generally only at field capacity for short periods; therefore, there is relatively little runoff risk to nearby streams.

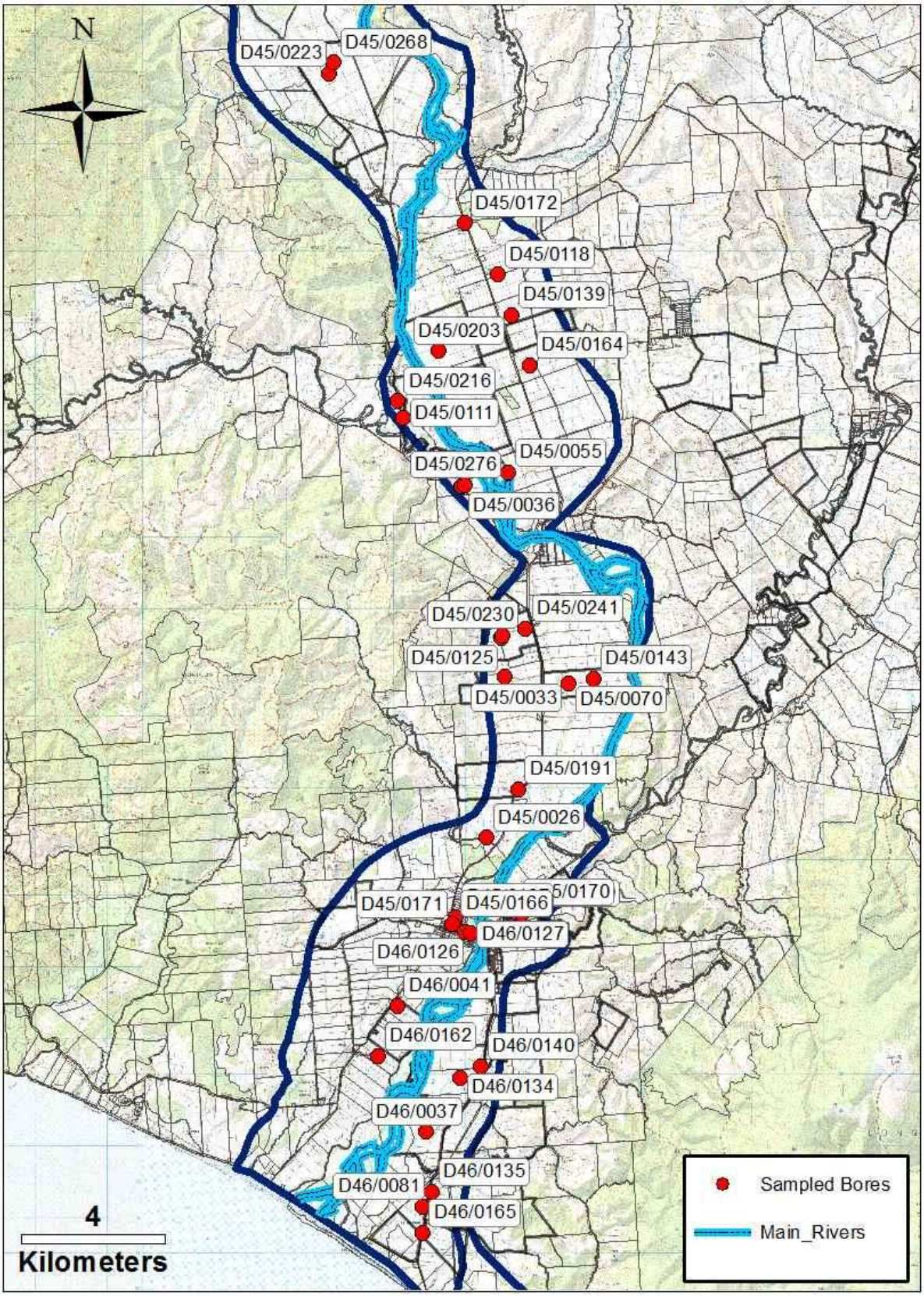

Figure 1. Location of shallow groundwater bores used to assess the extent of nitrate contamination within the lower reaches of the Lower Waiau Groundwater Zone (dark blue outline), 2012. Waiau River shown in light blue; property boundaries in black.

Hydrogeology

Wilson, (2007) assessed the general hydrogeology of the Lower Waiau Groundwater Zone, with the following descriptions of the area taken from her work and that of Fitzharris et al., (1992) and Turnball and Allibone, (2003). The Lower Waiau Groundwater Zone includes a series of unconfined aquifer systems that occur in alluvial terraces adjacent to the lower reaches of the Waiau River (Figures 2 - 4). The terrace age and elevation above river level decrease in a stepwise fashion towards the active river channel of the Waiau River (Turnball and Allibone, 2003). Limited bore log information indicates the unconfined alluvial terrace aquifers are thin (median thickness of 17.5 m; range of 4.0 to 55.0 m) and overlie mud- and sandstone units of the Waiau Group at depth.

