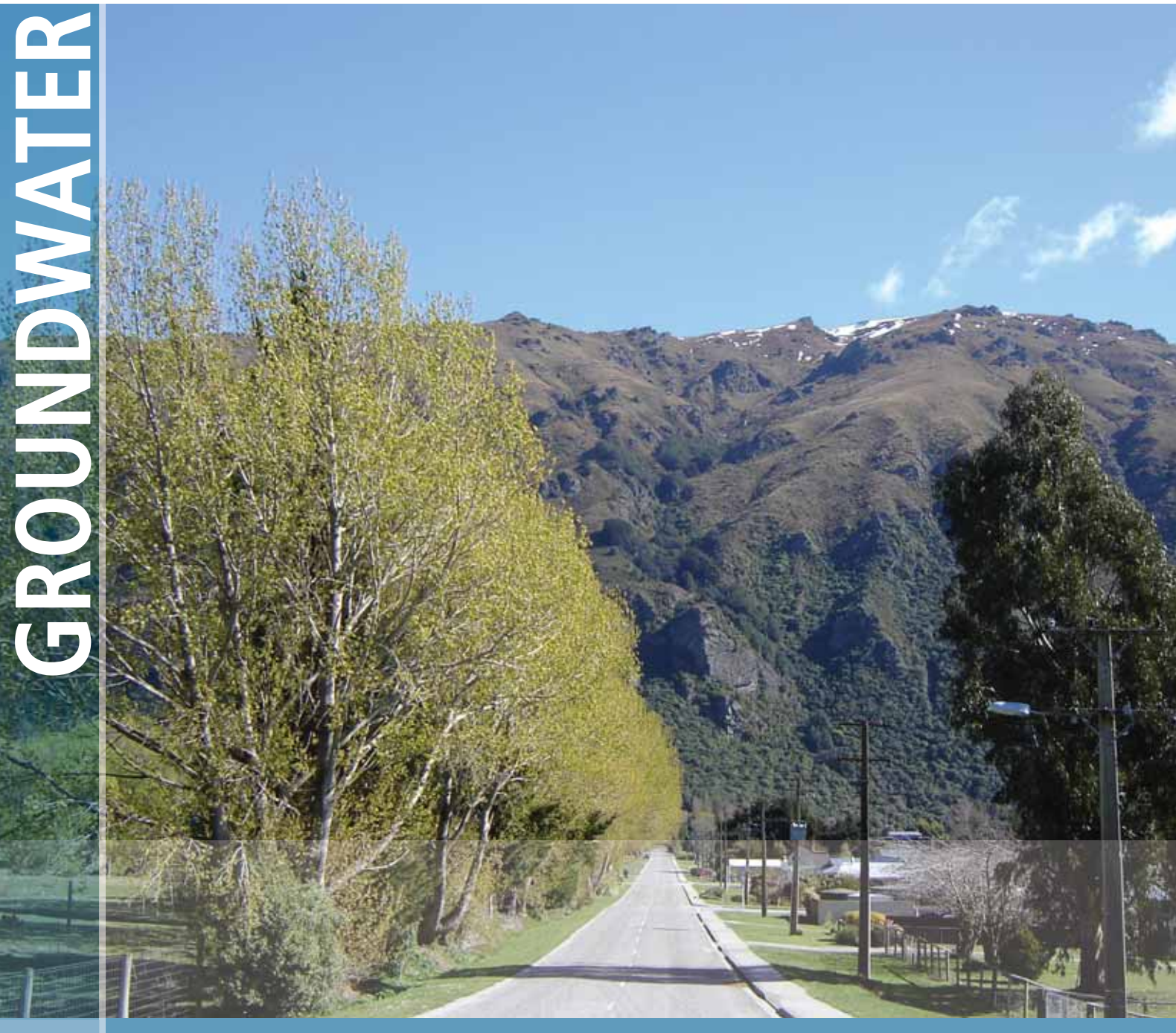
GROUNDWATER

Groundwater Quality in Kingston and Glenorchy



Otago Regional Council

Groundwater quality in Kingston and Glenorchy

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Chairman's foreword – Groundwater Quality in Kingston and Glenorchy

Otago's prosperity is largely based on water. Lake Wakatipu is one of the largest lakes in New Zealand and is part of the Clutha River Catchment which has the largest annual discharge of any river in New Zealand. However, despite the large total water volumes present in the region's water bodies, many areas of Otago are short of water. Groundwater is frequently the sole or major source of water to supply basic water needs to communities and stock watering.

Otago Regional Council's Regional Policy Statements for Water provides for Otago people and communities to have access to water for their present and reasonably foreseeable needs.

Groundwater resources have varying rates of recharge and often form a complex dependency with adjacent water courses, wetlands and stream networks. The effects of inappropriate land and water use on groundwater quality and quantity are often long-term and in some cases permanent. It is therefore important that particular consideration be given to the protection of aquifers for the continuing benefit of present and future generations.

Through Otago Regional Council's Regional Plan: Water and our Annual Plans we ensure linkage with the community to deliver the protection of our groundwater aquifers.

This report describes the water quality of the groundwater in Kingston and Glenorchy. It is based on local knowledge, scientific evidence and monitoring information. The best way forward is to carefully monitor this valuable resource and maintain control so that contamination does not affect its use. This is a complex topic and further monitoring and review of the aquifer will continue to ensure a sustainable water supply to these communities.

Executive Summary

This report provides an analysis of groundwater quality monitoring in the Kingston and Glenorchy areas over the 2002-2003 period, as well as results of preliminary groundwater investigations by J K Lindqvist Research for the Otago Regional Council during 1996-1997. Houses in Kingston have individual wells for water supply whereas Glenorchy has a community water supply now, which is sourced from one well adjacent to the Buckler Burn.

The report objectives are:

1. To show the temporal and spatial variation in groundwater quality in the Kingston and Glenorchy areas.
2. To identify significant changes (if any) from the 1996-1997 groundwater quality survey results.
3. To determine if any groundwater quality issues exist in the Kingston or Glenorchy areas, and if so, recommend further baseline monitoring.

Up to 24 sets of groundwater quality samples have been collected from the Kingston area, and ten water quality samples have been collected from the Glenorchy area from 1996 to 2003. Significant issues for Kingston and Glenorchy groundwater quality are:

- That results of bacterial samples for Kingston indicated some (periodic) contamination exists within the more densely (central town area) located allotments. Of the six groundwater quality samples taken at Glenorchy, no counts (<1 cfu/100mL) of faecal coliform bacteria were found.

- Very low nitrite-nitrate nitrogen (NNN) levels have been measured from most Kingston groundwater samples, which points to low natural environmental levels. Higher individual values (1.9 – 2.4 mg/L) may indicate possible influence from garden fertiliser application or septic tanks. Very low NNN levels were recorded for the Queenstown Lakes District Council community supply bore at Glenorchy.

- Consistently higher ammoniacal nitrogen levels have been found at Kingston bore F42/0113, with an average concentration of 0.213 mg/L (however, only one faecal coliform count has been identified there). This level of contamination may point to an influence from septic tank effluent disposal.

- Both the Kingston and Glenorchy aquifer systems are reasonably vulnerable to direct land use impacts. In Glenorchy, the water supply is sourced from a well adjacent to the Buckler Burn, away from the township itself, and is not at immediate risk. Kingston appears to be most vulnerable from local septic tank discharges, as they are directly adjacent to many wells used for domestic water supply.

- Major ion concentrations used to define hydrochemical water types shows that Kingston and Glenorchy groundwater is of a relatively recent (recharge) evolutionary path, which confirms that both aquifers are relatively vulnerable to land use impacts.

Monitoring of wells in Kingston during October and early February (holiday season) should be carried out to provide longer term trends in the aquifer for bacterial counts

(faecal coliforms), NNN and ammoniacal nitrogen. The most suitable sites to be used for future sampling indicators of spatial and temporal changes are identified.

Table of Contents

List of Tables

List of Figures

1 Introduction

This report provides an analysis of groundwater quality monitoring in the Kingston and Glenorchy areas over the 2002-2003 period, as well as results of preliminary groundwater investigations by J K Lindqvist Research for the Otago Regional Council during 1996-1997. Most of the background information provided in this report is taken from Lindqvist (1997). The purpose of the preliminary survey was to obtain baseline information aimed at extending the Otago Regional Council's database concerned with groundwater resources and identify any issues surrounding groundwater use and quality.

The current report is aimed at addressing the following:

1. To show the temporal and spatial variation in groundwater quality in the Kingston and Glenorchy areas.
2. To identify significant changes (if any) from the 1996-1997 groundwater quality survey results.
3. To determine if any groundwater quality issues exist in the Kingston or Glenorchy areas, and if so, recommend further baseline monitoring.

The Otago Regional Council has the responsibility to ensure that groundwater resources are used and managed in a sustainable fashion, thus baseline information about the physical, microbiological, chemical characteristics and current use is important.

2 Background Information

2.1 Geology and physiography

Kingston township lies at the southern end of Lake Wakatipu, 40km south of Queenstown (Figure 2.1). On the 1:250 000 scale geological map, Kingston is underlain by glacial moraine deposits and younger (post-glacial) alluvial fan and lake shoreface deposits (New Zealand Geological Survey, 1962). Eyre Mountains on the west side of the lake and Hector Mountains on the east side are composed of schist. The Kingston Stream alluvial fan extends to the lake shore on the south-eastern side of the township and several small unnamed streams drain the western margin.

