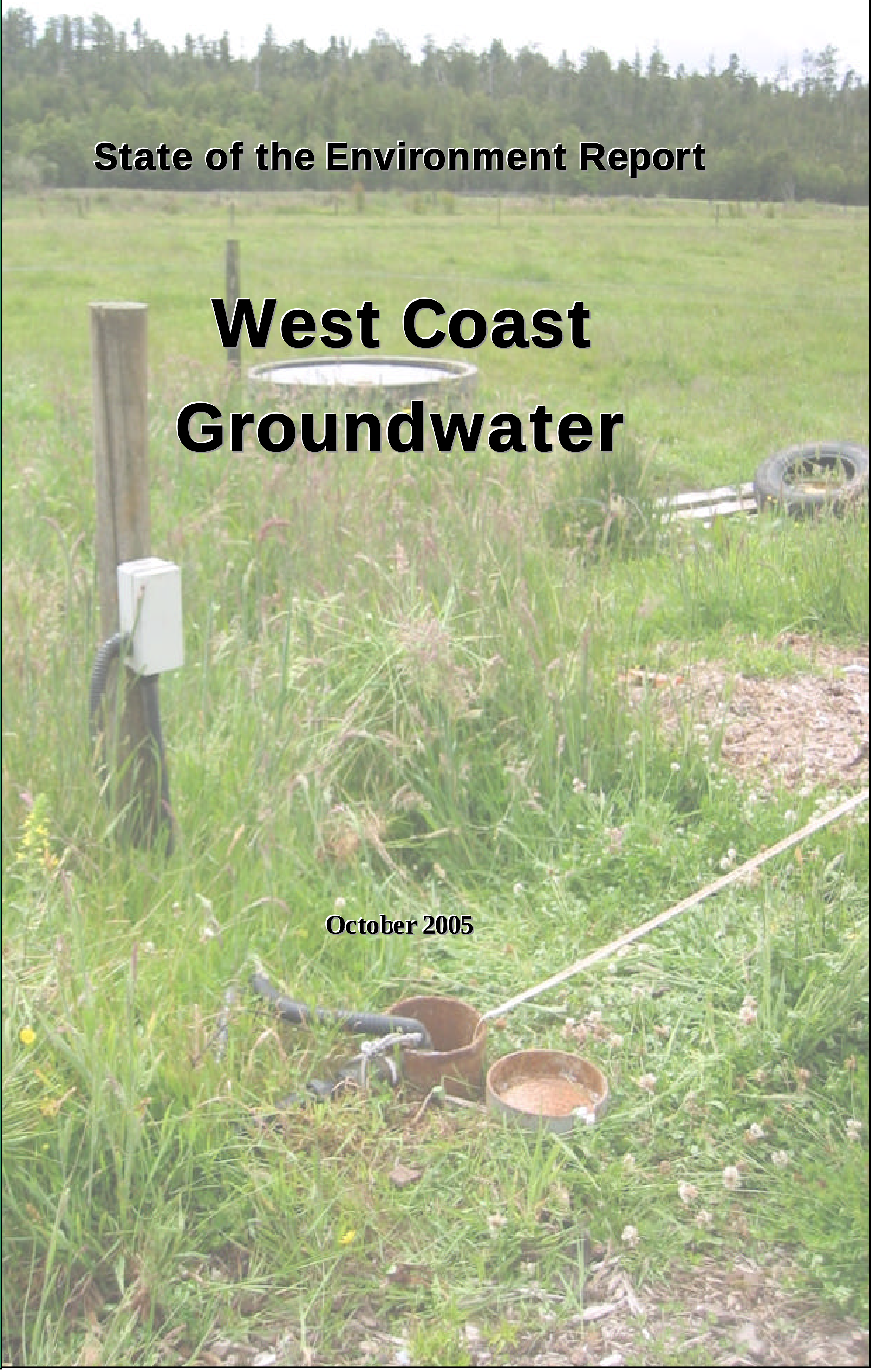
State of the Environment Report

West Coast Groundwater

October 2005



THE WEST COAST
REGIONAL COUNCIL

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EXECUTIVE SUMMARY

At the request of the West Coast Regional Council (WCRC), the Institute of Geological and Nuclear Sciences Ltd. (GNS) in collaboration with WCRC staff has prepared this Groundwater State of the Environment Report. The following topics are covered in this report:

1. An initial resource overview of groundwater resources in the West Coast Region prepared primarily by WCRC staff.

2. A presentation of information from GNS Client Report 2004/156 titled "Assessment of groundwater quality in the West Coast Regional Council State of the Environment Monitoring Programme to March 2004." This GNS report was an overall assessment of data obtained from nearly six years of monitoring groundwater quality in samples from eight National Groundwater Monitoring Program (NGMP) wells in the West Coast Region.

3. A summary of information provided in the Master of Science thesis "Groundwater Quality and Farm Nitrogen Management on the West Coast, South Island, New Zealand" completed by Tim Baker at Victoria University of Wellington in 2004 (Baker, 2004).

4. A summary of groundwater levels for the West Coast Region using all available data.

The summary of Baker (2004) includes an interpretation of the effects of dairy land use on groundwater quality in the areas studied and a discussion of the relationship of that information to other West Coat dairy catchments with similar hydrology.

The summary of groundwater level data for the West Coast Region includes analysis for temporal trends, a comparison of groundwater levels and groundwater quality at sites where both types of data are available, a discussion of the implications of available groundwater level data to groundwater level fluctuations in other West Coast Region catchments, and a discussion of the relevance of available data on groundwater level and quality relationships to such relationships in other West Coast Region catchments.

The West Coast Region has substantial groundwater resources that serve as an important source of water for drinking and other purposes by communities and individuals, agriculture, and other industries and users. Most currently identified groundwater resources in the West Coast Region are located in alluvial materials adjacent to the Region's major rivers such as the Grey and Hokitika and, similarly, most resource consents to take groundwater have been issued for users within the Grey District. Groundwater quality in the West Coast Region is monitored in samples from seven NGMP wells. The WCRC obtains water level data for these and 22 other wells.

It was concluded in both relevant GNS work and Baker (2004) that groundwater quality in the West Coast Region is generally good in comparison to guidelines such as New Zealand Drinking Water Standards. There are two exceptions to this general case: (1) numerous exceedances for health-based bacterial indicators; and (2) exceedances of the aesthetic-based guidelines for iron and/or manganese in samples from some wells. Although nitrate-nitrogen concentrations did not exceed guideline values in sampled wells, levels in some cases were sufficiently high as to indicate anthropogenic sources (including agricultural). These guidelines are used as a reference point and would not necessarily apply if the well involved is not used to supply water for human consumption or water used in farm dairies for milking and cleaning equipment that contact milk. Additionally, there are statistically significant increasing trends for chloride, nitrate-nitrogen, and sulphate in most of the NGMP wells in the West Coast Region. This is consistent with and may reflect intensified dairying operations in the West Coast Region over the last 10 to 15 years. However, nitrogen isotope data indicates that the source of nitrogen is more likely fertilizer or soil organic nitrogen than animal wastes. An additional factor is that age dating data for groundwater samples indicate ages on the order of 12 years in the Grey River drainage and eight years in the Hokitika River drainage. In that event, the full impact of intensifying dairying operations may not yet be evident.

Analysis of West Coast Region groundwater level data provides little indication of seasonality or trend. Similarly, there is little indication of any relationship between groundwater level and water quality in the West Coast Region. The strongest indication of such a relationship was for sulphate in well HK34 located within the Hokitika River drainage. Although that relationship was statistically weak, it was in a direction that would be consistent with expectations for a surface source of contamination (i.e., an trend of increasing sulphate concentration with a rising water table). Analysis of groundwater level data for the Hokitika

River also indicates a possible groundwater flowpath from the vicinity of upgradient wells HK39 and HK40 to downgradient well HK28 with concentrations of chloride, nitrate-nitrogen, and sulphate all increasing along it.

Given the nature of the available data, the fact that only weak relationships were indicated by it, and the absence of related hydrogeologic and hydrologic information for comparisons, it is not possible to extend or extrapolate conclusions drawn from the Grey and Hokitika catchments to other drainages in the West Coast Region.

1.0 INTRODUCTION

The West Coast Regional Council (WCRC) commissioned the Institute of Geological and Nuclear Sciences (GNS) to prepare a report of the state of the environment for groundwater in the West Coast Region. It was agreed that this report would provide the following information as proposed by GNS in a letter to the WCRC of 8 March 2005:

1. Information from GNS Client Report 2004/156, "Assessment of Groundwater Quality in the West Coast Regional Council State of the Environment Monitoring Programme to March 2004;"

2. A brief summary of Tim Baker's thesis, "Groundwater Quality and Farm Nitrogen Management on the West Coast, South Island, New Zealand." This is cited herein as Baker (2004). The summary was to specifically include:

   a. An interpretation of the effects of dairy land use on groundwater quality in the areas studied;

   b. A discussion of how the results may be used to predict effects on groundwater quality in other West Coast dairy catchments with similar hydrology;

3. A summary of groundwater levels in the West Coast region, using all available data, including:

   a. Calculation of temporal trends in groundwater levels;

   b. A comparison of groundwater levels and groundwater quality at sites where both types of data are available;

   c. A discussion of how the groundwater level data may be used to predict groundwater level fluctuations in other catchments in the West Coast Region;

   d. A discussion of how any observed relationships between groundwater levels and groundwater quality may be extended to other catchments in the West Coast Region.

It was also agreed that GNS would work collaboratively with WCRC staff on this project and that WCRC would provide information for a preliminary chapter of the report giving a resource overview for the West Coast Region.

The work envisioned above has been completed and this report has been prepared to provide the resulting information.

2.0 RESOURCE OVERVIEW

2.1 Groundwater general background

Groundwater is simply defined as that water occurring in the "interconnected pores below the water table in an unconfined aquifer or located in a confined aquifer" (Fetter, 1994). Aquifers are various types of geologic formations (e.g., unconsolidated sediments like sands and gravels or consolidated rocks such as limestone) that are "saturated and sufficiently permeable to transmit economic quantities of water to wells and springs" (Driscoll, 1986 and Fetter, 1994). Figure 1 illustrates the general case involving an unconfined or water table aquifer underlain by a confined aquifer. Note that the confined aquifer is sandwiched between confining layers of relatively impermeable geologic materials, one of which also separates it from the unconfined aquifer.