Otahu Flat, Dean Burn, Clifden and Papatotara are characterised by relatively broad river flats adjacent to the Waiau River (Figures 2 & 3). These river flats contain a sequence of up to six distinct alluvial terraces that step down towards the current river channel. Across these terraces, groundwater and surface water resources are closely linked. Groundwater under the higher older terraces feed spring-fed streams that originate along the base of terrace risers (steps). These streams in turn lose flow as they recharge aquifers across intermediate terrace surfaces and ultimately discharge into springs and wetland areas adjacent to the river. Free draining soils on these terraces facilitate the rapid movement of water through to the aquifer, which increases the risk of nitrate leaching from land activities on the surface.

Groundwater recharge is primarily via rainfall and runoff from surrounding hills with a mean annual land surface recharge estimated at 490 mm/yr (Lincoln Environmental, 2003). Aquifer recharge also occurs from the numerous streams, which flow across the alluvial terraces adjacent to the river (Figure 3). Interaction between the Waiau River unconfined aquifers is limited to the narrow riparian strip along the recent floodplain.

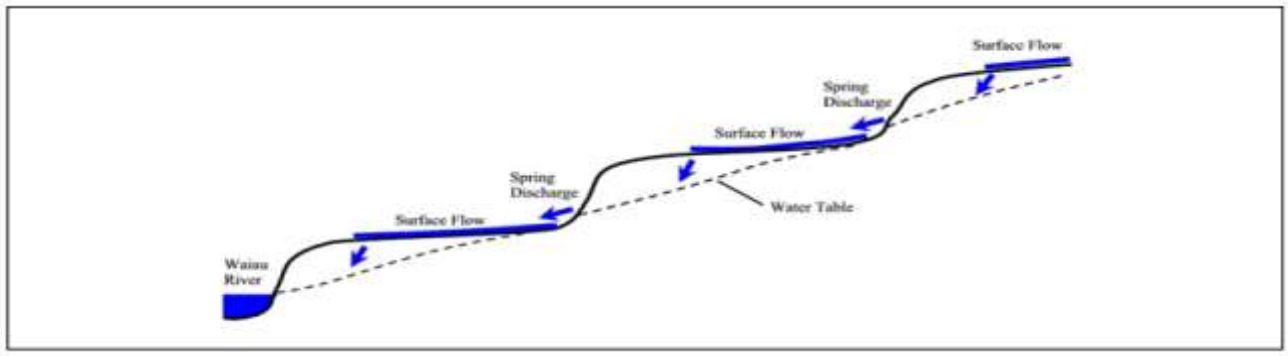

Figure 2. Schematic cross section of the lower reaches of the Lower Waiau Groundwater Zone (Wilson, 2007).

Bores that drill through the relatively thin sequence of Quaternary gravels intercept Cenozoic sedimentary rocks including the Mako & Belmont Coal Measures. Around Clifden some of the aquifers are hosted in limestone deposits and are therefore very different to the well-defined alluvial gravel aquifers of the Waiau River floodplain.