Geomorpholigical evidence indicates that the Lake Wakatipu Catchment drained to the south, down the Mataura River, during the last glaciation. River channels of substantial size, now swamp-filled, are preserved south of the town. Wakatipu Glacier moraine deposits exposed on the southern ramparts and east of the town, and in cuttings on State Highway 6, consist of bouldery sandy clay with some thin bedded sandy or silty clay. Small remnants of well-sorted sandy gravel, related to local alluvial fan developments and former high-level lake shorelines are also exposed. Within the township, relics of 1-2m high terraces aligned parallel with the modern lake shore mark former higher lake shore levels.

Following a glacial or post-glacial lake level high, the receding lake appears to have dropped in stages. In the Kingston township area, and elsewhere on the Lake Wakatipu deltas, this process left a gently stepped profile with several low lakeward-sloping terraces. At Kingston, this process left a succession of generally low permeability till deposits overlain by better sorted gravely sand alluvium and lake-shore gravels of variable (commonly <1-3 m) thickness, which form the aquifer system.

The Glenorchy township is situated at the northern end of Lake Wakatipu. It lies at the meeting point of a gravel fan delta built by the Buckler Burn on the eastern lake margin, and the southward prograding delta and plain built by the combined Dart and Rees Rivers (Figure 2.1). The Dart/Rees delta front extends 2.5km from Glenorchy to Kinloch township on the west side of the lake. A complex of alluvial sand and mud flats, mires and small ponds at the lower delta margin includes a Department of Conservation wetland reserve on the east side of the delta.

The most recent published account of the geology of the Glenorchy area is the 1:250 000 geological map by New Zealand Geological Survey (1962). Mountain ranges on both the east and west sides of the lake are composed of schist. The calcium tungstate mineral scheelite ($CaWO_4$) was formerly mined from gold-bearing quartz/scheelite/calcite veins in schist in the Buckler Burn catchment on the slopes of Mount Judah, approximately 4km east of the town.

The low terrace flats on which the urban area lies gradually slope to the edge of Lake Wakatipu. Local information indicates that it is partly underlain by peaty soils as well as sandy gravel. Higher terrace deposits are well exposed on the south bank of the Buckler Burn and in the Glenorchy refuse tip. The high terraces are underlain by the remains of the early Buckler Burn gravel delta that prograded into the lake in early post-glacial times.

Several exposures of sandy pebble gravel with thin silts show high-angle bedding surfaces dipping lakeward at 18-22°, which is typical for sub-aqueous fan-delta slope deposits. Sub-aerial alluvial fan deposits locally overlie the inclined bedded gravels. Examination of Buckler Burn alluvial deposits indicates that these generally clay and silt-free gravels are likely to have good aquifer characteristics.

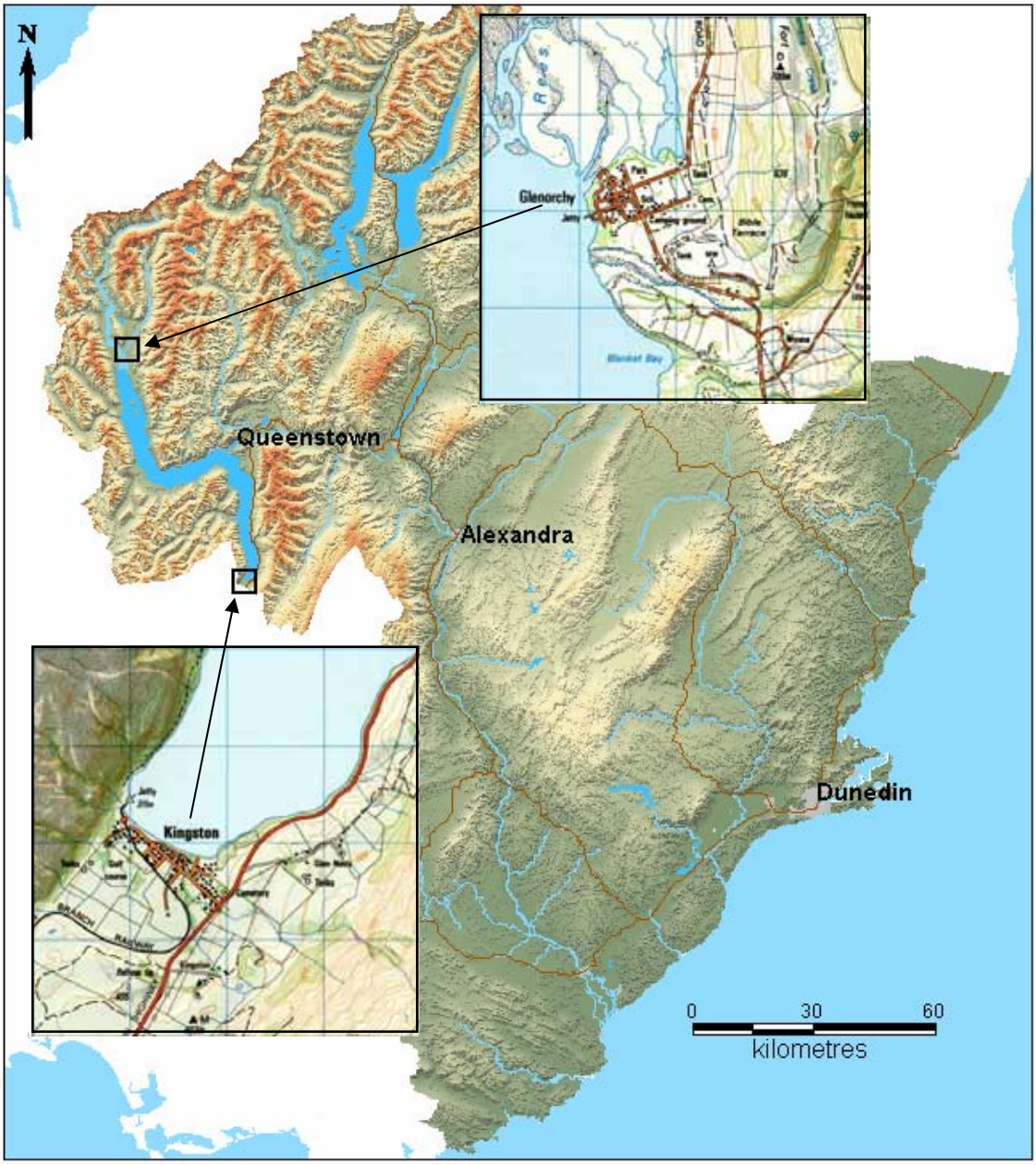

Figure 2.1 Location of Kingston and Glenorchy townships

2.2 Climate and land use

Kingston township, administered by the Queenstown Lakes District Council (QLDC), contains approximately 300 surveyed residential sections. Fewer than half were developed in 1996-1997. Although the total permanent residential population is approximately 80, the summer holiday population increases markedly. Many

permanent residents are retired. Businesses operating in the town include a grocery store/restaurant, Shell Service Station, tavern, and workshop facilities associated with Tranz Rail's Kingston Flier steam excursion train, which operates between Kingston and Garston. The town has a golf course and bowling green on the south-west boundary. Two mixed sheep and cattle stations occupy the lower relief flanks of Hector Mountains east of the town, and valley-floor land on the southern town margin.

Many Kingston properties are owned by Southland residents, attracted to the area for its peaceful setting, trout fishing and water sport opportunities. Composed of sandy pebble gravel, the lake shore at Kingston is sheltered during southerly winds but is exposed to heavy wave action during northerly wind events. The rainfall site at Kingston recorded a mean annual precipitation of 762mm (high 1153mm) for the 1959-1965 and 1969-1980 periods. Although monthly rainfall fluctuations vary between 50 and 200mm in any one year, mean monthly precipitation is evenly distributed throughout an average year during the period recorded.

The Glenorchy area, as indicated by Otago Regional Council rainfall site at Rees Valley Station, had a mean annual precipitation of 1448 mm (high 1880mm, low 1203mm) for the 1988-1994 period. Over this period, mean monthly precipitation was evenly distributed, with a slight increase recorded during the late-winter or early-spring interval.

Business in Glenorchy focuses on eco-tourism activities such as tramping, board sailing, fishing and hunting, skiing, jet boating, flatwater and river kayaking, camping and horse riding. Several horse trek businesses operate within the town area. Facilities include a camping ground, two small hotels, several guest houses, a school, a Department of Conservation information and maintenance centre, and a service station. General development of the area is likely to advance at a greater pace with sealing of the Queenstown-Glenorchy road, completed in 1999.

To the east, various farming concerns utilise the lower slopes of Mt Judah and "The Fort", a long ridge to the north-east of Glenorchy, for sheep and cattle grazing. Terrace flats have been developed there into good quality pasture.

2.3 Groundwater occurrence and use

A postal survey of Kingston landowners organised by the Otago Regional Council in late December 1996 – early January 1997 resulted in the detection of approximately 50% of Kingston groundwater bore sites. As there are many absentee owners, survey returns provided valuable contact information that helped in the location of additional sites. The sites characterised in Appendix 1, include 33 bores, wells or springs. Site locations are shown in Figure 2.2. Overall, Kingston bores and wells are quite shallow. The maximum water table depth (4.3 m; F42/0104) was recorded on the south-east town margin, on the Kingston Stream fan, and reduces down-gradient towards the lake margin (Figure 2.2). A slight artesian flow from the Holiday Camp bore (F42/0108) on the bank of the weakly incised Kingston Stream indicates a deeper aquifer system probably consisting of gravelly sand units interlayered with low permeability muddy units of glacial till or lake bed origin. The single spring site was a distributed seepage from sandy gravel at the excavated foot of the 3m terrace.

Users of groundwater include individual residents plus the Kingston Holiday Camp, and Kingston Store and Café. Consumption is confined to shop or domestic use and cottage garden irrigation. Several nearby households are connected to the bore-and-holding-tank system operated by the camping ground. Few of the bores have substantial casings, many utilising shallow small-diameter pipes driven to 2-3m. All are equipped with surface impeller or piston pumps.