As is also shown in Figure 1, access to groundwater is generally provided by wells drilled into and screened within aquifers. Except in relatively rare cases where a well is screened in a confined aquifer under sufficient pressure that it is Artesian (i.e., groundwater flows above ground from the wellhead without pumping), pumps must be installed in wells to bring the water to the surface for use.

2.2 West Coast region groundwater resources

The West Coast Region occupies most of the west coast of the South Island of New Zealand and includes three districts. From south to north these are the Westland, Grey, and Buller Districts. Locations of the Districts within the West Coast Region and the West Coast Region itself are indicated in Figure 2.

Groundwater is an important source of water for drinking and other purposes to many communities and individuals living in the West Coast Region. It's used by communities for public water supply, by agriculture for irrigation and watering stock, for washing, processing, and producing bottled water by industry, and by tourists.

The WCRC has only a partial understanding of the region's aquifer systems. This is a result of the fact that most West Coast Region communities have historically relied on surface water resources for their water supply and that many of the wells in the Region have been developed as a permitted activity or in shallow alluvial aquifers without producing logs to record the geologic materials involved.

Most identified West Coast Region aquifers are located in the alluvial materials adjacent to the Region's streams. These aquifers are the product of tectonic influence, most notably the Alpine Fault (a sharp western boundary to the Southern Alps), periods of extensive glaciation, high rainfall, and the erosive force of the Region's streams. The relatively high erosion rates have deposited alluvial material across the majority of lowlands to the west of the mountainous Southern Alps shown in Figures 3, 4, and 5 for each of the three districts, respectively.

The thickness of the alluvial gravels is typically 20 to 40 metres, but can be as much as 70 to 80 metres in parts of the Grey Valley. The basement of these aquifers is sandstone, mudstone (in particular the Kaita Bluebottom Group), and conglomerate. Most current groundwater abstraction in the West Coast Region is from such shallow aquifers with water tables on the order of 5 to 12 metres below ground level (BGL). In addition, uplifted marine limestones are also important aquifers. These are often associated with karstic landforms, caverns, and spring flow features in the West Coast Region.

A number of low temperature-tectonic geothermal systems, expressed at the ground surface in warm springs or seeps, are also associated with the tectonic setting of the Southern Alps. Such systems that have been identified are indicated in Figure 6 from Mosely (1992). These systems contain mainly meteoric waters that having fallen as rain and snow on the ground surface have then percolated downwards and been heated at depths as great as 5 km. The warm waters subsequently rise along high permeability pathways such as faults. These systems have temperatures in the range of about 20 to 100^{o}C.

2.3 Abstraction of groundwater in the West Coast region

The WCRC maintains a Groundwater Bore Inventory of bores and wells in the Region. However, as the WCRC does not require a resource consent be obtained prior to drilling a bore, the database does not contain the details of all bores and wells in the region. As a consequence, knowledge of aquifers in the Region is limited.

There are currently 450 bores listed in the Groundwater Bore Inventory. As can be seen in Figures 3, 4, and 5, the majority of these are located in the Hokitika River and Grey River valley areas.

Resource consents to take groundwater for the years 1997 through 2004 are graphically shown in Figure 7. The Resource Management Act in 1991 required that all existing water rights be renewed within 10 years. For that reason, there was a notable increase in the number of resource consents to take groundwater granted during 2001. Thirteen of the 26 resource consents granted in that year were for existing school and community water supplies. Other than that perturbation, there is no discernable trend in the allocation of groundwater by resource consent in the West Coast Region indicated in Figure 7.

Of the 100 resource consents that were processed to take groundwater during the 1997 to 2004 period, nearly half were within the Grey District. The distribution of these, as indicated in Figure 8, was 29, 47, and 22 percent for the Westland, Grey and Buller Districts, respectively.

Unlike some other areas of New Zealand, overuse of groundwater aquifers has not been an issue to date in the West Coast Region. Operators of shallow unconfined bores note seasonal fluctuations in groundwater levels and other changes related to precipitation events recharging these aquifers; however, when necessary, water supply can generally be secured by drilling a deeper well into a more extensive confined aquifer.

2.4 Groundwater management in the West Coast region

2.4.1 General concerns

A number of issues related to impacts on groundwater quality and, therefore, groundwater management have arisen in the West Coast Region. These may require further investigation and education in the future. They include:

1. Potential contamination from agricultural operations (e.g., fertilizer and cattle faeces);

2. Potential diversion of springs away from spring fed creeks;

3. Potential increase in fines (i.e., very fine sediments) carried by groundwater from anthropogenic activities in the immediate vicinity of poorly protected bores; and

4. Other general groundwater protection issues.

2.4.2 Policy

The WCRC has developed a Proposed Water Plan and a Discharge to Land Plan. These plans include policies and rules for the management of groundwater resources. Essentially, they provide for the allocation of groundwater at sustainable yields to ensure both quality and quantity are maintained.

2.4.3 Monitoring

Currently, the WCRC routinely monitors groundwater levels at 27 sites in the West Coast Region. These sites are listed in page 2 of Table 1 (with east-north coordinates and a map reference for each) and locations of them are shown in Figure 12. The WCRC has assigned alphanumeric identification codes to these wells and they are referred to within this report by those codes. The first two letters of each well code indicate the drainage involved (i.e., BU for Buller River, GR for Grey River, HK for Hokitika River, and IN for Inanganua River). One of the 28 sites listed in Table 1, well HK39, is no longer used. All of these sites are located in the areas of higher groundwater use of the Grey River and Hokitika River valleys. Water level readings are manually taken at each of these sites approximately every six weeks. This program commenced in the year 2000 in order to provide monitoring data regarding the possible seasonality of groundwater levels and the effect of precipitation on them.

In addition to the 27 well WCRC groundwater level monitoring network, groundwater quality has been monitored in eight wells. These sites are listed in page 1 of Table 1 (with east-north coordinates and a map reference for each) and locations of them are shown in Figure 10. This program was established in September 1998 to provide data pertinent to the effects of various land uses on groundwater quality and to determine trends in groundwater quality in the West Coast Region. It was set up in conjunction with the National Groundwater Monitoring Programme (NGMP) run by GNS. These sites are sampled on a quarterly basis (i.e., every three months). One of the original seven NGMP wells (i.e., well HK39 in the Kowhitirangi area of the Hokitika River drainage) was sampled only between September 1998 and June 2001. It was essentially replaced by well GR02 in the Slaty Creek area of the Grey River drainage, first sampled in June 2003.

2.4.4 Education

The potential for groundwater contamination can be reduced by the appropriate design and installation of wells with particular attention to measures for wellhead protection. Such measures ensure that the wellhead and well casing are sealed to prevent contaminants from directly entering groundwater in close proximity to the well. The WCRC, in a joint venture with a number of other regional councils, is promoting education in this area through use of an information brochure titled "Secure Your Well-Head." This brochure was first produced in 2001. A copy of this brochure is presented as Appendix A to this report.

Contaminants can readily enter wells that are not properly installed and managed. For example, precipitation, irrigation, and flood waters can move bacteria, viruses, and toxic substances (e.g., pesticides and trace metals) overland and down the sides of well cases into the groundwater supply when wells have not been properly constructed. It is important to seal the area around the wellhead with concrete that is sloped so that surface water from precipitation will drain away from the well. It is equally important to seal the annular space between the well casing and surrounding soil from the surface to the top of the well screen to eliminate that potential pathway for contaminant migration. It is also important to keep this area clear of rubbish, pesticides, fertilizer, offal, compost, and animals. Sometimes people used older out of service wells to dispose of rubbish or other wastes. Contaminants moving down the well bore into groundwater in such cases can migrate underground and contaminate wells being used to supply water. All wells need to be protected, whether in use or not, and older wells no longer in use should be plugged. Other recommendations for the protection of wells are presented in the brochure "Secure Your Well-Head" (see Appendix A).

Contaminants may also enter groundwater as a result of various human activities (i.e., anthropogenic sources). A major concern in this regard is anthropogenic sources of nitrogen that can result in the contamination of groundwater with nitrates. These typically occur as a function of waste disposal (e.g., the application to land surfaces of human and animal wastes or from underground discharges of septic tank effluents) or agricultural operations that concentrate grazing animal populations in relatively small areas, but they can also occur from other agricultural practices (e.g., the use of nitrogen containing fertilizers). Nitrate contamination of New Zealand groundwaters from sources of this type have been well documented (Close, et al., 2001). As noted in the discussion of Baker (2004) in Chapter 4 of this report, this potential source of nitrate contamination is particularly relevant in the West Coast Region at this time because of intensification of dairying operations. Relatively low concentrations of nitrates from groundwaters may enter associated surface water systems and thereby contribute to eutrophication. Nitrates at sufficiently high concentrations may also be toxic to humans consuming the water.

3.0 GROUNDWATER QUALITY IN THE WEST COAST REGION

3.1 Introduction

GNS Client Report 2004/156 titled "Assessment of Groundwater Quality in the West Coast Regional Council State of the Environment Monitoring Programme to March 2004" was completed and published in November 2004. It was commissioned by the WCRC for the purpose of "State of the Environment" reporting as follows:

1. To assess groundwater quality from all NGMP sites in the West Coast Region (seven active sites and one inactive site) in comparison to national or international water quality guidelines;

2. To asses groundwater quality in reference to three important land uses in the West Coast Region (dairy farming and urban and rural residential uses).

3. To compare WCRC groundwater quality to other regions of New Zealand; and

4. To calculate and interpret trends in West Coast Region groundwater quality since the commencement of sampling NGMP wells in September 1998.

The report addresses those purposes and, in addition, contains recommendations for the future of groundwater monitoring in the West Coast Region. The following subsections of this chapter of this report summarize information presented in GNS Client Report 2004/156. The reader is directed to that complete report if additional detail is desired.

3.2 Assessment of groundwater quality in comparison to guidelines

The eight NGMP wells in the West Coast Region for which groundwater quality data existed are listed in page 1 of Table 1. Additional information on their design, installation, nearby potential sources of contaminants, and geology they were drilled in is presented in Table 2. Their locations are also indicated in Figure 10.