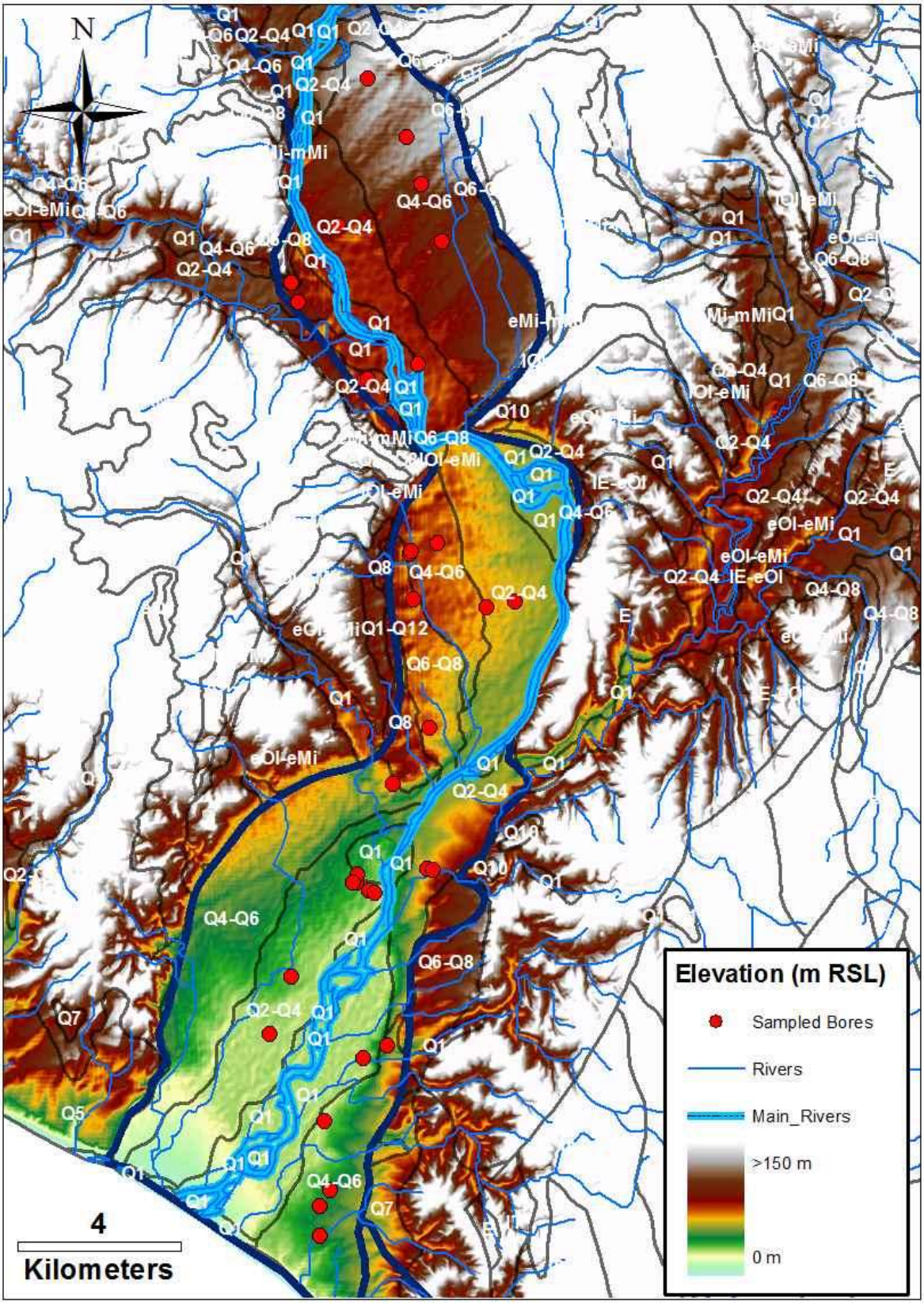

Figure 3. Elevation map of Lower Waiau Groundwater Zone including bore locations; stratigraphic age (Q1(youngest) – Q6(oldest)), rivers and geological units (black outlines). Note river terraces show a general increase in age with distance from the modern day Waiau River and its floodplain. The Lower Waiau Groundwater Zone is bounded by the Fiordland Mountains to the west and Takitimu and Longwood Mountains to the e ast.

Land Use Activities

Review of land use and compliance data for the Lower Waiau Groundwater Zone shows that the Lower Waiau Groundwater Zone remains relatively undeveloped when contrast with other Groundwater Zones regionally. Nonetheless, consents data for the area of the survey reveals a significant increase in the number of dairy consents since 2000, which includes consents to discharge Farm Dairy Effluent (FDE) to land (Figure 4). From Figures 3 and 4 it is evident that all FDE irrigation occurs on alluvial gravel terraces and associated high-risk soils. Over the 2005 - 2011 period Compliance Officers inspected a number of farms (consent #: 93614; 202304; 204627) within the surveyed area that had been regularly and heavily over applying FDE and/or over stocking around the Otahu Flat area. Similar long-term non-compliance associated with over application of FDE and over stocking of dairy cows is recorded for farms (consent #: 203487) within the Te Waewae area in the southeast of the Lower Waiau Groundwater Zone (Figure 4). No records of dairy cow or livestock wintering are currently available for the survey area. However, it is recognised that wintering practices result in high leaching losses under stony alluvial soils (AgResearch Ltd, 2009 – 2012).