In Glenorchy, the postal survey of landowners in the district organised by the Otago Regional Council in early January 1997 resulted in the location of less than half of the Glenorchy groundwater bore sites eventually found. The 10 sites are characterised in Appendix 1 and their locations and static water levels are plotted in Figure 2.3. The one bore in use, located near the Buckler Burn, is operated by the QLDC for the town supply. Water is pumped to concrete holding tanks located on an elevated terrace, east of the town.

The contoured potentiometric surface for Glenorchy (Figure 2.3), shows a groundwater gradient extending from the QLDC community supply bore, located higher on the Buckler Burn Delta, northwards to the urban area.

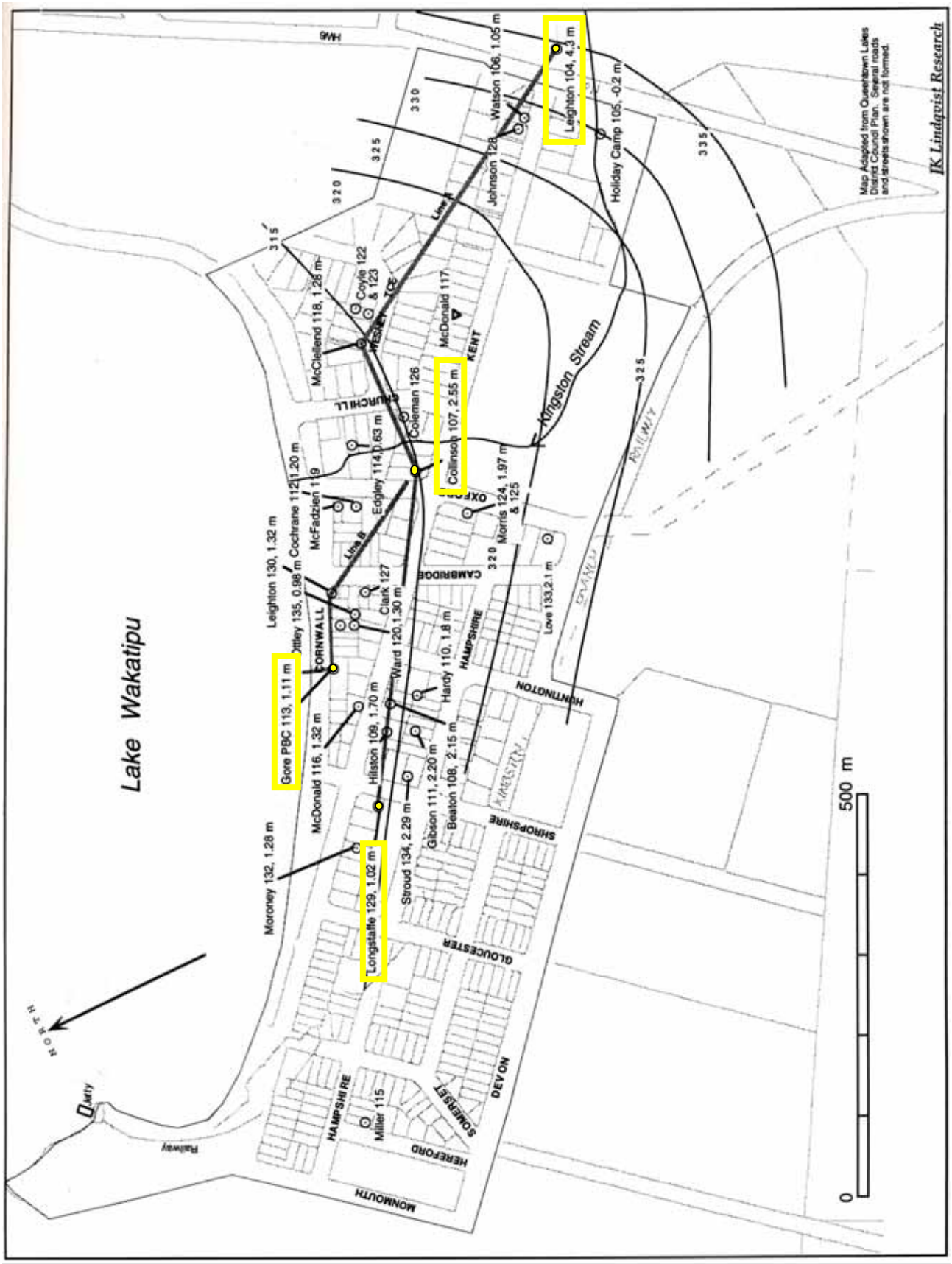

Figure 2.2 Piezometric contour map, depth to water table and location of bores for the Kingston township area. The bore numbers are given in abbreviated form, e.g. 129 becomes F42/0129. Yellow boxes highlight bores recommended for long-term monitoring

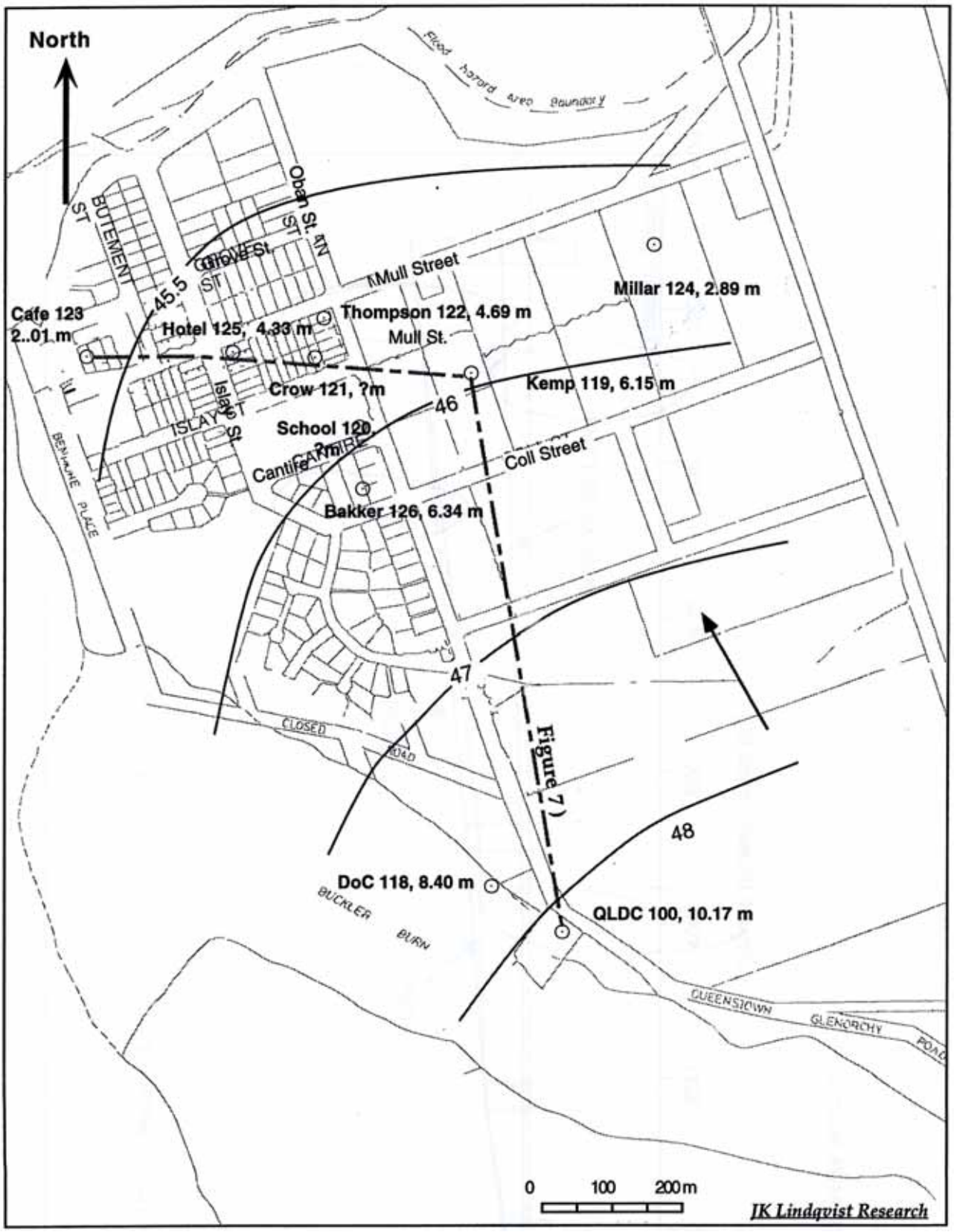

Figure 2.3 Piezometric contour map, depth to water table and location of bores for the Glenorchy township area. The bore numbers are given in abbreviated form, e.g. 126 becomes E41/0126

3 Groundwater Quality

Up to 24 sets of groundwater quality samples have been collected from the Kingston area from 1996 to 2003 (Table 3.1). Results of the chemical and physical analysis are presented in Appendix 2.

Ten water quality samples have been collected from the Glenorchy area from 1996 to 2003. Most samples (6) are from the QLDC bore near the Buckler Burn (collected from storage tanks at the eastern end of the town). Statistical results of the chemical, microbial and physical analyses are presented in Table 3.1 and Table 3.2. Significant issues for each determinand are addressed below.