Results from the analysis of data indicated that, in general, groundwater quality at the eight NGMP sites in the West Coast Region is good in comparison to guidelines. Additional details regarding this assessment are as follows:

1. The median values of most analytes at most sites were below relevant guideline values used for comparison. These guidelines were the health-related Maximum Allowable Value (MAV) or the aesthetic guideline value (GV) from New Zealand Drinking Water Standards (New Zealand Ministry of Health, 2000). In addition, the Trigger Value (TV) based the 95 percent level of protection for freshwaters (Australia and New Zealand Environment and Conservation Council, 2000). The only systematic transgressions of guideline values were for the bacterial indicator faecal coliform bacteria and for iron and/or manganese. Faecal coliform bacteria exceeded guidelines for samples from all wells except well HK39 (now out of NGMP service). Iron and/or manganese exceedances occurred for samples from wells GR04, BU01, and GR02.

2. Concentrations of bacterial indicators exceeded the New Zealand Drinking Water Standard health-related MAV of 1 cfu/100 mL for roughly one-third of samples from all wells.

3. Of particular note was that median nitrate-nitrogen concentrations were low at all NGMP sites in the West Coast Region (on the order of 2 mg/L or less). Although levels of nitrate-nitrogen above 1 mg/L may indicate anthropogenic sources, concentrations must approach 3 mg/L before agricultural impact can be identified with confidence. The New Zealand TV for protection of freshwaters is 7.2 mg/L and the New Zealand Drinking Water Standard for nitrate-nitrogen is 11.3 mg/L.

4. The elevated concentrations of iron and/or manganese reported at three sites exceeded the New Zealand Drinking Water Standards GVs of 0.2 and 0.05 mg/L, respectively. These have been established not for health reasons but specifically for the aesthetic reason of preventing staining of laundry and sanitary ware (high levels of these elements may also cause objectionable taste). Because concentrations of these elements in excess of the GVs would not be expected in oxygenated waters, such levels indicate that either the waters involved have low levels of oxygen (this may occur naturally or as a result of contamination) or that concentrations are elevated because iron and manganese in sediments in unfiltered samples were dissolved when the samples were preserved by acidification.

3.3 Assessment of groundwater quality in reference to land use

With the available data, it is impossible to (statistically) determine whether or not the medians, MADs (median absolute deviation which indicates variation of values with respect to the median) or trends of the monitored parameters differ significantly in relation to land use. A second problem arises because the capture zone of each well is presently unknown.

Taking those obvious limitations in the data set into account, statistical analysis of the data (utilizing the Kruskal-Wallis test and box and whisker plots) suggests that the median concentrations of eight of the variables for which there were data differed significantly at the 95 percent confidence level between the three land use categories evaluated (i.e., dairy, urban and rural residential). Variables for which median values differed significantly as a function of land use were:

1. The four cations calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na);

2. Silicon dioxide (SiO_2);

3. Bicarbonate alkalinity (HCO_3);

4. Nitrate-nitrogen (NO_3–N); and

5. Chloride (Cl).

Further discussion of possible land use implications for water quality were made with respect to trends (see Subsection 3.5).

3.4 Groundwater quality compared to other regions

GNS Client Report 2004/156 took three approaches in comparing groundwater quality in the West Coast Region to other regions of New Zealand. These were:

1. Comparison of rank percentiles for each parameter to those for NGMP sites in New Zealand as a whole;

2. Assignment of West Coast Region sites to hydrochemical facies classifications; and

3. Assignment of West Coast Region sites to categories based on observed trends across NGMP sites New Zealand as a whole.

It was concluded with regard to these three approaches that:

1. Based on median values (i.e., 50^{th} percentile), most monitored parameters at the West Coast Region NGMP sites have significantly lower concentrations than for NGMP sites across New Zealand as a whole. Based on the 25^{th} and 75^{th} percentile (interquartile range), data from West Coast Region NGMP sites covers a narrower range of compositions than NGMP sites across New Zealand as a whole. This was expected and is consistent with the fact that NGMP wells in the West Coast Region tap groundwaters that are relatively dilute and pristine and are geochemically similar to one another compared to NGMP wells across New Zealand as a whole.

2. Of the six hydrochemical facies identified for NGMP groundwaters across New Zealand as a whole, groundwaters from all sites in the West Coast Region fell into two classifications. These were 1B-1 or 1B-2. These classifications are both described as "Little Human Impact, Low Total Dissolved Solids (TDS), and Calcium-Sodium-Bicarbonate Water." In comparison, 42 percent of all NGMP sites are classified as being 1A-1 or 1A-2 ("Signs of Human Impact, Moderate TDS, and Sodium-Calcium-Magnesium-Bicarbonate-Chloride Water"), 32 percent are classified as being 1B-1 or 1B-2 (like all the West Coast Region sites), and 26 percent are classified as being 2A or 2B ("Reduced Confined Aquifer, Higher TDS, Calfium-Sodium-Bicarbone Water"). This means that groundwaters at West Coast Region sites are relatively dilute and have relatively low impact from anthropogenic sources (e.g., agriculture) when compared to NGMP sites across New Zealand as a whole.

3. Trend information indicates that more of the West Coast Region NGMP sites have an indication of slow change in groundwater quality (87 percent) than for NGMP sites as a whole across New Zealand (71 percent).

3.5 Trends in West Coast region groundwater quality

For most variables, there were no discernable trends in water quality over the period of 1998 through 2004 (i.e., statistically significant at the 95 percent confidence level). This included all major cations, silicon dioxide, and pH. In contrast, it was found that there were significant increasing trends for chloride, nitrate-nitrogen, and sulphate in the six wells with the longest records (i.e., wells HK31, GR17, GR04, HK34, BU01, and HK25). For most variables in most wells the increase occurred across the entire period of record. However, for well HK34 the increasing trend was limited to the September 1998 through January 2000 period.

The increasing nitrate-nitrogen concentrations were cited as "convincing evidence of increasing human/agricultural impact on groundwater quality" in the West Coast Region. The increases of chloride and sulphate were noted as "co-occurring" and expected because of their presence in manure, sewage effluent, and fertilizer. In this regard, it was also pointed out that most of the wells were shallow (i.e., less than 10 metres total depth and, obviously, also intersected shallow water tables within a few metres of ground level). Although there are no logs with reports of the exact lithology for most of these wells, because of their location in proximity to stream systems it is likely that some, if not all, are located in relatively permeable sands and gravels typically associated with such systems. However, such aquifers may be very heterogeneous and can contain substantial thickness of fine-grained alluvially deposited materials of low permeability. This is another important factor in the susceptibility of these wells to contamination from associated or adjacent land uses.

3.6 Conclusions

GNS has reached the following conclusions from NGMP data:

1. At present, the groundwater quality at the NGMP sites in the West Coast Region is quite good. This is evidenced by such things as nitrate-nitrogen concentration typically less than ca. 2 mg/L, which is low in comparison to other regions of New Zealand. This conclusion is qualified by the fact that concentrations of nitrate-nitrogen at some sites are approaching the level indicative of marginal but detectable agricultural impact (ca. 3 mg/L).

2. Bacterial indicators exceed the health-related MAV for roughly one third of samples from all bores. This contamination probably results from leaching of effluent or manure associated with agricultural land use. High rainfall, shallow water tables, and porous aquifers accentuate the potential for this problem. It is also often a function of inappropriate well construction.

3. Concentrations of iron and manganese exceed the aesthetic-based guideline at three sites on some occasions. These are probably the result of naturally low levels of oxygen in the aquifers.

4. There is evidence of deterioration in groundwater quality in the West Coast Region. Concentrations of chloride, nitrate-nitrogen, and sulphate increased significantly in at least half of the NGMP wells since 1998. This is likely the result of increased leaching from manure, sewage effluent or fertilizer and appropriate management strategies should be adopted as soon as possible.

5. The distribution of NGMP wells in the West Coast Region is too sparse to identify relationships between hydrochemistry and surrounding land use, or to provide a reliable estimate of baseline hydrochemistry. There are too few sites for such a large region, the majority of the sites fall into the dairy land use category, and the likely capture zones are small.

4.0 ADDITIONAL STUDIES - BAKER 2004[1]

4.1 Introduction

Baker (2004) investigated the relationship between groundwater quality in the West Coast Region and agricultural practices with respect to management of nitrogen. He focussed specifically on dairy farming and pointed out that dairy farming has been intensifying in New Zealand over the last 10 to 15 years. During that time frame, both the average herd size and stocking rate have increased, with the total population of cows in New Zealand increasing by 55 percent between 1990/1991 and 2002/2003 and the national average stocking rate increasing from 2.4 to 2.6 cows/hectare. There has also been a "marked increase" in the use of nitrogen fertilizers on New Zealand dairy farms in association with the intensification of dairying.

The statistics presented by Baker (2004) indicate that while dairy farming in the West Coast Region has followed the national trend in New Zealand, stocking rates are somewhat below the national average. Slightly fewer than three percent of New Zealand dairy herds are located in the West Coast Region. Nevertheless, with over 100,000 cows and a net worth of $100 million, dairying is the leading agricultural activity in the West Coast Region. Average herd size and stocking rate in the Region are 269 cows and 2.03 cows/hectare, respectively.

Stocking rates, effluent disposal practices, and the rate and timing of nitrogen-containing fertilizer applications are farm management practices that can influence the potential impact of dairy farms on groundwater quality. Obviously, increases in stocking rates have the potential to increase the application of waste materials containing nitrogen from cows to the ground. This may be as a result of direct deposits of faeces and urine to land while grazing or through land application of dairy shed effluent (DSE).

4.2 Methods used

Baker (2004) studied 22 wells in three West Coast Region areas: (1) five wells in a portion of the Hokitika River drainage in the vicinity of Kowhitirangi; (2) 15 wells in portions of the

[1] Information presented in this Chapter of the report has been extracted from Baker (2004). Statements may be verbatim quotes or paraphrased to minimize bulk of text.

Grey River drainage near Ahaura (seven wells) and Totara Flats (eight wells); and two wells in a portion of the Inangahua River drainage near Reefton. Three of these wells were NGMP wells (HK39, GR17, and HK34). Although the other 19 were not, five of them (GR10, GR19, GR21, HK35, and HK37) are included in the WCRC water level program (see Table 1). Data on the locations of these wells and other relevant information is presented in Tables 1 and 2. Their locations are indicated in Figure 11.

Baker (2004) sampled most of these wells on four occasions during 2001 (April, June, August, and October). Samples were analysed for a limited suite of variables including bacteria, ammonia and nitrate-nitrogen, conductivity, dissolved oxygen, iron, pH, phosphorous, and temperature. In addition, nitrogen isotope ratios were determined in samples from six Grey and Inangahua River drainage wells (GR09, GR19, GR20, GR06, GR15, and IN43) and the concentrations of chlorofluorocarbons (CFCs) R-11 and R-12 were determined in samples from four Hokitika and Grey River drainage wells (HK39, GR06, HK34, and GR15). For the three NGMP wells, Baker (2004) reviewed NGMP data from the 1998 through 2003 time frame.