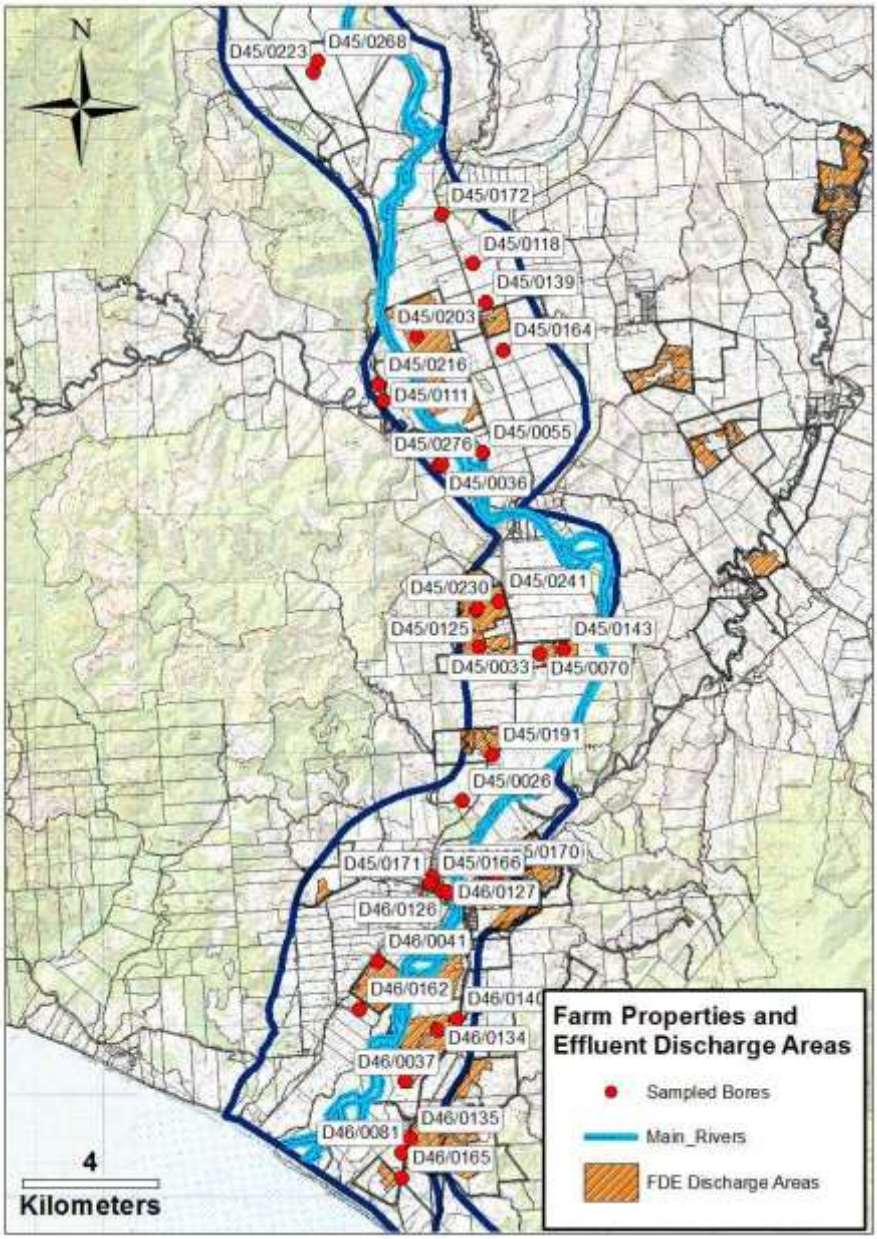

Figure 4. Property boundaries (black) and consented Farm Dairy Effluent Discharge (FDE) areas hatched. Note this map does not display the extent of off farm wintering for dairy or other livestock.

Sampling details

Nineteen bores were sampled from wells northeast of Dean Burn through to the settlement of Te Waewae in the south, over a four-day period in mid-December 2011. The samples were collected in accordance with the National Groundwater Sampling Protocol (GNS, 2006). In addition to the 19 shallow bores sampled, archive data from recent (2005 onwards) monitoring bore data was included to increase spatial coverage resulting in a total of 35 bores (Figures 1, 3 and 4). For bores with more than one measurement, the median NO_3-N value was calculated and used for subsequent interpretation.

The depths of the bores sampled ranged between 3 and 55 metres below ground with all but three of the bores screened in unconfined aquifers. Based on information in ES's consents and WELLS databases, 24 of the bores sampled are used for dairy shed and stock supply, 2 for domestic drinking water and stock supply, 5 for community water supply, with the remainder having no specified use.

Three of the bores sampled were later identified as being within the confined aquifers of the Waicoe Formation calcareous mudstones (D45/0268, D45/0223) and the Mako & Belmont Coal Measures (D45/0036). Another shallow bore (drilled depth of 23 m) intercepts the limestone dominated semi-confined Clifden Subgroup aquifer (D45/0118).