Table 3.1 Summary groundwater quality statistics for Kingston and ANZECC 2000 Guidelines for human drinking water

Parameter	Units	Mean	Median	Range	Number of Samples	ANZECC Drinking Water Standards (2000)
pH	pH units	6.34	6.34	5.5 – 7.14	24	7.0 – 8.5
Ammoniacal Nitrogen	mg/L	0.036	0.008	0 – 0.24	24	0.01
Bicarbonate	mg/L	59.2	60	18 - 90	21	200
Calcium	mg/L	13	18	3 – 20	7	*
Chloride	mg/L	2.3	2.1	0.8 – 4.8	24	250
Electrical Conductivity	uS/cm	0.1	0.1	0.03 – 0.16	23	<1.0
Dissolved Reactive Phosphorus	mg/L	0.003	0.006	0 – 0.013	24	N/A
Faecal Coliform Bacteria	cfu/100mL	1	0	0 - 10	19	<1
Iron Total	mg/L	2.3	0.4	0 - 16	9	0.2
Magnesium	mg/L	2.4	3.1	0.7 – 3.6	7	*
Nitrite-nitrate nitrogen	mg/L	0.44	0.15	0 – 2.42	24	11.3
Potassium	mg/L	0.92	0.93	0.3 – 1.8	24	N/A
Sodium	mg/L	3.8	4.2	1.8 – 7.5	24	200
Sulphate	mg/L	2.2	1.6	0 – 11.1	24	250
Total Nitrogen	mg/L	0.91	0.67	0.15 – 2.4	12	N/A
Total Organic Carbon	mg/L	3.8	1.5	0.6 – 14.9	11	N/A

Notes: ** - Hardness Total (Calcium + Magnesium) < 200 mg/L*
N/A - Guideline value not available

Table 3.2 Summary groundwater quality statistics for Glenorchy and ANZECC 2000 Guidelines for human drinking water

Parameter	Units	Mean	Median	Range	Number of Samples	ANZECC Drinking Water Standards (2000)
pH	pH units	7.06	6.90	6.5 – 8.42	10	7.0 – 8.5
Ammoniacal Nitrogen	mg/L	0.01	0	0 – 0.09	9	0.01
Bicarbonate	mg/L	64	63	48 - 84	8	200
Calcium	mg/L	13	13	11 - 15	2	*
Chloride	mg/L	0.7	1.0	0 - 2	10	250
Electrical Conductivity	uS/cm	0.13	0.11	0.1 – 0.26	10	<1.0
Dissolved Reactive Phosphorus	mg/L	0	0	0 – 0.002	9	N/A
Faecal Coliform Bacteria	cfu/100mL	0	0	0	6	<1
Iron Total	mg/L	8	0.05	0 - 24	3	0.2
Magnesium	mg/L	0.9	0.9	0.6 – 1.2	2	*
Nitrite-nitrate nitrogen	mg/L	0.31	0.27	0.08 – 0.81	9	11.3
Potassium	mg/L	1	0.74	0.49 – 2.1	10	N/A
Sodium	mg/L	2.2	1.2	0.5 – 9.9	10	200
Sulphate	mg/L	4.9	4.9	0.6 – 8.8	10	250
Total Nitrogen	mg/L	0.36	0.34	0.31 – 0.47	4	N/A

Notes: ** - Hardness Total (Calcium + Magnesium) < 200 mg/L*
N/A - Guideline value not available

2.2 Coliform bacteria

In Kingston, 15 of 19 groundwater samples did not detect the presence of any faecal coliforms. Four samples returned positive counts of faecal coliform bacteria. The highest count (10 cfu/100mL) sampled on 18 February 2003, was taken at a bore (F42/0129) that is centrally located within the township. The other three positive samples were for 4, 2 and 1 cfu/100mL (colony forming unit per hundred millilitres), sampled over the period of 14 October 2002 to 18 February 2003. The bores (F42/0107, F42/0108 and F42/0113), are also centrally located within the township. The results of bacterial samples for Kingston tend to indicate that some (periodic) contamination exists within the more densely (central town area) located allotments.

Of the six groundwater quality samples taken at Glenorchy, no counts (<1 cfu/100mL) of faecal coliform bacteria were found.

2.3 Nitrite-nitrate nitrogen , ammoniacal nitrogen and phosphate

Very low nitrite-nitrate nitrogen (NNN) levels have been measured from most Kingston groundwater samples (Figure 3.1), which points to low natural environmental levels. Higher individual values (1.9 – 2.4 mg/L) may indicate possible influence from garden fertiliser application or septic tanks. Phosphorus levels in Kingston groundwater samples indicate some possible agricultural (fertiliser) and/or urban (fertiliser, detergents) contamination (Table 3.1).

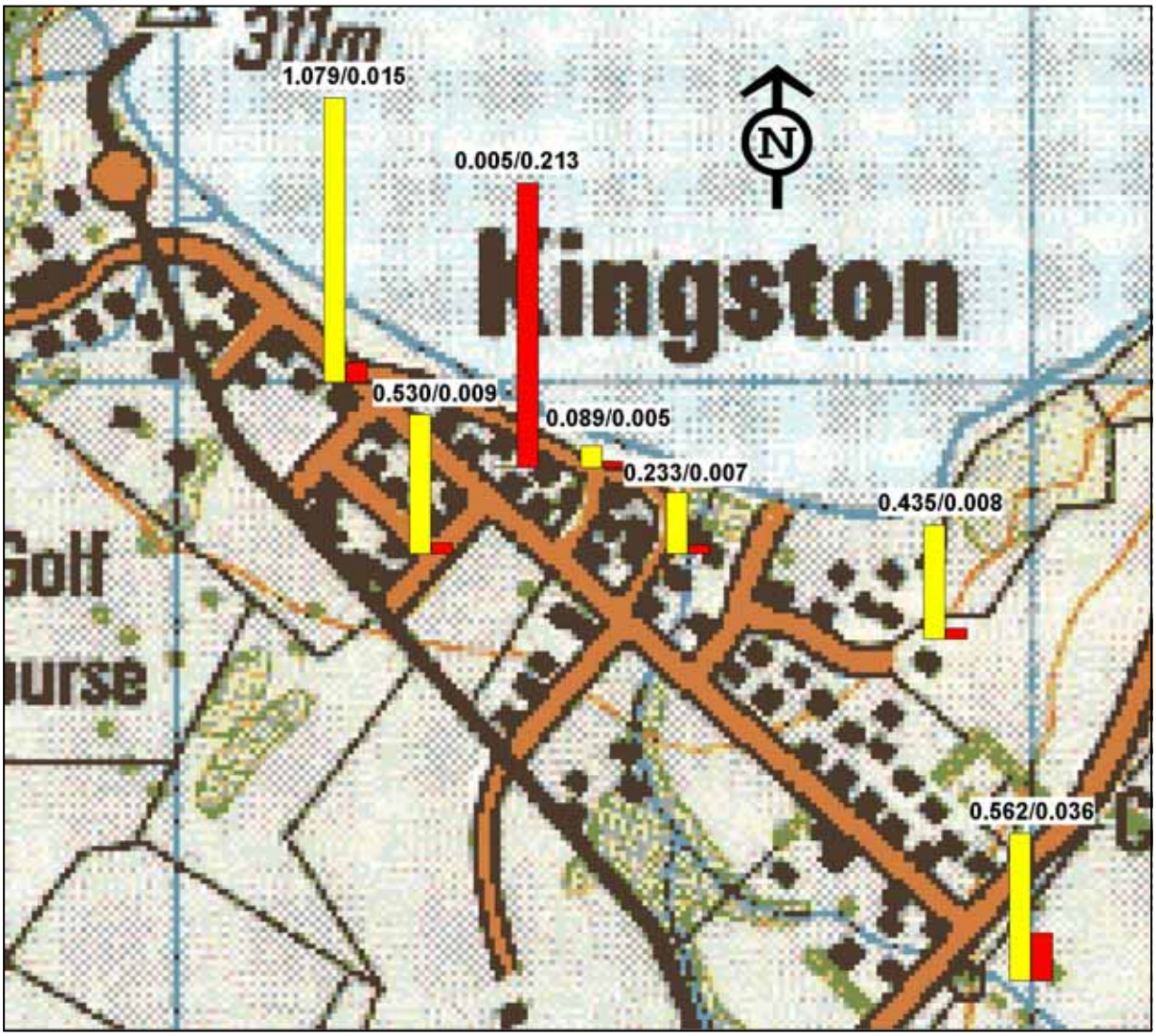

Figure 3.1 Distribution of mean concentrations over the period of 1996 to 2003 for nitrite-nitrate nitrogen (NNN; mg/L) and ammoniacal nitrogen (NH_4-N; mg/L) in Kingston

Notes: *Yellow bars represent NNN concentrations*
Red bars represent NH4-N concentrations
Figures denote actual concentration in mg/L as NNN/NH4-N

Consistently higher ammoniacal nitrogen (NH_4-N) levels have been found at Kingston bore F42/0113, with an average concentration of 0.213 mg/L (Figure 3.1). This level of contamination may point to an influence from septic tank effluent disposal.

The plot of NNN versus NH_4-N for Kingston groundwater samples (1996 – 2003), on Figure 3.2, shows a typical land-use trend. Concentrations of both nutrients typically increase and reflect the variation of land use in the immediate area. There were, however, two occasions where NH_4-N was elevated in relation to NNN. The two samples, rather than indicating heavily reducing conditions in groundwater, probably reflect some contamination from a septic tank source (one of the two samples also detected faecal coliform bacteria (1cfu/100mL).