In addition, Baker (2004) reviewed existing management practices with regard to allowable nitrogen loading rates and applied two computer models to estimate appropriate nitrogen loading rates in terms of the amount of nitrate-nitrogen leaching to groundwater they predict. These models were the Di and Cameron (2002) nitrogen leaching estimation (NLE) model produced at Lincoln University and the Ledgard, et al. (1999) OVERSEER nutrients budget model produced at Massey University.

4.3 Baker (2004) conclusions

Baker (2004) found only incomplete information on the installation and hydrogeology of the wells he sampled. As a result of his study, Baker (2004) reached the following conclusions:

1. Groundwater quality in the areas sampled was “generally high” and within Ministry of Health drinking water guidelines. However, bacteria and iron levels in some wells exceeded health-based or aesthetic-based drinking water standards.

2. Although levels of nitrate-nitrogen did not exceed the health-based drinking water standard, concentrations elevated above natural "were evident."

3. Iron concentrations were high in one well (i.e., in the range of 1.5 to 8.1 mg/L). This was attributed to reducing conditions. That would be consistent with the low dissolved oxygen (i.e., in the range of 6.4 to 57.7 percent of saturation) and nitrate-nitrogen (i.e., much less than 1 mg/L) levels also reported.

4. Analysis of data from longer term sampling of NGMP wells indicated statistically significant increasing concentrations of chloride and nitrate-nitrogen in wells GR17 and HK34.

5. Nitrogen isotope data from the six wells sampled was in the low single digit d^{15}N range (i.e., 1.51 to 4.58 ‰). This is indicative of fertilizer or soil organic nitrogen sources rather than animal sources. Nevertheless, Baker (2004) concluded that the "strong increasing trends" of nitrate-nitrogen and chloride "suggest that effluent" is also contributing to this increase.

6. Age dating using CFCs indicated that the age of unconfined water in the Hokitika and Grey River drainage aquifers sampled was on the order of eight years in the Kowhitirangi and 12 years in the Ahuara areas. These ages would suggest that results of the recent intensification of dairying are only "just starting to become evident in the groundwater quality, or are yet to reach groundwater."

7. The current WCRC maximum nitrogen loading rate for DSE of 275 KgN/hectare/year is high compared to maximum levels established by other New Zealand regional councils. Use of the computer models NLE and OVERSEER suggests that this rate may be sustainable. However, there are many limitations to both of these models, and the validity of model assumptions to the West Coast Region is unknown. For example, the NLE model has not been tested in an area where drainage (i.e., precipitation minus evapotranspiration) exceeds 600 mm/year (a likely scenario for the West Coast Region). In addition, there are currently no controls in the West Coast Region on the use of nitrogen-based chemical fertilizers.

4.4 The effects of dairy land use on groundwater quality

In summary, Baker (2004) indicates that it is likely that historic dairy land use practices may have increased nitrate-nitrogen levels in some of the wells in the West Coast Region he sampled, or wells that are sampled as a part of the NGMP, above natural background levels. However, these levels currently are still far below the health-based New Zealand drinking water standard. Similarly, chloride may also have been increased in these wells by dairy land use practices. However, nitrogen isotope data indicates that the source of the nitrate-nitrogen reported in these groundwater samples may have been from chemical fertilizers rather than animal wastes. Additionally, the groundwater ages determined from CFC analysis would indicate that groundwater samples Baker (2004) took in 2002 as well as NGMP samples collected from 1998 through 2003 are too old to be fully indicative of the impact of more recent intensification of dairying. Therefore, the full impact of such intensification, if any, may not be evident for some time.

It is also noteworthy that there are currently insufficient Region-specific data on processes effecting nitrogen in the soil to allow accurate computer modelling of the leachability of nitrate-nitrogen from applications of DSE at the allowed West Coast Region rate of 275 KgN/hectare/year. Furthermore, the lack of management limitations on the application of nitrogen-based fertilizers is an important factor.

4.5 Prediction of effects on groundwater quality elsewhere

Given the lack of critical site-specific information, it is difficult to generalize from the areas studied by Baker (2004) to other West Coast Region dairy catchments in other than broad terms. We have insufficient data for rigorous comparisons. It would be necessary to have detailed information on well installations, unsaturated and saturated zone properties, land use practices, and climate data both at sites studied by Baker (2004) and sites for which a comparison was desired. Nevertheless, it is reasonable to hypothesize that the possible impacts indicated by Baker (2004) have general relevance to other locations both in the West Coast Region and elsewhere in New Zealand.

Application of wastes or chemical fertilizers containing nitrogen upgradient from or in the vicinity of wells poses a risk of contaminating the groundwater extracted from those wells and increasing the intensity of such practices increases the risk. At the same time, improved wellhead protection and regulation of potential anthropogenic sources of contaminants are measures that can help to reduce this risk.

5.0 GROUNDWATER LEVELS IN THE WEST COAST REGION

5.1 Introduction

The WCRC provided GNS with an Excel file containing all available water quality and water level data from wells within the region. These data, derived from the WCRC database, are presented in Appendix B. They were analysed and evaluated with respect to West Coast Region groundwater levels and their relationship to groundwater quality. These data included the following:

1. Quarterly water quality and water level data from September 1998 through March 2004 for all eight NGMP wells listed in Table 1. Although the intended sampling frequency was quarterly, there were substantial data gaps and for most wells data were available for only 65% of the quarters involved. The locations of these wells are shown in Figure 10. For five of these wells (HK31, HK39, GR04, HK34, and HK25), there was an additional listing of more frequently obtained water level data (usually on the order of six observations/year) for which corresponding water quality data were not available.

Well HK39 was not sampled after June 2001 and sampling of well GR02 only commenced in June 2003.

2. The more frequently obtained water level data only noted above from early 2000 through April 2005 for the 27 current WCRC wells listed in Table 1. This included the above five NGMP wells. The locations of the 22 wells not part of the NGMP are shown in Figure 12. The starting dates for obtaining water level data for these wells varied but fell within the first half of 2000. In all cases except one, data were available through April 2005. There were no data for well GR44 after February 2002.

All groundwater level data were obtained using an electric-tape water level indicator. In the past, the length of the tape for this indicator was 15 metres. A new 80 metre tape was placed in service in 2004. All depth measurements are taken using the top of the well casing as a reference point. The top of all well casings is within 10 centimetres of ground level. Top of casing elevations have not been determined by survey. However, ground level elevations have been estimated from 1:50,000 topographic maps using well coordinates and topographic contours. These are listed as altitudes in Table 1.

5.2 Analysis of groundwater level data

5.2.1 Time series plots

Time series plots of groundwater level data were prepared for 28 of the 30 sites (eight NGMP and 22 other WCRC sites). In the case of water level data, these are also known as hydrographs. Copies of these are presented in Appendix C. The vertical scale on all of these except two has been set at a common length of 10 metres to allow ready comparison. For WCRC wells GR21 and GR19 it was necessary to use a vertical scale for the plots of 20 metres to show the greater amount of variation in the data from them. Plots could only be made for six NGMP sites. Data for two wells were not plotted: (1)GR17; and (2)GR02. In the former case, there was only one possibly useable data point through March 2004 (a water level of 21.6 metres on 17 June 1999). On all other previous monitoring occasions, the water level was reported as greater than the 15 metre length of the water level indicator tape used. Only three water level measurements had been entered into the NGMP data base provided for well GR02.

Visual review of time series plots allows for a qualitative introduction to the data. In this case, it was evident that there was some variation in water levels over time but little indication of any trends. For most wells, the water level database included occasional outliers. Figure 13 shows the time series plot for water level data from two wells and a linear best fit line to the data for each. These are NGMP wells HK31 and GR04, presented at the top and bottom of Figure 13, respectively. Well HK31 is typical of most of the plots for these 26 data sets. The linear best fit line for HK31 well data is very close to horizontal (the slope for this line was –0.014 metres/year). A greater degree of data variation is evident for the data set from well GR04. As is discussed with regard to trend in Subsection 5.2.3 below, the data set for this well had the greatest indication of trend of all of the 26 wells. The linear best fit line for well GR04 data indicates a declining trend of 0.25 metres/year.

5.2.2 Descriptive statistics, seasonality, and outliers

Descriptive statistics were calculated using the Microsoft Excel spreadsheet computer program. Minimum, median, mean, maximum, and standard deviation values and the number of data points available for each well (i.e., count) were calculated for all 30 wells (8 NGMP and 22 other WCRC) and are presented in Table 3. It is noteworthy that the median and mean values generally appear to be similar.

Data for 25 and 26 of the wells, respectively, were also tested for seasonality and outliers. There were insufficient data in the cases of NGMP wells GR17 and GR02 and the other WCRC wells GR21 and GR19 for any such testing. In addition, there was insufficient data to test the NGMP well BU01 for seasonality. These tests were performed for information purposes and were not used to transform or eliminate points from the data set. Testing was performed using the computer program WQStat+. WQStat+ tests for seasonality using the nonparametric Kruskal-Wallis test at the 0.05 significance level. WQStat+ tests for outliers using a parametric U.S. Environmental Protection Agency (USEPA) method at a 0.05 significance level. Results for seasonality and outlier testing are presented in Table 3. There was little indication of seasonality for water level in any of the wells. Seasonality was indicated for only one NGMP well (i.e., HK31) and two other WCRC wells (i.e.,GR10 and GR16). There were outliers in the data set for most wells. Outliers were identified for all six NGMP wells and 13 of the 20 other WCRC wells with sufficient data for testing. In most cases, outliers were in the high direction (i.e., a data point indicating a higher water table elevation or shallower depth to water than was characteristic for the data set). Only the NGMP well HK31 and other WCRC well HK26 had outliers in the low direction. Outliers could result from various factors including uncommon hydrologic events, such as floods or droughts, or measurement errors.

5.2.3 Trend

Data from the same 26 wells tested for outliers were also tested for trend. There was insufficient data for this test in the other cases (i.e., the same wells that could not be tested for outliers listed above). These tests were performed using the computer program WQStat+. WQStat+ tests for trend using the nonparametric Mann-Kendall analysis and also uses the nonparametric Sen's slope estimator to calculate the true slope.