Groundwater Results

NO_3-N (nitrate as nitrogen) concentrations ranged from below detection <0.01 to 12.4 mg/L[1]. The spatial distribution of NO_3-N values are displayed in Figure 5 and are a 'best' estimate of the spatial distribution of NO_3-N concentrations based on bore water results. However, given the sparse nature of the sampled wells the representation is only an approximation of the 'true' NO_3 distribution[2].

Only one bore (D45/0164) exceeded the drinking water standard (a value of 12.4 mg/L or ~10% in excess of the NZDWS) on a farm located close to the Begley Rd and Clifden Blackmount Rd intersection on the surface of the highest terrace (stratigraphic age Q4-Q6; Figures 1, 3 - 5). A generalised pattern of the highest nitrate concentrations within the older (Q4/6 – Q8) more elevated terraces distal from the Waiau River is evident. Examples include the high terraces of Otahu Flat that are transected by the Clifden Blackmount Rd, those terraces east and west of Te Karara Bush north of Tuatapere and to the southeast about the settlement of Te Waewae (Figures 3 - 5). The worst affected areas appears to be in the vicinity of Otahu Flat on a flight of elevated terraces east of the Waiau River. This same area of elevated NO_3 coincides with farming operations noted for a high degree of non-compliance including excessive stocking rates and over application of FDE.

Electrical conductivity (EC) is an indirect measure of the number of ions in the water and can sometimes be used as an indication of the amount of contaminant present. Higher EC values in groundwater can reflect either longer rock water interaction times, more readily dissolvable aquifer materials or contamination. Generally an alluvial gravel lowland aquifer would have EC ranging between 100 to 200 μs/cm although there can be considerable variability. Around 70% of the bores sampled in the survey had EC results outside of this range, which is interpreted as an indication of human impact on groundwater quality.

From Otahu Flat to the Waiau River mouth electrical conductivity (EC) shows a general decreasing trend perhaps reflecting the greater number of small streams feeding the Waiau River south of Clifden and in particular south of Manuka Island and/or high rainfall inputs (Figure 3). Groundwater EC also decreases with proximity to the Waiau River and in places where the Waiau River valley and its floodplain narrow due to the natural constrictions about the Clifden Gorge and Manuka Island areas. These general trends in EC are attributed to dilution of groundwater by stream and river waters of

[1] The maximum acceptable limit in the New Zealand drinking water standards is 11.3 mg/l, NO_3 as N.

[2] Zero concentration boundaries (for NO3-N) were inserted to limit the spread of contoured data beyond the margins of the Groundwater Zone.

lower EC. Groundwater NO_3-N concentrations show a similar general pattern to EC indicating dilution of groundwater by stream and river water of lower NO_3-N concentrations. Dilution by the Waiau River about the Manuka Island/Tuatapere area likely limits the build-up of NO_3 in the groundwaters tapped by the Tuatapere community water supply with a median NO_3-N concentration of 2.5 mg/L for these 5 bores (Figures 3 & 5; bores D46/0126, D46/0127, D45/0166, D45/0167 and D45/0171). Those bores identified as being within the confined aquifers of the Waicoe Formation calcareous mudstones (D45/0268, D45/0223) and the limestone dominated semi-confined Clifden Subgroup aquifer (D45/0118) also exhibit EC values, oxidising conditions and nitrate concentrations similar to those of the unconfined alluvial aquifers.