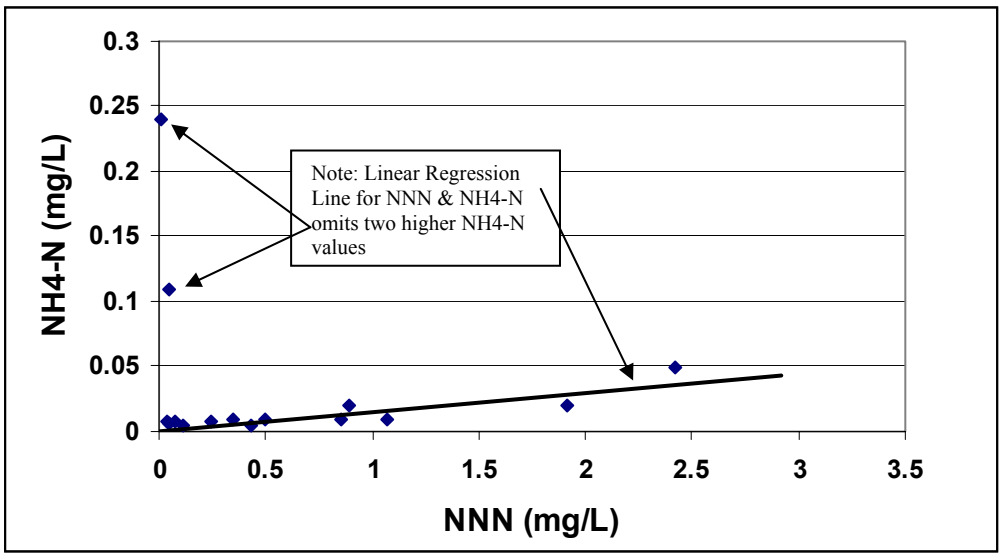

Figure 3.2 NNN (mg/L) versus NH_4-N (mg/L) for Kingston groundwater sites sampled from 1996 to 2003 and linear regression line (y=0.0147x, R^2 = 0.62)

Very low NNN levels were recorded for the QLDC community supply bore at Glenorchy. All samples lie within the 1995 Ministry of Health standards of 50 mg/L (as NO_{3-}) and 3 mg/L (as NO_{2-}) and point to low contamination by farming practices. A higher value of 0.81 mg/L (as NNN on Table 3.2) or 3.6 mg/L (as NO_{3-}) from the Holiday Camp bore reflects possible septic tank, fertiliser or animal waste contamination of groundwater.

Time series NNN plots (Figure 3.3 and Figure 3.4) for Kingston and Glenorchy have been produced where successive samples have been taken at sites from 1997 to 2003. Only two sites in Kingston (F42/0104 and F42/0107) and one site in Glenorchy (E41/0100) have been sampled sufficiently to allow time series evaluation of the data.

Figure 3.3 shows that Kingston groundwater generally has low NNN over time. However, the resource is vulnerable to periodic contamination, as concentration highs occur on Figure 3.3, corresponding to changes in climatic conditions.

Figure 3.4 shows a steady increase in NNN concentrations for bore E41/0100 at Glenorchy. Whilst NNN concentrations are still relatively low, there is some indication of increased land use impact on the Buckler Burn Catchment, the recharge source for the bore.

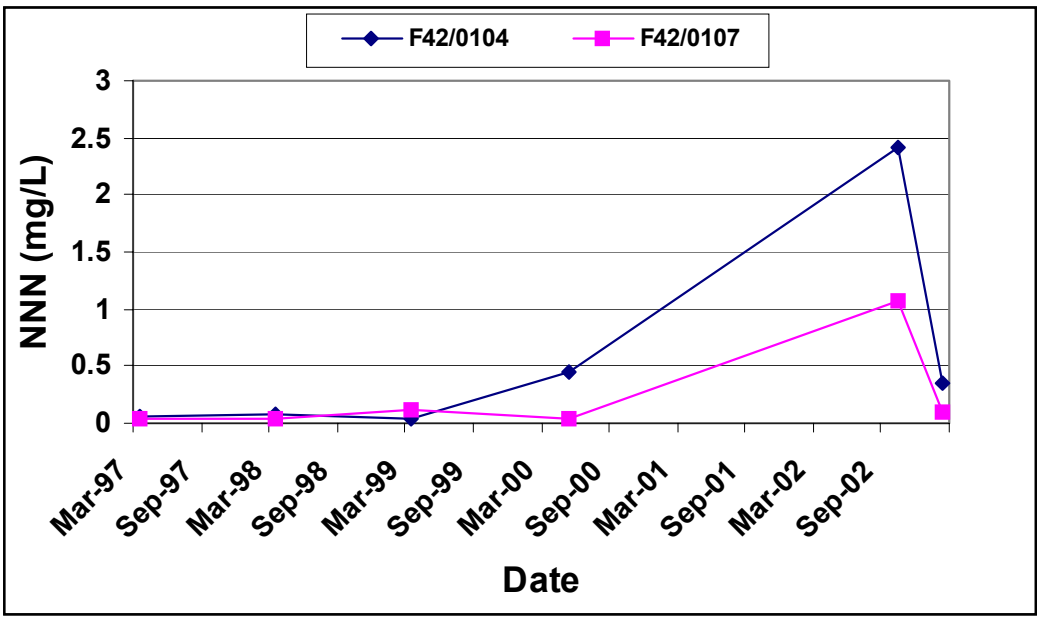

Figure 3.3 Time series for NNN (mg/L) for bore sites F42/0104 and F42/0107 in Kingston from 1997 to 2003

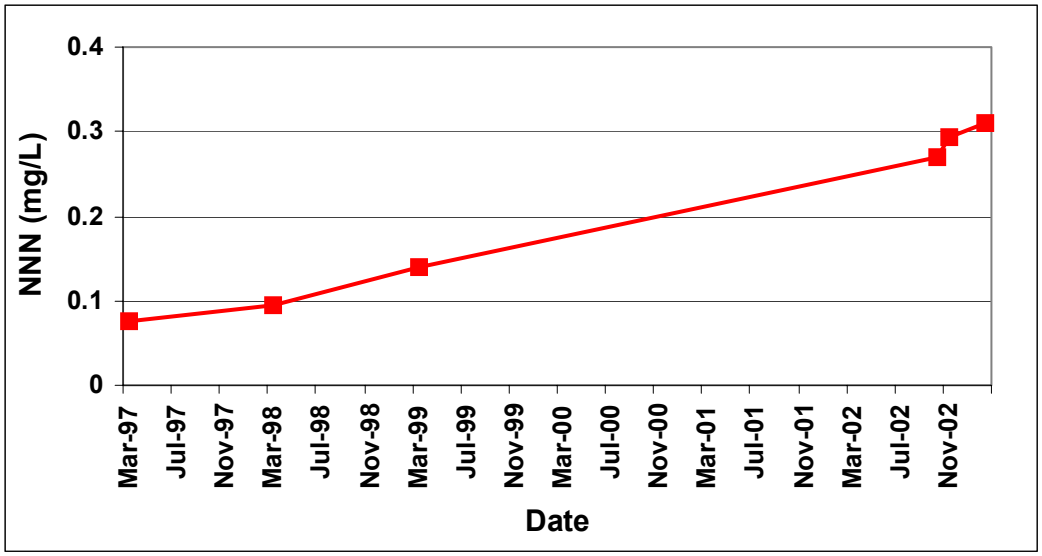

Figure 3.4 Time series for NNN (mg/L) for bore site E41/0100 (QLDC Bore) in Glenorchy from 1997 to 2003

To validate the visual assessment of parameter time-series trends for Kingston and Glenorchy sites with sufficient data, Kendall trend tests were performed. Kendall trend test results are presented in Table 3.3 below.

Table 3.3 Kendall trend test results for NNN and NH_4-N, Bore sites E41/0100 in Glenorchy and F42/0104 and F42/0107 in Kingston (1996 – 2003)

Parameter	NNN (mg/L)	NNN (mg/L)	NNN (mg/L)	NH_4-N (mg/L)	NH_4-N (mg/L)	NH_4-N (mg/L)
Groundwater Quality Site – Bore number	**(S)**	**Slope**	**p-value**	**(S)**	**Slope**	**p-value**
F42/0104	7	0.077	>0.2	5	0.002	>0.2
F42/0107	9	0.011	0.2	9	0.001	0.2
E41/0100	**15**	**0.042**	**0.01**	9	0.001	0.2

Notes: *(S) – Mann Kendall Test Statistic*
Slope – Annual Gradient (units/year)
Values in bold represent a significant trend at the 1% level

Groundwater quality trends were not significant by the Kendall test in all but one occasion (Table 3.3). One site showed a significant upward trend for NNN (p-value = 0.01). This site (QLDC Bore E41/0100 at Glenorchy) was significant at the 1% level for an upward trend of 0.042 mg/L/year NNN. This indicates that there is possibly a low but increasing impact of land use emerging in the Buckler Burn Catchment, as the Buckler Burn is the source of recharge for bore E41/0100 (Figure 2.3).

2.4 Iron

Kingston groundwater samples contain significant iron, with a maximum of 16 mg/L recorded at Bore F42/0104 located in an elevated area east of the township. This sample may also reflect corrosion of the bore casing. The high iron concentrations correspond with the generally low pH of Kingston groundwater.

QLDC community supply bore samples at Glenorchy contain little iron (<0.1 mg/L). An anomalously high iron content of 24 mg/L recorded in a high-turbidity bailed sample from the Holiday Camp bore reflects rust contamination from the steel casing at that site.

2.5 Major chemical constituents

For all groundwater samples taken in the Kingston and Glenorchy areas, six major ions (Ca^{2+}, Mg^{2+}, K^+, HCO_3^-, Cl^- and SO_4^-) form the main chemical constituents, with their total concentration normally greater than 80% of the total dissolved solids in water. The concentrations of the various constituents of groundwater are controlled by the availability of elements in the soil and rock through which the water has passed and various geochemical constraints and processes.