Results of trend testing are also presented in Table 3. There was little indication of trend in water level at any of the wells. A significant trend at either the 0.01 or 0.05 significance levels was indicated for only two of the six NGMP (i.e.,GR04 and HK34) and three of the 19 other WCRC wells (i.e.,GR45, HK24, and GR44) with sufficient data for testing. The largest magnitude trend was -0.227 metres/year in NGMP well GR04. A negative trend means that the water table elevation is decreasing over time (i.e., the water level measured below top of well casing is increasing). Figure 14 shows the Sen slope plot produced by WQStat+ for the data from this well. Although a trend line is plotted in Figure 14 and it is statistically significant at the 0.05 level, it can be seen from Figure 14 that there is considerable variation in the data. A smaller magnitude negative trend was calculated for the other WCRC well GR44 and small positive trends were calculated for the other three wells noted above.

5.2.4 Contouring of water elevation data

If the elevation of the reference point for water level data is known, water elevation can be calculated from it. Where wells are properly located and coordinates for their locations are known, water elevation data may be contoured to produce a potentiometric surface. The potentiometric surface for an unconfined groundwater system is a representation of the water table. This representation can be used to indicate the direction of ground water flow, which is perpendicular to the contour lines.

Ground elevations for the wells in Table 1 were either provided by the WCRC or picked off of 1:50,000 topographic maps using the coordinates for each well. WCRC staff indicated that the reference points used for each water level measurement are the top of the well casing (TOWC) and that TOWC in each case is within approximately 10 centimetres above or below ground level. Using these reference elevations, water level elevations were calculated for two groups of wells and for two representative dates. The wells were: (1) wells in the Ahaura, Atarau, Ngahere, and Totara Flats areas of the Grey River drainage; and (2) wells in the Kokatahi and Kowhitirangi areas of the Hokitika River drainage. The dates were June 2001 and December 2004. These dates were selected because June 2001 was the first date for which data were available for the largest number of wells. Since it was a winter time date, the latest summer time date (i.e., December 2004) was selected for comparison. Water elevations were then contoured using the computer program Surfer with default settings (with the exception of modifications made to enhance the graphical presentation), and the kriging algorithm.

The resulting plot for Grey River wells generally showed a potentiometric surface indicating the direction of groundwater flow to be toward the west and the Grey River. However, the spatial layout of the wells involved and the topographic and drainage features make this plot of questionable utility. In contrast, the plot for the Hokitika wells does not have the confounding problems noted above and thus, with one possible qualification, should be reasonably valid. The qualification is the possible influence of the Kokatahi River under which groundwater in this area would have to pass. The Hokitika River plot for December 2004 data is presented as Figure 15. It shows a potentiometric surface indicating the direction of groundwater flow to be generally to the north. The plot for June 2001 data was very similar.

5.3 Comparison of groundwater level and groundwater quality

5.3.1 Correlating groundwater level and quality data

GNS concluded in previous work that there were statistically significant increasing trends at the 95 percent confidence level for the water quality variables chloride, nitrate-nitrogen, and sulphate only and that these occurred for data from six of the NGMP wells (i.e., HK31, GR17, GR04, HK34, BU01, and HK25). Since there are no water level data from well GR17, the possible relationship of these water quality trends with water levels was compared for a linear correlation for the other five wells. All data from dates where there were both water level measurements and water quality results available were used. This reduced the total data base available for analysis because water level measurements were missing from the data base on a number of occasions for the 1998 through 2001 period (particularly for wells HK34 and BU01). Since a water level measurement was not available for the well HK34 when the sample analysed for water quality was taken on 11 June 2001, a water level measurement on 8 June 2001 was substituted because it was sufficiently close in time that it was probably indicative of the level three days later. There were no other cases when a measurement was missing and where alternative water level data were sufficiently close in time for such a substitution. The comparison was made using the Grapher computer program and testing for a linear fit.

Results for this comparison are shown in Table 4. There are two parts of the linear correlation analysis that are relevant to the possible significance of a correlation between two variables: (1) the magnitude of the effect indicated by the magnitude of the line's slope; and (2) the strength of the correlation indicated by the coefficient of determination. A large slope and a high coefficient of determination would indicate a significant relationship between the two variables. As can be seen in Figure 16, the units for slope are mg/L change in concentration per metre change in water level (mg/L-m). In most cases, there were only small slopes (11 of the 15 slopes in Table 4 were less than 1 mg/L-m) and very low coefficients of determination (less than 0.6). Additionally most of the slopes were negative (all in the cases of nitrate-nitrogen and sulphate but only two of the five wells in the case of chloride). Therefore, a very weak negative relationship between water levels and water chemistry was what was predominantly indicated. However, it is interesting to note that a negative relationship means that the concentration of the water quality variable increases as the depth below ground of the water level decreases. This would be the expectation in cases of surface sources of contaminants.

The data for sulphate in well HK34 and the linear line of best fit are presented in the upper portion of Figure 16 to illustrate the case of both the highest slope and greatest coefficient of determination and therefore the most likely indication of a relationship for any of the variables at any of the wells. The line through the data points is not horizontal, but there is considerable scatter. More typical of the general case would be that of nitrate-nitrogen versus water level for well BU01. These data and the linear line of best fit are presented in the lower portion of Figure 16. The line through the data points is nearly horizontal, indicating that there is no correlation between water level and nitrate-nitrogen concentration at this well.

5.3.2 Groundwater flowpath

Figure 15 also indicates that there is a groundwater flow path from the vicinity of the wells

HK39 and HK40 to the vicinity of wells HK36 and HK37, past well HK34 (offset somewhat to the west of this flowpath), to the vicinity of the wells HK31 and HK32, and finally to the vicinity of the wells HK28, HK29, and HK30. This apparent flowpath would cross the Kokatahi River (between wells HK36 and HK37 and wells HK31 and HK32). Given the shallow water table involved, some interaction with that stream would be expected, but there are no other wells in the vicinity of the Kokatahi River to provide more information on groundwater flow direction. Groundwater flowing along this path would potentially be progressively impacted by anthropogenic activities along it. The only data available to test this theory comes from the three year period from 1999 through 2001, when water quality data from three wells were available (i.e., before sample collection from well HK39 stopped in 2001). Median values for chloride, nitrate, and sulphate from the NGMP wells HK39 and HK34 (as can be seen in Figure 15, well HK34 is offset somewhat to the west of this flowpath), and well HK31 for that period indicate the following:

1. Chloride –

   a. HK39 2.40 mg/L
   b. HK34 2.30 mg/L
   c. HK31 3.35 mg/L

2. Nitrate-nitrogen –

   a. a. HK39 0.92 mg/L
   b. b. HK34 0.65 mg/L
   c. c. HK31 0.98 mg/L

3. Sulphate –

a. a. HK39 3.25 mg/L
b. b. HK34 4.20 mg/L
c. c. HK31 4.90 mg/L

The median concentrations for these variables, which could be related to anthropogenic sources in the area, are all higher downgradient for well HK31 than for the upgradient well HK39. However, the difference is not large for nitrate-nitrogen and a consistent progression is seen only for the sulphate data.

5.4 Prediction of groundwater levels in other catchments

Groundwater level data from the Grey and Hokitika River catchments cannot be used to predict groundwater levels in other catchments in the West Coast Region in anything other than a broad sense (e.g., water levels in alluvial wells will rise after major precipitation events that increase streamflow). There appear to be three reasons for this: (1) we do not have site-specific information about the lithology in areas for which we have water level data, and we do not have similar information for other areas where we might like to predict water levels; (2) we do not have comparative hydrologic data of other kinds (e.g., precipitation and streamflow); and (3) there is little indication of seasonality or trend in the water level or other hydrologic data available (it should be noted with respect to this that the data record is short from a hydrologic standpoint, five years or less). In order to use these available water level data for predicting water levels in other catchments, it would be necessary to have additional site specific hydrologic data for both the catchments involved in this assessment and other drainages of concern.

The WCRC provided precipitation records for two stations. These were Butcher Creek at Butcher's Gully and Grey River at Waipuna. The WCRC also provided streamflow data for three stations. These were Butcher Creek at Lake Kaniere Road, Grey River at Dobson, and Hokitika River at Gorge. These data are graphically presented in Figures 17 and 18. They are also summarized in Table 5.

Although there is an indication of a relatively minor period of reduced precipitation and streamflow in the late summer quarter (March to April time frame), these data show little indication of seasonality or trend. The West Coast Region receives substantial and frequent precipitation throughout the year, and this precipitation is reflected in the streamflow measured in the Region. For example, data for 2000 through 2005 indicate that precipitation occurred to some degree at least half of the days of each year. Total annual precipitation for years with complete or nearly complete data averaged 3,750 and 1,920 mm for the Butcher Creek and Grey River gauges, respectively, and median streamflows for the gauging stations on the Grey and Hokitika Rivers were 249,000 and 63,900 L/second, respectively. These are substantial levels of precipitation and streamflow. The long term mean annual precipitation for measuring stations in the West Coast Region is the second highest of any region in the country (NIWA, 2005).

5.5 Extension of observed groundwater level and quality relationships

There were no significant relationships between groundwater level and quality identified in this assessment of data. However, there was an indication of a possible and reasonable relationship between the level of groundwater in well HK34 and sulphate, in which the concentration of sulphate appeared to increase as the water level increased (i.e., the water table became shallower). This would be expected in the case of a surface source of a contaminant (e.g., land application of chemical fertilizers or animal wastes). However, none of the coefficients of determination were very high, indicating at most a very weak relationship.

5.6 Data gaps

There are gaps in the available water level and quality database that reduce its usefulness. For example, comparison of water level and quality data to determine whether or not there are evident relationships requires paired data points (i.e., water level measurements for the same times at which samples were taken and analysed). However, there are a number of dates on which samples were collected and analysed but for which there are no water level data available. Some of these were for dates prior to the commencement of WCRC's program of obtaining water level measurements on a more frequent and broader basis than when NGMP wells were sampled; however, there are gaps both before and after the commencement of that program. Water levels should be measured each time a well is sampled. If for no other reason, this is necessary to properly calculate purge volumes prior to sampling.