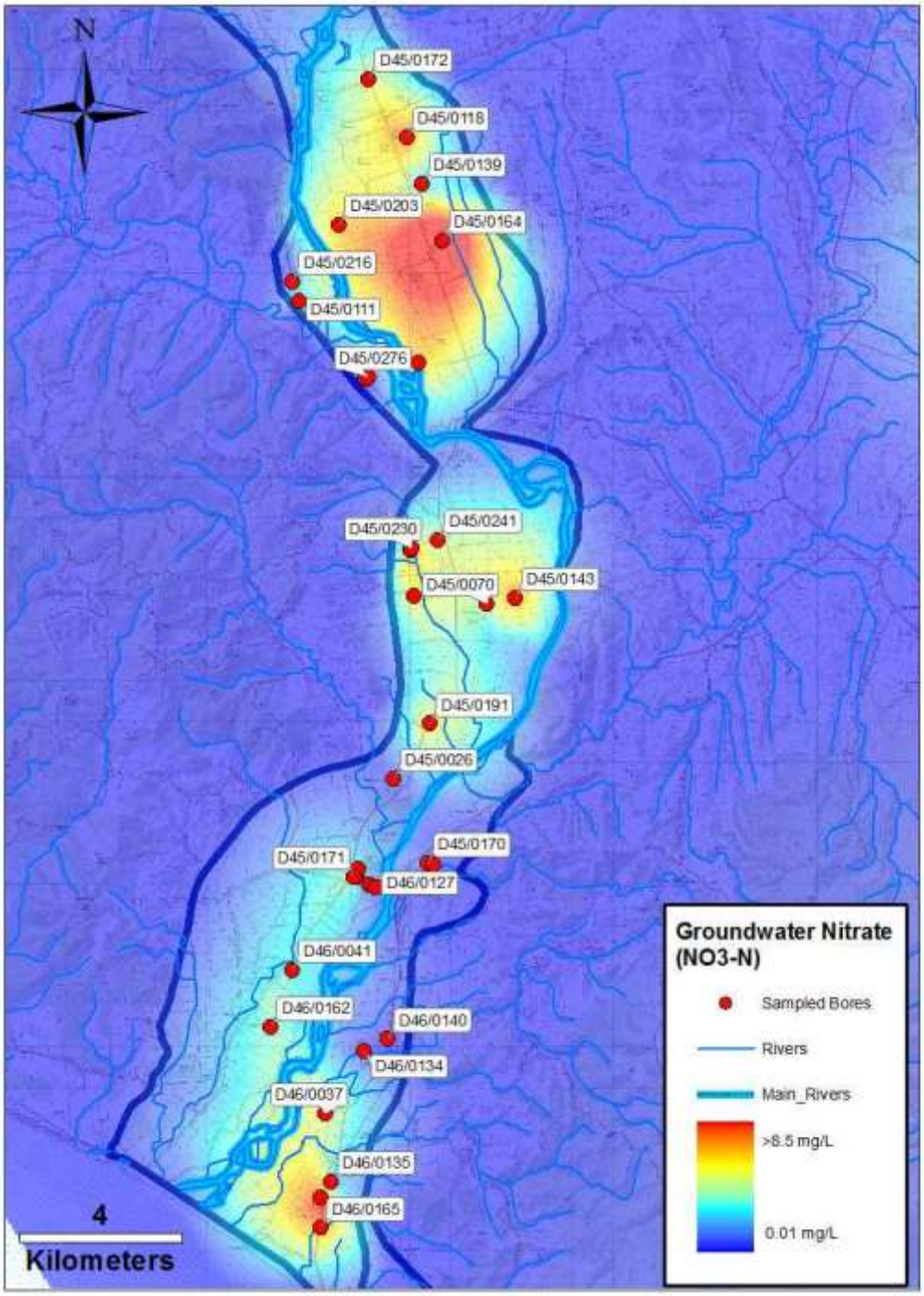

Figure 5: NO_3-N (mg/L) concentrations from the 15th – 19th of December 2012 Lower Waiau Groundwater Zone. Nitrate scale is defined by the detection limit at 0.01 mg/L up to 8.5 mg/L or 85% of MAV.

Within the high terrace aquifers distal from the Waiau River, and/or those aquifers receiving minimal recharge from surface streams or rivers, groundwater NO_3 concentrations accumulate to levels far in excess of natural background for the Southland region (≤1.0 mg/L NO_3-N; Figures 3 & 5). Increased NO_3-N concentrations reflect the general intensification of farming practices within the Lower Waiau Groundwater Zone associated with increased N loading from fertilisers and animal wastes. Temporal trends of increasing EC and/or NO_3-N concentrations are evident for 4 of the 5 wells with long-term (i.e. ≥ 5 years) records (Figures 6 & 7). These temporal trends coincide with a proliferation of dairying operations within the Lower Waiau Groundwater Zone since 2000 (Environment Southland Consents and Compliance Data).

The susceptibility of Lower Waiau groundwaters to NO_3 contamination reflects the predominance of oxidising (high dissolved oxygen concentrations) conditions and minor thickness of the unconfined gravel aquifers. High dissolved oxygen concentrations (D.O.) in groundwaters enable NO_3-N to build to high concentrations whereas D.O. concentrations less than 2 mg/L result in the active removal of NO_3-N via denitrification (McMahon and Chapelle, 2009). An assessment of the redox status of groundwaters sampled in this survey shows that ~85% of the bores are categorised as oxidising with a median D.O. concentration of 7.2 mg/L (n = 16). Only one bore exhibits a mixed redox state (both oxidising and reducing) with two anoxic wells (one of which occurs within the confined Mako and Beaumont Coal Measure aquifer) all of which have NO_3-N concentrations less than 0.1 mg/L. No general spatial trend in oxygen or redox status was evident. The high proportion of oxidising groundwaters within the Lower Waiau Groundwater Zone is typical of alluvial gravel aquifers within Southland, and worldwide, which makes them especially susceptible to NO_3 contamination under intensive land use (McMahon and Chapelle, 2009; Rissmann, 2011).