The relative concentrations of the major cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and anions (HCO_3^-, Cl^- and SO_4^-) in Kingston and Glenorchy groundwater is shown on a standard Tri-Linear Piper diagram in Figure 3.5.

If the proportion of the respective cations and anions in a groundwater sample were balanced, the sample would plot in the middle of the respective cation and anion

triangles in Figure 3.5. If one particular parameter or a combination of constituents has a greater proportion than the others, then the sample would plot nearer to the corner of the triangle representing the higher concentration for those particular constituents.

The cation triangle in Figure 3.5 indicates that for all bores sampled, the relative proportion of calcium is high compared to the proportions of magnesium, sodium and potassium. Similarly, for the anions plot the relative proportions of bicarbonate are high, while chloride and sulphate are low. All samples plot within a similar range and thus are of similar background composition. The groundwater chemistry may be broadly classified as Calcium-Bicarbonate type water which indicates that the groundwater is of recent evolution and/or is recently recharged.

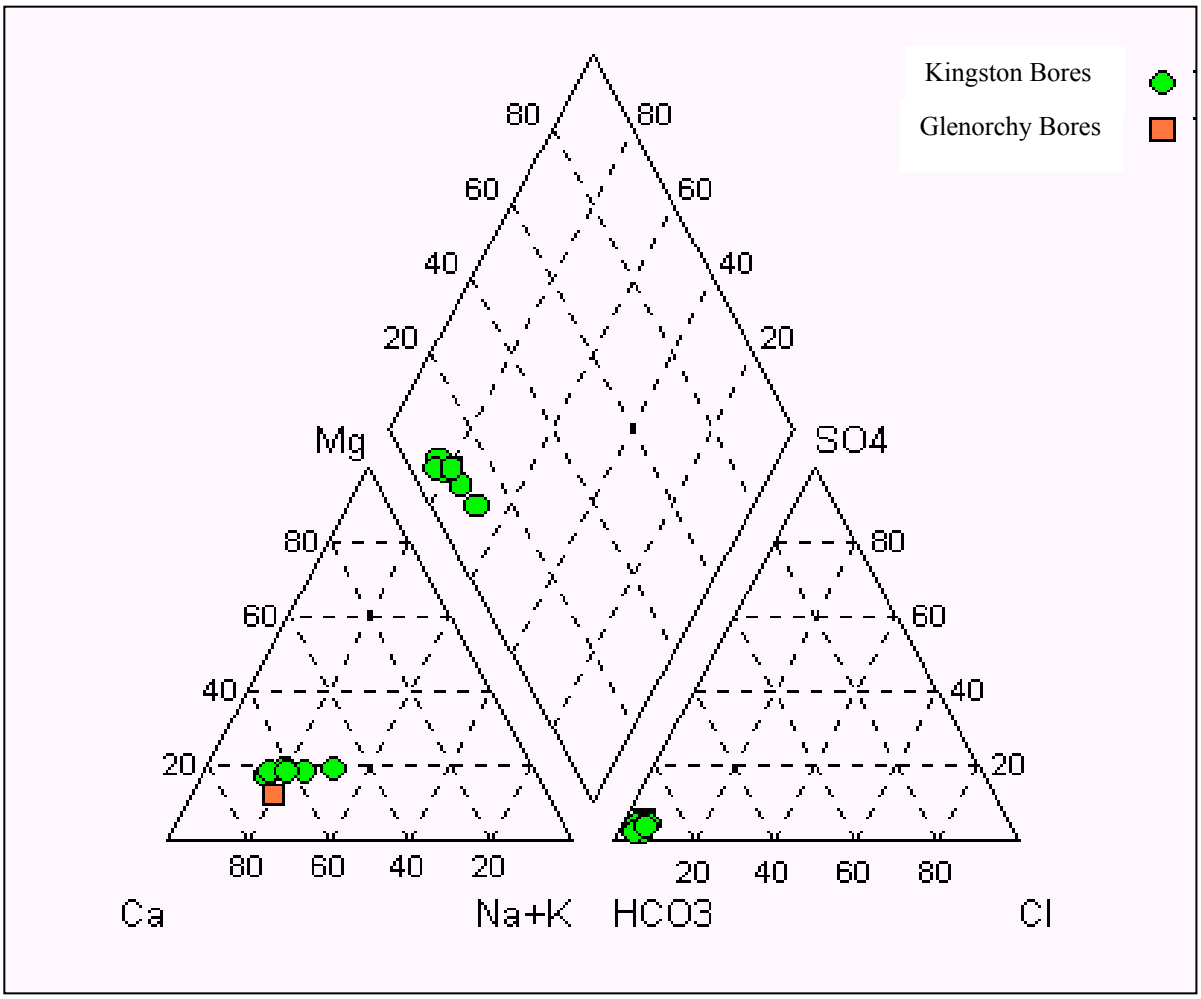

Figure 3.5 Trilinear diagram of major ions (% meq/L) in Kingston and Glenorchy groundwater

The Schoeller diagram shown on Figure 3.6, represents major ion concentrations to show hydrochemical water types. From Figure 3.6, it can be seen that the concentration of most constituents (Mg^{2+}, Na^{+}, K^{+}, Cl^{-} and SO_4^{-}), generally lie within 1 – 10 mg/L, and the dominant ions of Ca^{2+} and HCO_3^{-} between 10 – 100+ mg/L. This shows again, that Kingston and Glenorchy groundwater is of a relatively recent (recharge), evolutionary path.

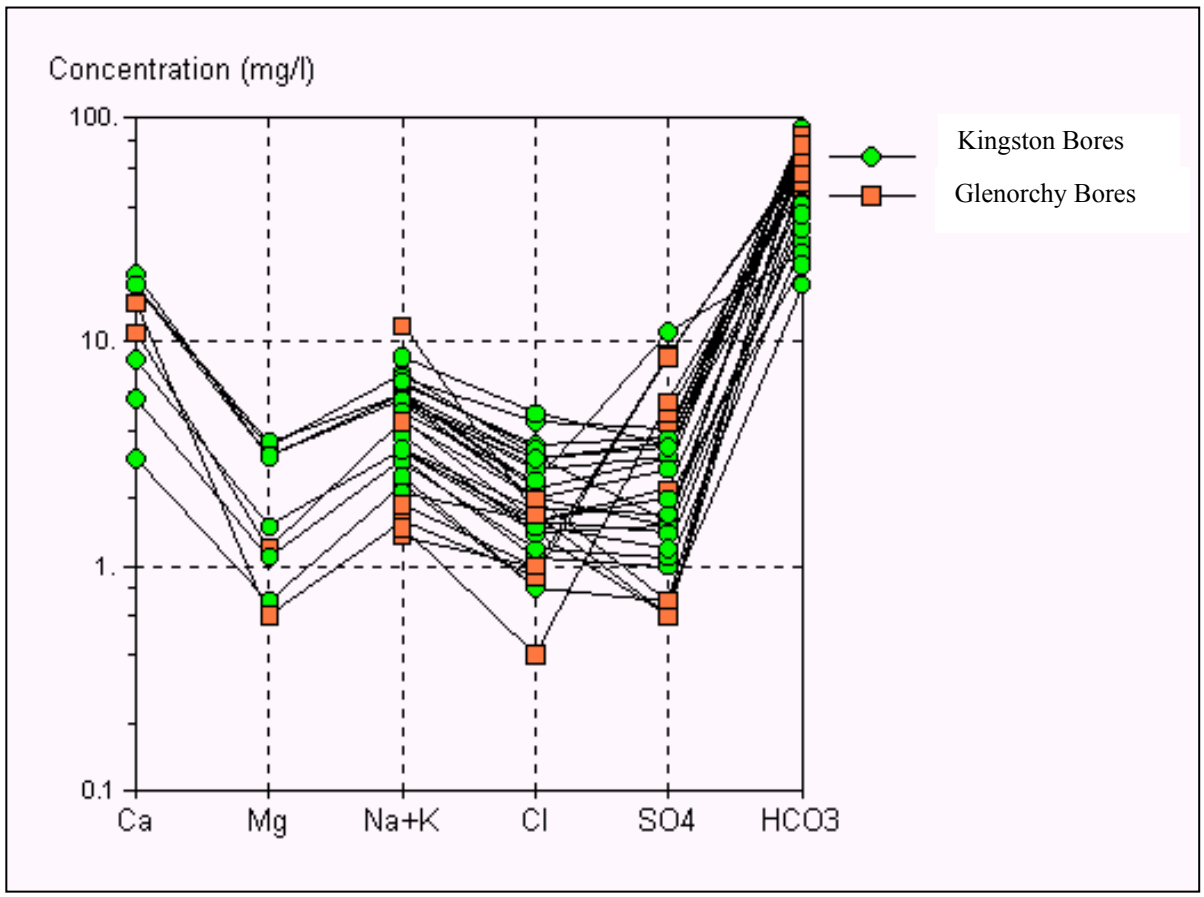

Figure 3.6 Schoeller diagram of major ions (mg/L) in Kingston and Glenorchy groundwater

Considering the Piper and Schoeller diagrams in Figure 3.5 and Figure 3.6 and the results of baseline monitoring (Table 3.1 and Table 3.2), it can be shown that for both Kingston and Glenorchy the aquifer systems are reasonably vulnerable to direct land use impacts. The situation in Glenorchy is that the water supply is sourced from a well adjacent to the Buckler Burn, away from the township itself. The site is then not affected by local land use impact and or discharges via septic tank disposal fields. Kingston appears to be most vulnerable from local septic tank discharges, as they are directly adjacent to many shallow wells used for domestic water supply.

4 Conclusions

1. The results of bacterial samples for Kingston tend to indicate that some (periodic) contamination exists within the more densely (central town area) located allotments. Of the six groundwater quality samples taken at Glenorchy, no counts (<1 cfu/100mL) of faecal coliform bacteria were found. Bacterial contamination in Kingston then, may be more likely during the holiday season.