The case of well GR17 is illustrative of a particular data gap problem. Essentially none of the 30 water level values in the WCRC database appear to be reliable. Most are listed as greater than 15 metres, indicating that the water level indicator tape might have been too short for the circumstances of this well. A new water level indicator with a longer tape was placed in service in 2004. Since that time most values have been listed as greater than 80 metres. This contrasts sharply with data from nearby wells having water levels on the order of 5 to 6 metres and an indication from WCRC staff that the total depth of this well is 38 metres. Special care should be exercised in the future to obtain accurate water level measurements at this site. This site also illustrates an additional data gap problem with regard to collection of samples for laboratory analysis. Out of 23 quarterly sampling dates between September 1998 and March 2004, only 14 samples were collected for laboratory analysis (about 61%).

Comparison of laboratory measurements of chloride concentrations with field measurements of conductivity provides another illustration of the data gap situation. This is a potential quality assurance check that can be performed. However, in the case of these two variables the total amount of data available for all NGMP wells amounts to 74 data points for chloride and 53 for conductivity. Therefore, there are at least 21 missing field conductivity data points and any such comparison is restricted to the 53 data points for which there are values for both. Furthermore, conductivity is a standard variable that should be measured before and during purging prior to sampling.

6.0 CONCLUSIONS

This Groundwater State of the Environment Report for the WCRC has been prepared in accordance with the GNS proposal of 8 March 2005. The following conclusions (keyed to the applicable chapters of this report) have been reached as a result of this assessment of available groundwater level and quality data and other information reviewed as a part of this project and/or provided by the WCRC:

1. Chapter 2 -

    a. The West Coast Region has substantial groundwater resources that serve as an important source of water for drinking and other purposes by communities and individuals, agriculture, and other industries and users.

    b. Most of the identified groundwater resources in the West Coast Region are located in alluvial materials adjacent to the Region's major streams such as the Grey and Hokitika Rivers. Similarly, most of the resource consents to take groundwater have been issued for users within the Grey District (nearly half).

    c. Groundwater quality in the West Coast Region is monitored through quarterly sampling of seven NGMP wells. One of the original seven wells was dropped from the program in 2001 and a new well was added in 2003. The WCRC also obtains routine groundwater level data from 22 other wells. These wells are located primarily in the Grey District.

    d. There is a continuing need for public education to protect groundwater resources in the West Coast Region.

2. Chapter 3 –

    a. With two exceptions, groundwater quality in the West Coast Region, as indicated by samples from NGMP wells, is generally good in comparison to guidelines such as the New Zealand Drinking Water Standards. The exceptions are for bacterial indicators and for iron and/or manganese. The New Zealand Drinking Water Standard for bacterial indicators has been exceeded in roughly one-third of the samples and in all wells but one. There were also exceedances of the aesthetic-based guideline for iron and/or manganese in samples from three wells.

b. Although levels of nitrate-nitrogen did not exceed any guideline value, they were high enough in some samples to indicate an anthropogenic (i.e., human caused) source.

c. Although groundwater quality in the West Coast Region compares favourably with data for other New Zealand regions and is generally considered to be within the 1B-1 or 1B-2 categories (i.e., "Little Human Impact"), the data suggest that there are correlations between land use practices in the Region and groundwater quality. Furthermore, there are statistically significant increasing trends for chloride, nitrate-nitrogen, and sulphate in the data from six of the NGMP wells. These trends may reflect intensifying agricultural operations in the Region.

d. It was recommended that quarterly groundwater monitoring be continued at all NGMP sites, that a one-off synoptic survey of water quality in other West Coast Region wells be performed, and that additional study pertinent to connections between groundwater quality and land use be performed to include age-dating of groundwater samples from NGMP wells and measurement of groundwater velocities.

3. Chapter 4 –

   a. Baker (2004) also reached all of the conclusions listed above with regard to Chapter 3.

   b. Intensifying agricultural operations within the West Coast Region makes ongoing assessment of groundwater quality particularly important in order to guide management practices and protect the resource.

   c. Nitrogen isotope data indicate the source of nitrogen in West Coast Region groundwaters sampled in 2001 was more likely to be chemical fertilizer or soil organic nitrogen, rather than animal wastes.

d. Age dating using CFCs indicates that the mean age of the groundwater sampled in 2001 was on the order of 12 years in the Grey River drainage and eight years in the Hokitika River drainage. This suggests that the full impact of recent intensification of agricultural operations may not yet be evident.

e. There is inadequate Region-specific information to reliably apply computer models of nitrogen leaching to groundwater in the West Coast Region.

4. Chapter 5 –

a. There is little indication of seasonality or trend in West Coast Region groundwater level data. However, there is an indication of one or more outliers in the data sets for most of the wells. Most of the outliers are in the high direction (i.e., indicating a shallower depth to water).

b. Contouring of water level data suggests that the direction of groundwater flow in the Kokatahi and Kowhitirangi areas of the Hokitika River drainage is generally to the north.

c. There is little indication of any relationship between groundwater levels and groundwater quality in the West Coast Region. The strongest indication of a relationship was for sulphate in well HK34 (Hokitika River drainage). However, the low coefficient of determination indicates that even this relationship is weak. Nevertheless, the relationship indicates increasing sulphate concentrations with increasing water levels (i.e., a shallower water table), which is consistent with the possibility of an anthropogenic surface source.

d. Water level and quality data allow delineation of a possible groundwater flow path in the Hokitika River drainage. The limited data indicate that chloride, nitrate-nitrogen, and sulphate concentrations may all increase along this flowpath. However, there are a number of qualifications regarding this subject (e.g., groundwater involved with this possible flowpath would have to cross underneath the Kokatahi River). This hypothesis depends on data from only three wells. One of these wells is no longer being sampled as part of the NGMP and another is offset somewhat from the flowpath.

e. Due to the lack of relevant site-specific well (lithology and well design/construction) and hydrologic data and the general lack of strong seasonality or trends in groundwater level, it is not possible to use the water level data currently available from the Grey and Hokitika River drainages to make specific predictions regarding groundwater level fluctuations in other catchments in the West Coast Region. However, broad general hydrologic relationships would be expected to be relevant.

f. No conclusive relationships between groundwater level and quality were identified in this assessment. Therefore, it is not possible to extend findings from these data to other catchments in the West Coast Region. Nevertheless, broad generalizations based on general principles would still be considered valid (e.g., shallow water table wells are more susceptible to surface sources of contamination than wells in deeper groundwaters).

g. There are substantial gaps in the water level and quality data base where data of one kind or another are missing. For example, for most NGMP wells, samples had only been taken on about 65 percent of the quarters between September 1998 and March 2004. This fact reduces the usefulness of the data and handicaps analysis of it.

h. There is an apparent lack of field and laboratory quality control and quality assurance measures, or at least a lack of documentation of them.

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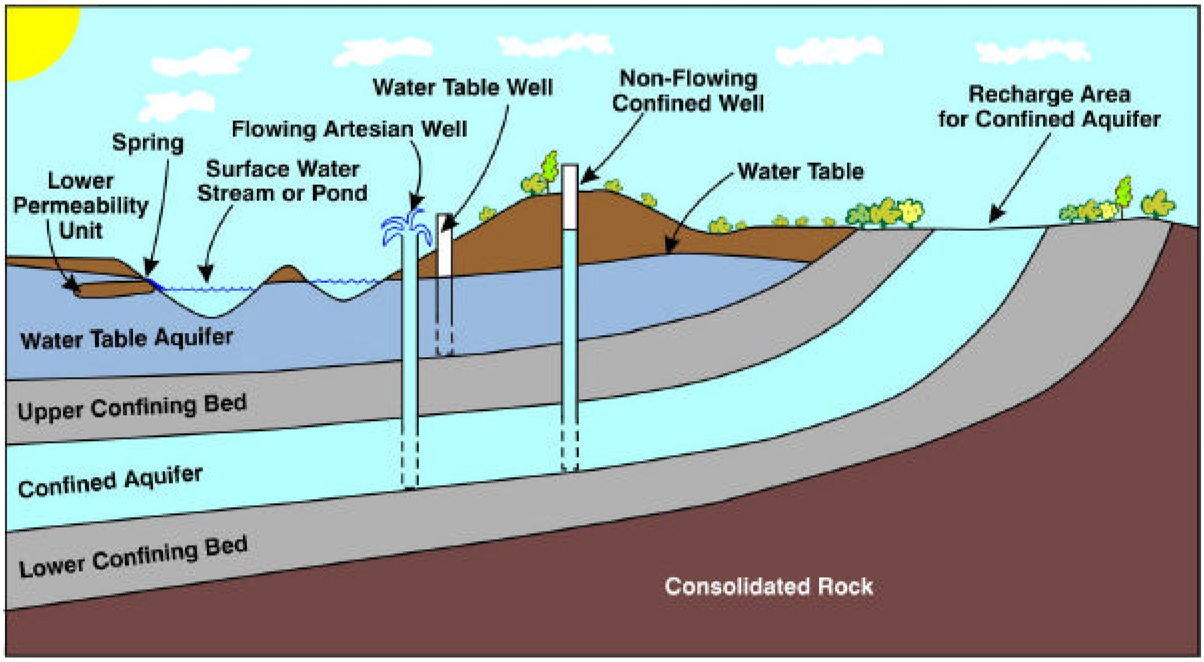


Figure 1. Generalised groundwater aquifer system.