Escherichia Coli (*E.coli*) was detected in only 2 (D46/0081 and D45/0111) out of 35 bores. The highest *E.coli* measured for bore D46/0081 (150 MPN) coincides with a NO_3-N concentration of 9.8 mg/L suggesting contamination of groundwater by animal wastes in this locality likely associated with faecal material on/and around the sampling point.

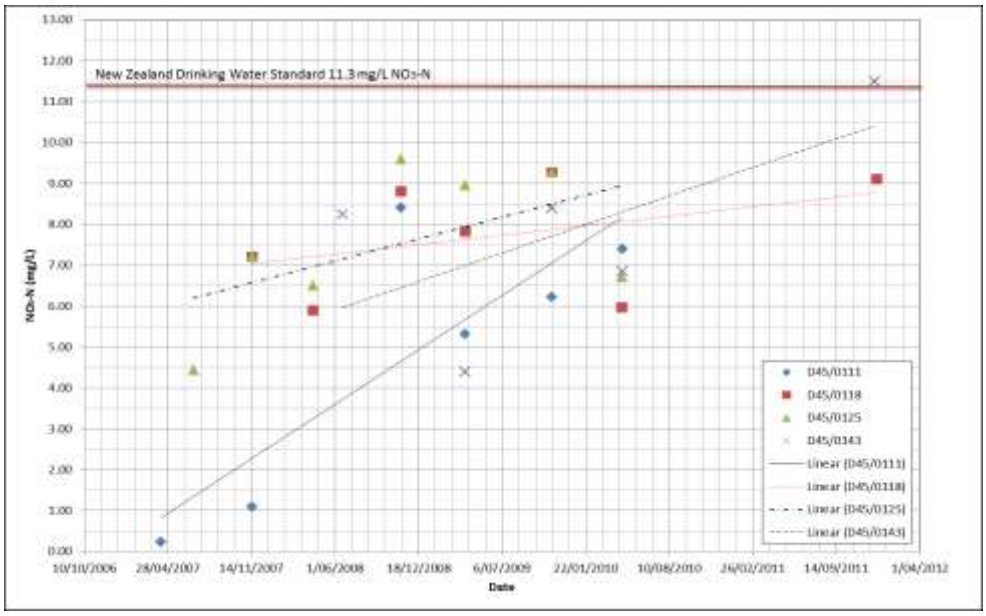

Figure 6: Linear regression trends of NO_3-N (mg/L-N) for monitoring bores with long-term records. Note general increase in NO_3-N with time.

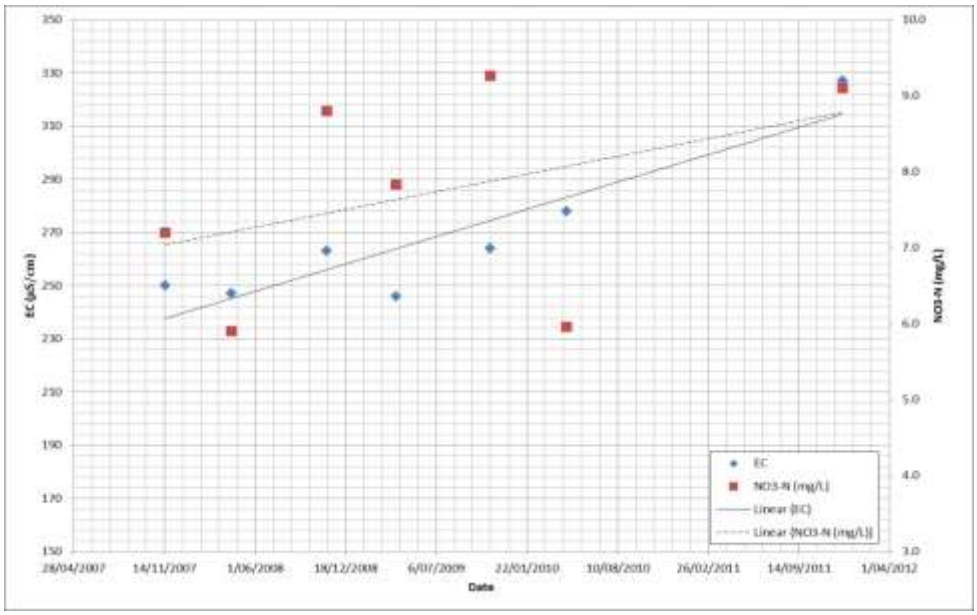

Figure 7. Example of increasing EC with NO_3-N over time for bore D45/0118.