2. Very low nitrite-nitrate nitrogen levels have been measured from most Kingston groundwater samples, which points to low natural environmental levels. Higher individual values (1.9 – 2.4 mg/L) may indicate possible influence from garden fertiliser application or septic tanks. Very low nitrite-nitrate nitrogen levels were recorded for the QLDC community supply bore at Glenorchy.

3. Consistently higher ammoniacal nitrogen levels have been found at Kingston bore F42/0113, with an average concentration of 0.213 mg/L. This level of contamination may point to an influence from septic tank effluent disposal.

4. Both the Kingston and Glenorchy aquifer systems are reasonably vulnerable to direct land use impacts. In Glenorchy, the water supply is sourced from a well adjacent to the Buckler Burn, away from the township itself, and it is not at immediate risk. Kingston appears to be most vulnerable from local septic tank discharges, as they are directly adjacent to many shallow wells used for domestic water supply.

5. Major ion concentrations used to define hydrochemical water types shows that Kingston and Glenorchy groundwater is of a relatively recent (recharge) evolutionary path, which confirms that both aquifers are relatively vulnerable to land use impacts.

5 Recommendations

Monitoring of wells in Kingston during October and early February (holiday season) should be carried out to provide longer term trends in the aquifer, for bacterial counts (faecal coliforms), nitrite-nitrate nitrogen and ammoniacal nitrogen. The most suitable sites to be used for future sampling indicators of spatial and temporal changes in groundwater contamination are: F42/0104, F42/0107, F42/0113, and F42/0129.

6 References

Australia and New Zealand Environmental and Conservation Council (ANZECC), 2000. Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters. ANZECC.

J K Lindqvist Research, 1997. Groundwater Investigations 1996/97 Glenorchy.

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New Zealand Geological Survey, 1962. New Zealand Geological Map 1:250,000, Wakatipu. Sheet 22, First Edition.

Appendix 1 Wells data for the Kingston and Glenorchy areas

Well Number	Water Quality Site Number	Depth (m)	Diameter (mm)	Date Drilled	Grid Reference	Well Owner	Locality	Address	Well Use	Well Yield (L/s)
E41/0100	OTA7520498	18.4	250	30-Jun-94	E41:459-843	Q L D C	GLENORCHY	QUEENSTOWN	SCHEME	5.9
E41/0113		30	100		E41:454-852	GLENORCHY HOTEL	GLENORCHY	GLENORCHY	DISUSED	0
E41/0114		30	100		E41:453-848	A H I UNITS	GLENORCHY	GLENORCHY	DISUSED	0
E41/0116		25	150	1-Jan-97	E41:460-832	CHARTERHALL TRUSTEES LTD	DUNEDIN	P O BOX 1092	SCHEME	1.4
E41/0118		6.23	50	1-Jan-70	E41:457-845	CONSERVATION DEPT	GLENORCHY	CNR MULL AND OBAN ST	DISUSED	0
E41/0119	OTA7520465	7.2	50	1-Jan-60	E41:458-851	KEMP CAMPING GROUND	GLENORCHY	PO BOX 4	DISUSED	0
E41/0120	OTA7520466	0	20	1-Jan-40	E41:456-850	MINISTRY EDUCATION	GLENORCHY	OBAN STREET	DISUSED	0
E41/0121		0	20	1-Jan-50	E41:455-851	CROW R	GLENORCHY	ISLAY STREET		0.24
E41/0122		5.6	50	1-Jan-50	E41:455-852	THOMPSON H	WAITATI	69 DOCTORS POINT	DISUSED	0
E41/0123		5.36	50	1-Jan-30	E41:453-852	RHONDA GOLLOP	GLENORCHY	MULL STREET	DISUSED	0
E41/0124		3.7	300	1-Jan-20	E41:459-853	MILLER	GLENORCHY	PARADISE, PRIVATE BAG	DISUSED	0
E41/0125		6.3	50	1-Jan-60	E41:454-851	CAMPBELL J & L	GLENORCHY	GLENORCHY HOTEL,MULL STREET	DISUSED	5.83
E41/0126		6.8	70		E41:456-849	BAKKER I J M	WAIKANE	1 PARETAI DRIVE	DISUSED	0.24
E41/0129		25	150	25-Nov-97	E41:458-833	CHARTERHALL TRUSTEES	QUEENSTOWN	P O BOX 621	SCHEME	5.6
E41/0133		0	100	14-Jul-99	E41:461-848	Q L D C	QUEENSTOWN	PRIVATE BAG 50072	MONITORING	0
E41/0144		12	125	8-Jan-01	E41:467-842	L Fox	Queenstown	Campbell Town Glenorchy R D	SCHEME	0.83
F42/0104	OTA7520485	9.3	1000		F42:750-323	Allen J	KINGSTON	SH6 (OPP KENT ST) P O Box 57	DOMESTIC	0.37
F42/0105	OTA7520484	2.1	320		F42:748-323	KINGSTON MOTOR CAMP	KINGSTON	NTH CNR SH6 AND KENT STREET	SCHEME	1
F42/0106		2.65	750		F42:749-324	WATSON R & G	KINGSTON	KINGSTON STORE KENT ST	COMMERCIAL	1
F42/0107	OTA7520482	3.72	320	1-Jan-65	F42:746-328	COLLINSON G K	KINGSTON	5 WATERFORD STREET	DOMESTIC	0.25
F42/0108	OTA7520481	4.45	50	1-Jan-75	F42:743-329	Thor-Poet V & Z	KINGSTON	156 KENT STREET	DOMESTIC	0.5
F42/0109		4.68	60	1-Jan-70	F42:743-329	HILSTON P T	INVERCARGILL	11 ANGLESEY STREET	DOMESTIC	0.5
F42/0110		3.22	50	1-Jan-80	F42:743-328	HARDY N M	INVERCARGILL	61 LAYARD ST	DOMESTIC	0
F42/0111		3.05	60	1-Jan-70	F42:743-328	GIBSON M P	GORE	22 KOA STREET	DISUSED	0
F42/0112		4.1	50	1-Jan-60	F42:746-328	COCHRANE S I	INVERCARGILL	32 JANET STREET	DISUSED	0
F42/0113	OTA7520480	4.42	100	1-Jan-82	F42:744-329	GORE POWER BOAT CLUB	GORE	PO BOX 260	DOMESTIC	0.2
F42/0114		1.75	100	1-Jan-60	F42:746-328	EDGLEY N F	INVERCARGILL	530 TAY STREET	DISUSED	0
F42/0115	OTA7520478	0	0		F42:738-332	MILLER C H	RD7 GORE	PYRAMID DOWNS	DISUSED	0
F42/0116		4.5	90	1-Jan-80	F42:743-329	MCDONALD G W	LUMSDEN	ELLIS RD FIVE RIVERS RD3	DOMESTIC	0
F42/0117		0	0		F42:747-326	MCDONALD G W	LUMSDEN	ELLIS RD, FIVE RIVERS RD3	DISUSED	0
F42/0118	OTA7520479	2.2	85	1-Jan-60	F42:749-327	McCLELLAND A R	Kingston	16 Wesney Terrace	DOMESTIC	0.25
F42/0119		0	0	1-Jan-70	F42:746-328	MCFADZIEN D J	WINTON	3 GOW STREET	DOMESTIC	0
F42/0120		3.25	80	1-Jan-60	F42:744-329	WARD A R	WINTON	14 HILLARY STREET	DISUSED	0.25
F42/0121		0	0	1-Jan-79	F42:745-326	MCRAE A F	KINGSTON	68 KENT STREET	DOMESTIC	0
F42/0122		0	50	1-Jan-80	F42:748-326	COYLE J D	GORE	CHARLTON RD	DISUSED	0
F42/0123		0	50	1-Jan-80	F42:748-326	COYLE J D	GORE	CHARLTON ROAD	DISUSED	0
F42/0124		0	70	1-Jan-80	F42:745-328	MORRIS M D	KINGSTON	NW CNR KENT & OXFORD ST	IRRIGATION	0
F42/0125		0	0		F42:745-328	MORRIS M D				0
F42/0126		3.6	50	1-Jan-80	F42:746-327	COLEMAN H A		PO BOX 70 RIVERSDALE	DOMESTIC	0
F42/0127		0	50	1-Jan-80	F42:744-327	CLARK J F	KINGSTON	CAMBRIDGE STRET	DOMESTIC	0.37
F42/0128		1.83	80	1-Jan-70	F42:749-324	JOHNSON B F	INVERCARGILL	39 WICKLOW STREET	DOMESTIC	0

Well Number	Water Quality Site Number	Depth (m)	Diameter (mm)	Date Drilled	Grid Reference	Well Owner	Locality	Address	Well Use	Well Yield (L/s)
F42/0129	OTA7520463	1.83	80	1-Jan-70	F42:742-330	LONGSTAFFE B G	DUNEDIN	3 EPSILON STREET	DOMESTIC	0.25
F42/0130	OTA7520487	2.45	50	1-Jan-97	F42:745-329	LEIGHTON J	KINGSWELL	CNR CORNWALL&CAMBRIDGE ST	DOMESTIC	0.8
F42/0132		2.8	70	1-Jan-70	F42:743-329	MORONEY K & P	KINGSTON	100 KENT STREET	DOMESTIC	0.25
F42/0133		3.5	0	1-Jan-70	F42:749-324	LOVE R	KINGSTON	SOUTH OXFORD STREET	DOMESTIC	0
F42/0134		3.33	900	1-Jan-80	F42:742-329	STROUD E R	KINGSTON	CNR HAMPSHIRE AND SHROPSHIRE	DOMESTIC	0.83
F42/0135		2.2	80	1-Jan-90	F42:744-329	OTTLEY ESTATE	INVERCARGILL	C/-DG MATHIESON 71 TERRACE ST	DOMESTIC	0.8
F42/0136		0	0		F42:743-318	Q L D C	QUEENSTOWN	PRIVATE BAG 50072	MONITORING	0
F42/0137		10	125	25-Aug-99	F42:744-327	MEECHANG M	NELSON	41 TOSSWILL RD	DOMESTIC	0.8