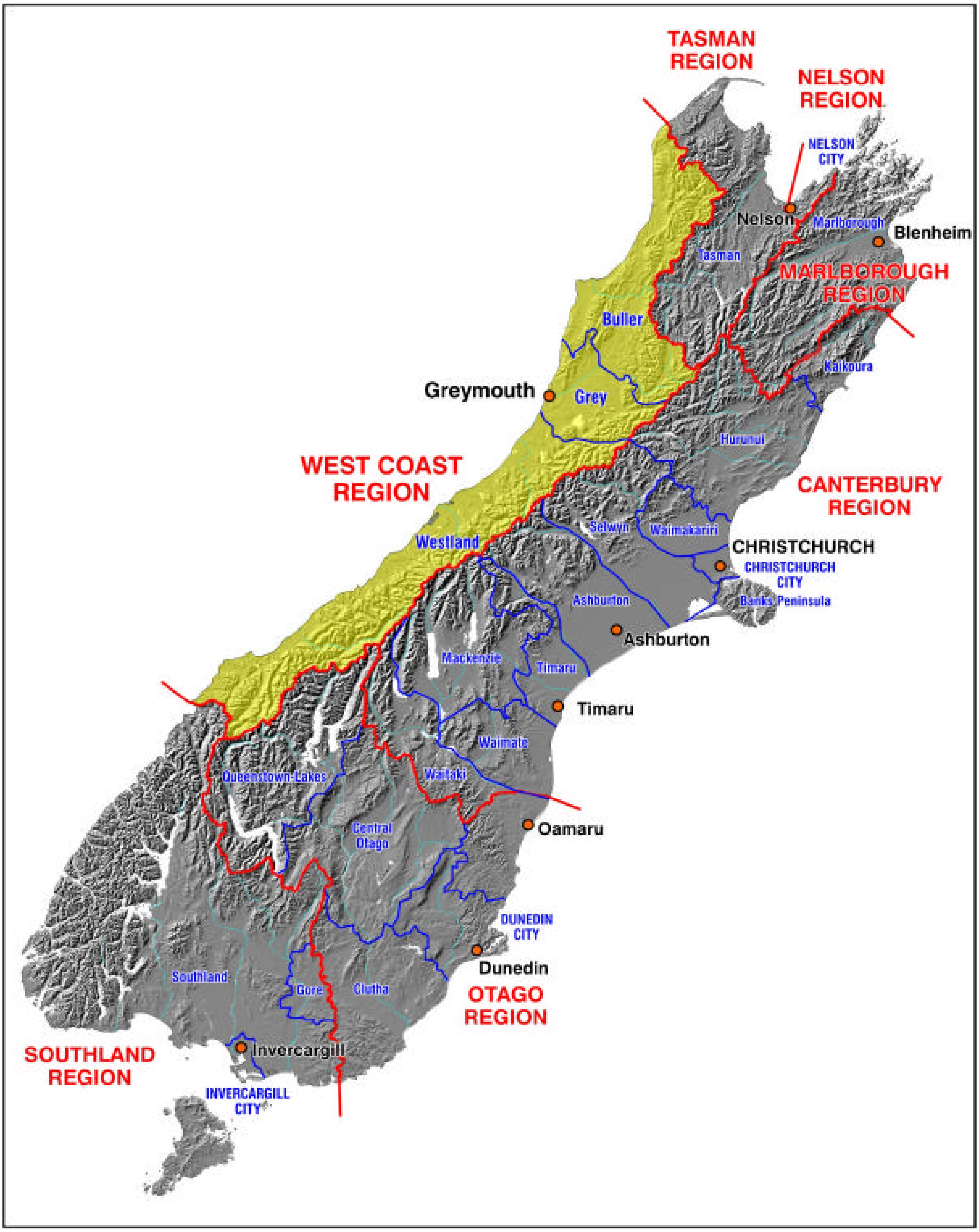


Figure 2. West Coast region and districts.

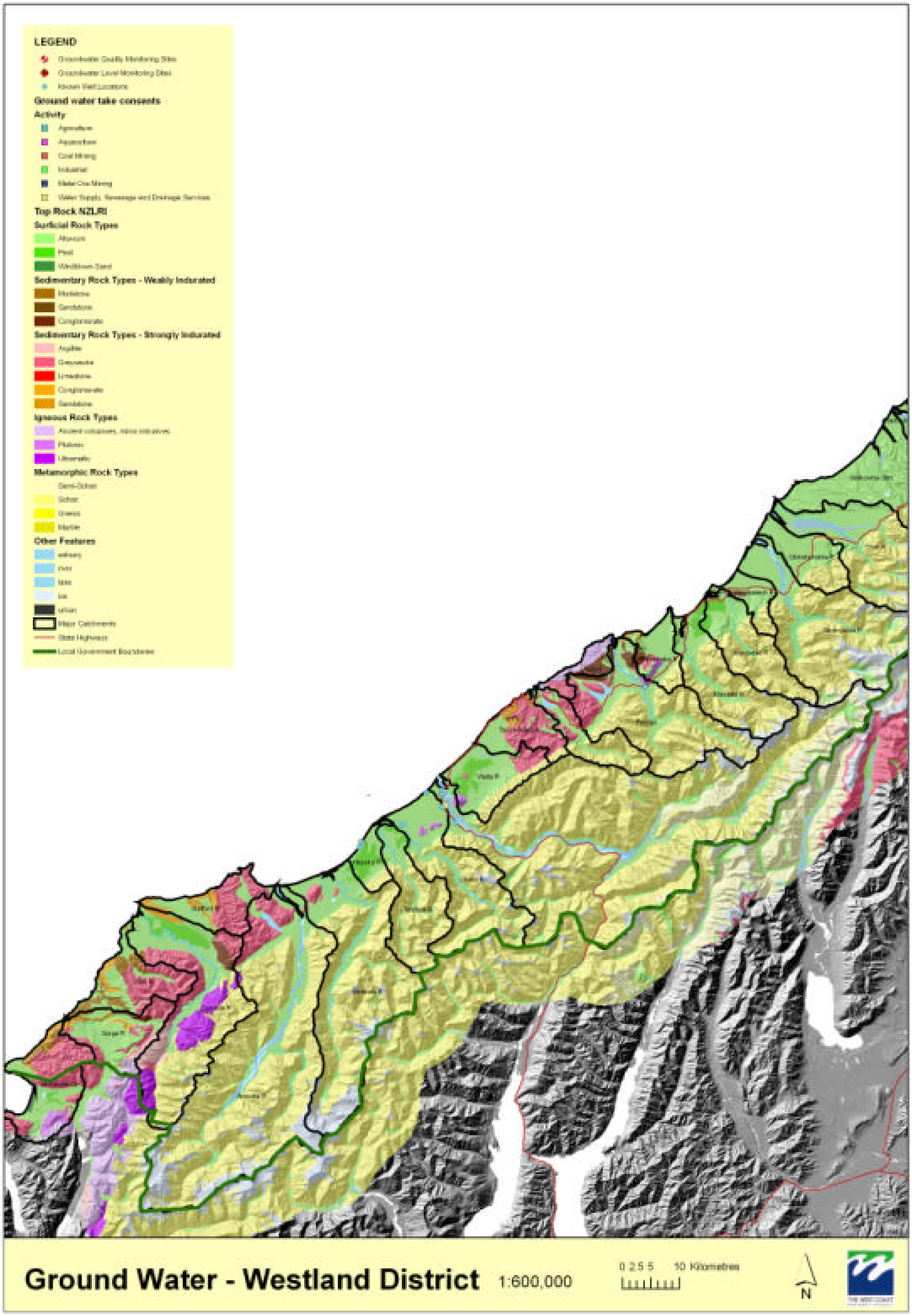


Figure 3. Westland district wells.

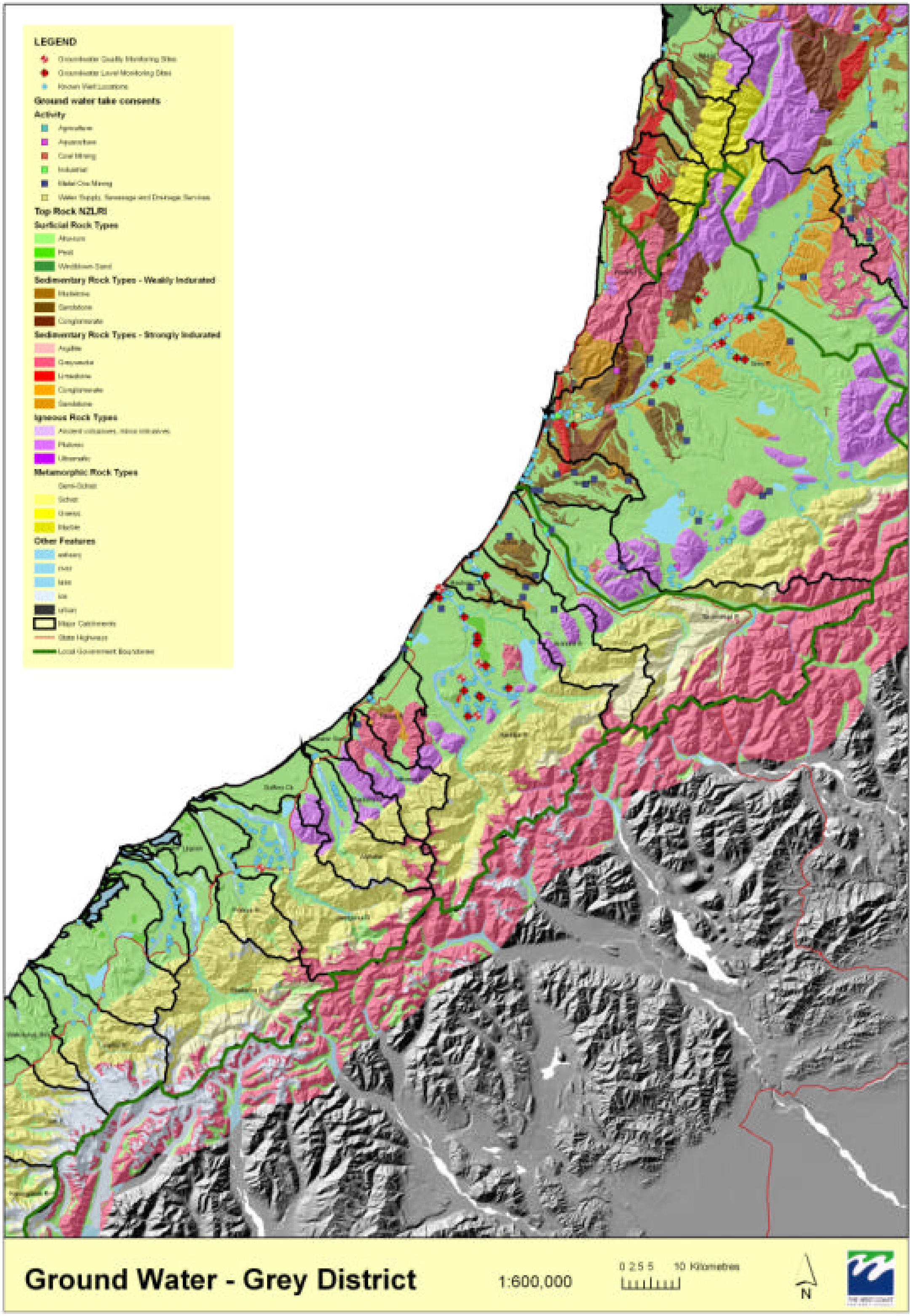


Figure 4. Grey district wells.