Summary and Recommendations

The groundwater quality results from the December 2012 survey and a review of the compliance monitoring data show a generalised pattern of the highest nitrate concentrations within groundwaters of the older (Q4/6 – Q8) more elevated terraces distal from the Waiau River associated with intensive agriculture. Due to a high degree of groundwater/surfacewater interaction in some areas, there is variability between nitrate concentrations measured on high terraces and low floodplain aquifers. Bores closer to the Waiau River may have a higher hydraulic connection with the river and streams and as a result of mixing, dilution of groundwater nitrates occurs. Bores with high nitrate concentrations are located on higher terraces that have far less hydraulic connection to the river systems.

From the information available, the land within the survey area is very sensitive to intensive farming activities. Monitoring data shows that as a result of the free draining soils, relatively thin gravel aquifers and shallow water tables that the risk of groundwater contamination from land use intensification is high. Regional intensification of dairy farming within the Lower Waiau Groundwater Zone since 2000 is likely responsible for increasing NO_3-N concentrations. If not for the high degree of groundwater and surfacewater interaction close to the Waiau River nitrate concentration in the bores may be equally high.

There is some minor potential for down gradient groundwater users to be affected by the high levels of nitrate in the groundwater as it moves through the aquifer, such as the Tuatapere town water supply. Currently the Tuatapere town water supply contains moderately low NO_3-N concentrations (<3.0 mg/L) but these may rise if regional intensification and dairy conversion continues up gradient. The domestic water supply of bore D46/0081 appears to be strongly affected by local FDE disposal.

Overall, the generalised increase in groundwater NO_3-N likely reflects the on-going intensification of agricultural practices within the Lower Waiau Groundwater Zone, which results in greater nitrogen loads to the land surface from fertiliser and animal wastes. The observation of temporal increases in contaminant concentration are concerning giving they relatively undeveloped nature of the Lower Waiau Groundwater Zone. Given the generally diffuse nature of contamination and strong temporal trends of increasing nitrate concentrations, I recommend the following:

- Notify Public Health South and Southland District Council, advise of increased NO_3 concentrations in areas of the Lower Waiau Groundwater Zone, and suggest routine

monitoring of the groundwater quality of the Tuatapere town water supply bores (D46/0127 and D46/0126).

- Quarterly (or other frequency as deemed relevant by Compliance Technical Officers) groundwater quality monitoring carried out at bores D45/0143, D45/0164, D45/0118, and D46/0081. At each site measure dissolved oxygen, total nitrogen, nitrate nitrogen, dissolved chloride, dissolved bromide, dissolved iodide, dissolved fluoride, boron and electrical conductivity as part of on-going compliance monitoring as soon as legally possible.

- Elevated nitrate concentrations are relatively localised to properties on high terraces distal from the Waiau River. It is recommended that the area of Otahu Flat be included in the ES database of known groundwater problem areas that will inform the Discharge Plan process.

- As bore D46/0081 is used for domestic drinking water, the owners were contacted and advice given on how to improve water quality via better bore head protection and/or filtering of groundwater for drinking purposes.

- Engage Land Sustainability to lead a Lower Waiau land use field day to inform the community of increased nutrient loading within the region.

References

AgResearch Ltd, 2009 - 2012. The influence of soil drainage characteristics on contaminant leakage risk associated with the land application of farm dairy effluent and dairy cow wintering. On-going.

Crops for Southland, 2002. Soil Information sheets. Prepared for Environment Southland.

Fitzharris, B.B., Mansergh, G.D., Soons, J.M., (1992). Basins and Lowlands of the South Island. In Landforms of New Zealand, 2nd Edition, Ed. Soons, J.M., and Selby, J.M. Longman Paul Publishers, Auckland, New Zealand.

Ministry of Health, 2005. Drinking Water Standards for New Zealand. ISBN 0-478-28392

McMahon, P. and Chapelle, F. (2008), Redox Processes and Water Quality of Selected Principal Aquifer Systems. Groundwater, 46: 259–271.

Turnbull, I.M., Allibone, A.H., (2003). Geology of the Murihiku area. Institute of Geological and Nuclear Sciences 1:250 000 geological map 20. 1 sheet + 74 pp. Lower Hutt, New Zealand Institute of Geological and Nuclear Sciences Ltd.

Rissmann, C.F., 2011. Regional Mapping of Groundwater Denitrification Potential and Aquifer Sensitivity. Technical Report for Environment Southland.

Wilson, K., 2007. Groundwater Zone Information Sheet, Lower Waiau. Prepared for Environment Southland.