Appendix 2 Groundwater quality monitoring data for the Kingston and Glenorchy areas from 1996 to 2003

SITE_ID	SITE_NAME	easting	northing	SAMPLE_DATE	Ammoniacal Nitrogen mg/L-N	Bicarbonate mg/L	Calcium mg/L	Chloride mg/L
OTA7520485	F42/0104	2175000	5532300	11-Mar-97	-0.005	18	3	0.8
OTA7520485	F42/0104	2175000	5532300	11-Mar-98	0.007			0.8
OTA7520485	F42/0104	2175000	5532300	17-Mar-99	0.11	58		1.4
OTA7520485	F42/0104	2175000	5532300	04-May-00	0.036			
OTA7520485	F42/0104	2175000	5532300	14-Oct-02	0.05	25		2.4
OTA7520485	F42/0104	2175000	5532300	18-Feb-03	0.01	22		1.6
OTA7520482	F42/0107	2174600	5532800	11-Mar-97	-0.005	28	5.6	1.1
OTA7520482	F42/0107	2174600	5532800	11-Mar-98	0.007			1.2
OTA7520482	F42/0107	2174600	5532800	17-Mar-99	0.005	41		1.6
OTA7520482	F42/0107	2174600	5532800	04-May-00	0.006			1.4
OTA7520482	F42/0107	2174600	5532800	14-Oct-02	0.01	42		3
OTA7520482	F42/0107	2174600	5532800	18-Feb-03	-0.01	32		1.8
OTA7520481	F42/0108	2174300	5532900	11-Mar-97	0.008	82	18	2
OTA7520481	F42/0108	2174300	5532900	14-Oct-02	0.01	63		2.7
OTA7520481	F42/0108	2174300	5532900	18-Feb-03	0.01	82		2
OTA7520480	F42/0113	2174400	5532900	11-Mar-97	0.24	90	18	2.3
OTA7520480	F42/0113	2174400	5532900	14-Oct-02	0.2	85		2.8
OTA7520480	F42/0113	2174400	5532900	18-Feb-03	0.2	90		3.3
OTA7520479	F42/0118	2174900	5532700	11-Mar-97	-0.005	85	20	2.2
OTA7520479	F42/0118	2174900	5532700	14-Oct-02	-0.01	58		3
OTA7520479	F42/0118	2174900	5532700	18-Feb-03	-0.01	88		3.5
OTA7520463	F42/0129	2174200	5533000	11-Mar-97	0.005	82	18	3.1
OTA7520463	F42/0129	2174200	5533000	14-Oct-02	0.02	60		4.4
OTA7520463	F42/0129	2174200	5533000	18-Feb-03	0.02	75		4.8
OTA7520487	F42/0130	2174500	5532900	11-Mar-97	-0.005	37	8.3	1.5
OTA7520498	E41/0100	2145900	5584300	12-Mar-97	-0.005	51	15	-0.6
OTA7520498	E41/0100	2145900	5584300	11-Mar-98	0.005			-0.6
OTA7520498	E41/0100	2145900	5584300	16-Mar-99	-0.005	57		0.4
OTA7520498	E41/0100	2145900	5584300	15-Oct-02	-0.01	64		1
OTA7520498	E41/0100	2145900	5584300	12-Nov-02	-0.01	62		0.9
OTA7520498	E41/0100	2145900	5584300	17-Feb-03	-0.01	67		1
OTA7520742	E41/0114	2145300	5584800	04-Aug-98	0.016			

SITE_ID	SITE_NAME	easting	northing	SAMPLE_DATE	Ammoniacal Nitrogen mg/L-N	Bicarbonate mg/L	Calcium mg/L	Chloride mg/L
OTA7520465	E41/0119	2145800	5585100	19-Mar-97	0.092	48	11	1.6
OTA7520465	E41/0119	2145800	5585100	11-Mar-98	0.018			-0.6
OTA7521004	E41/0123	2145300	5585200	12-Nov-02		84		1.7
OTA7521004	E41/0123	2145300	5585200	17-Feb-03		76		2
	Note: Negative sign represents below detection limit							
	Negative value represents the detection limit							

Electrical Conductivity mS/cm	Dissolved Reactive Phosphorus mg/L-P	Enterococci bacteria n/100ml	Escherichia coli Type 1 cfu/100mL	Faecal Coliforms MPN method MPN/100ml	Faecal Coliforms-membrane filt cfu/100ml	Iron Total mg/L	Magnesium mg/L	Nitrite/Nitrate Nitrogen mg/L-N
0.0337	0.007	-1		-1	-1	0.1	0.7	0.05
0.0371	0.003							0.075
0.0835	-0.001					16		0.044
								0.439
0.0782	-0.005		-1		-1			2.42
0.04	-0.005		-1		-1			0.348
	0.006	-1		-1	-1	0.1	1.1	0.036
0.0525	0.004							0.039
0.076	0.008					0.56		0.11
0.064	0.013							0.047
0.0763	0.006		3		4			1.07
0.0507	0.008		-1		-1			0.094
0.1483	0.009	-1		-1	-1	0.4	3.1	0.24
0.1058	0.009		-1		-1			0.852
0.1327	0.012		-1		2			0.498
0.1562	0.012	3		-1	-1	2.7	3.6	0.005
0.1306	-0.005		-1		-1			-0.005
0.1483	-0.005		1		1			-0.005
0.1593	0.011	-1		-1	-1	-0.1	3.1	0.58
0.0982	-0.005		-1		-1			0.572
0.1466	-0.005		-1		-1			0.152
0.1564	0.006	-1		-1	-1	0.7	3.4	0.43
0.1073	-0.005		-1		-1			0.896
0.1435	-0.005		21		10			1.91
0.0715	0.008	-1		-1	-1	0.2	1.5	0.089
0.0974	0.002	4		-1	-1	-0.1	0.6	0.075
0.1028	0.001							0.095
0.1236	-0.001					0.05		0.14
0.1034	-0.005		-1		-1			0.27
0.1006	-0.005		-1		-1			0.294
0.1193	-0.005		-1		-1			0.31
0.26	-0.001	-1			-1			0.67

Electrical Conductivity mS/cm	Dissolved Reactive Phosphorus mg/L-P	Enterococci bacteria n/100ml	Escherichia coli Type 1 cfu/100mL	Faecal Coliforms MPN method MPN/100ml	Faecal Coliforms-membrane filt cfu/100ml	Iron Total mg/L	Magnesium mg/L	Nitrite/Nitrate Nitrogen mg/L-N
0.1095	0.001	-2		-2	-2	24	1.2	0.81
0.1038	0.001							0.15
0.1641								
0.1805								
	Note: Negative sign represents below detection limit							
	Negative value represents the detection limit							

pH measured in Field pH units	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Temperature Deg_C	Total Nitrogen mg/L-N	Total Organic Carbon mg/L	Turbidity NTU			
6.5	0.3	2	0.7	10.9			0.6			
6.26	0.4	2.1	0.7	12.3						
7.14	1.8	2	0.6							
5.5	1.3	3.6	11.1	8.15	2.4	0.9				
5.97	0.32	1.8	2	10.93	0.43	0.6				
6.6	0.5	2.5	1	12			0.6			
6.47	0.5	2.4	1.1	14						
6.06	0.67	2.6	1.4	14						
5.52	0.52	2.7	1.5	11.1						
5.96	1.3	4.2	3.4	8.41	1.18	1.5				
6.15	0.41	2.9	1.7	13.37	0.15	0.8				
6.9	1.2	4.4	1.5	11.3			2.2			
6.25	1.4	4.2	3.1	9.12	1.34	4.2				
6.36	0.59	4.7	2.7	12.11	0.66					
6.7	1	4.8	-0.4	11.7			1.8			
6.3	1.1	4.2	-0.5	9.51	0.29	2.5				
6.42	0.86	5.8	-0.5	11.82	0.3	11.6				
6.7	1.3	4.6	3	14.5			-0.1			
6.32	1.6	4.2	3.6	10.01	0.68	1.3				
6.45	0.59	5.8	3.7	15.05	0.25	1.1				
6.7	1.4	5.8	1.6	11.5			1			
6.16	1.4	5.5	4.1	9.55	1.13	2.8				
6.2	1.1	7.5	3.5	12.55	2.14	14.9				
6.6	0.4	2.9	1.2	13.3			1.6			
7.6	1.1	4.8	9.2			0.2				
8.42	1	4.9	8.5							
6.75	1	5.4	9.2							
7.05	0.5	8.8	7.63	0.36	-0.3					
7.22	1	8.8	8.3	0.31	-0.3					
7.53	1.2	8.5	8.1	0.31	-0.3					
6.9				0.47						

pH measured in Field pH units	Potassium mg/L	Sodium mg/L	Sulphate mg/L	Temperature Deg_C	Total Nitrogen mg/L-N	Total Organic Carbon mg/L	Turbidity NTU			
6.5	2.7	2.2	10.5			11				
6.61	1.4	4.4	11.3							
6.55	9.9	0.6	9.1							
6.54	2.3	0.7	10.55							
	Note: Negative sign represents below detection limit									
	Negative value represents the detection limit									