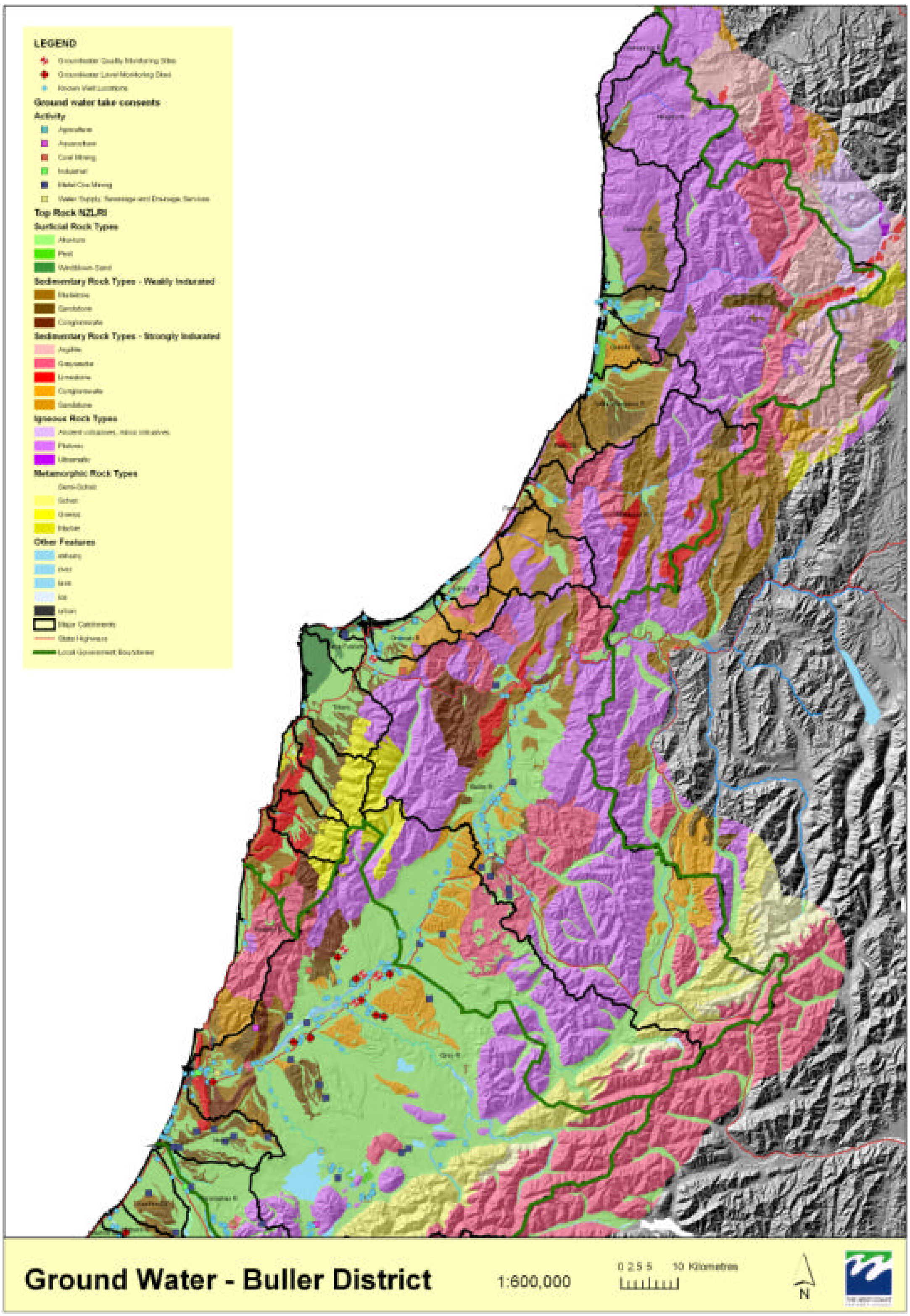


Figure 5. Buller district wells.

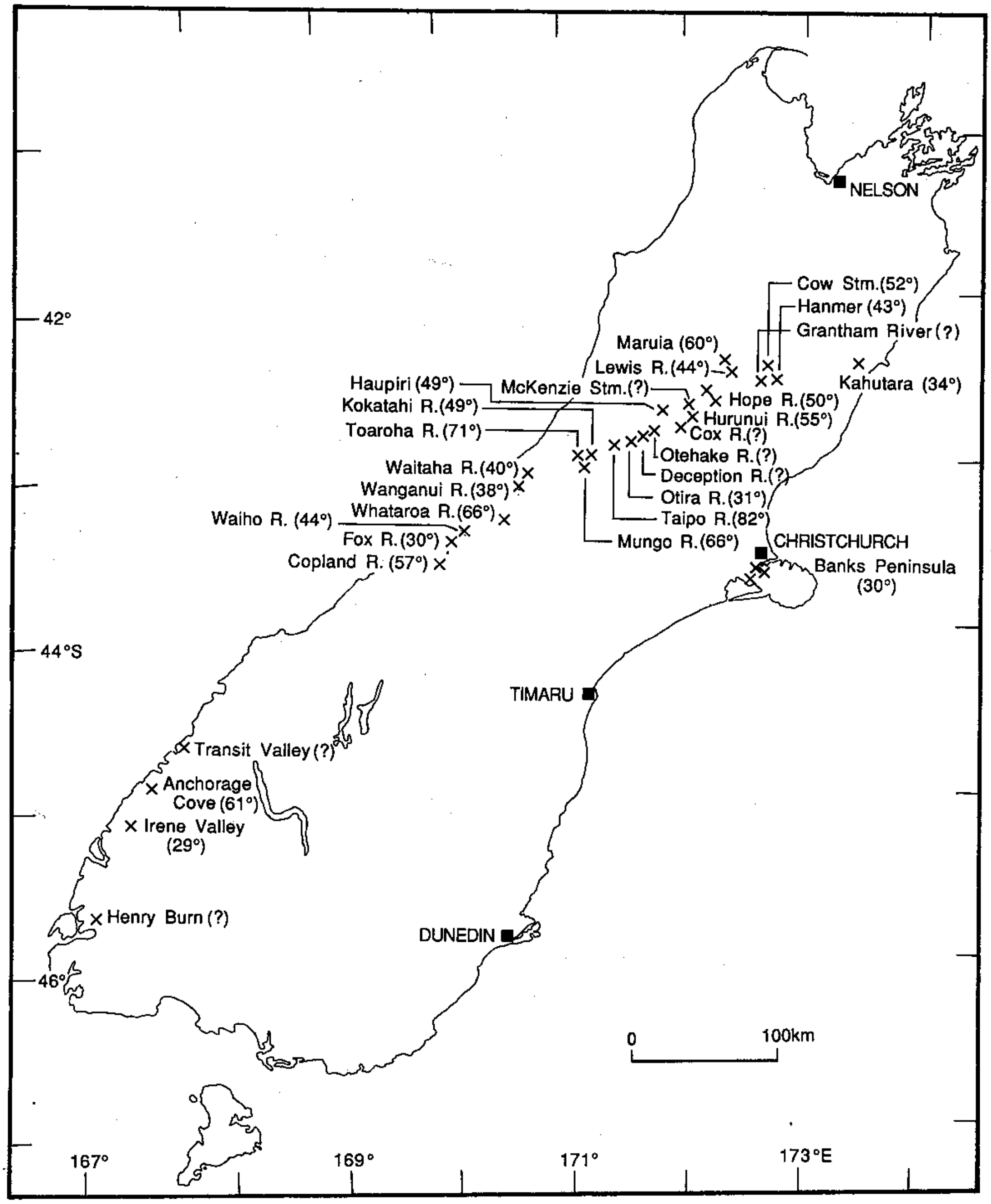


Figure 6. South Island low temperature geothermal springs (from Mosley, 1992).

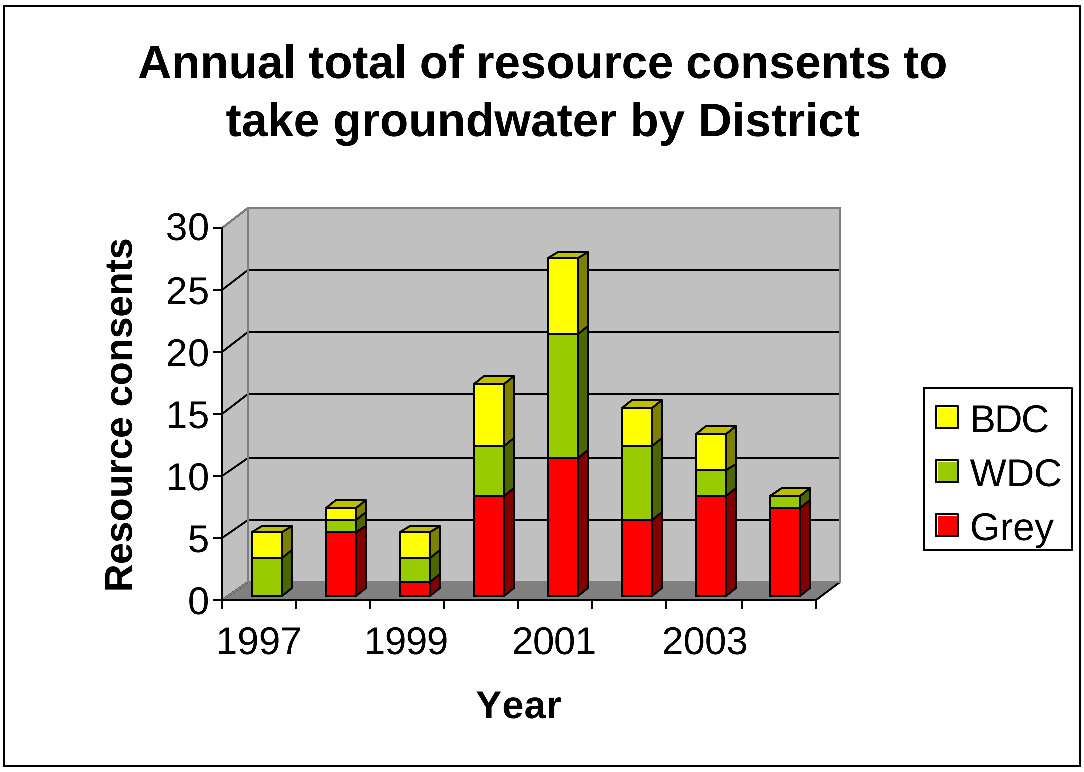


Figure 7. Groundwater resource consents issued 1997-2004.

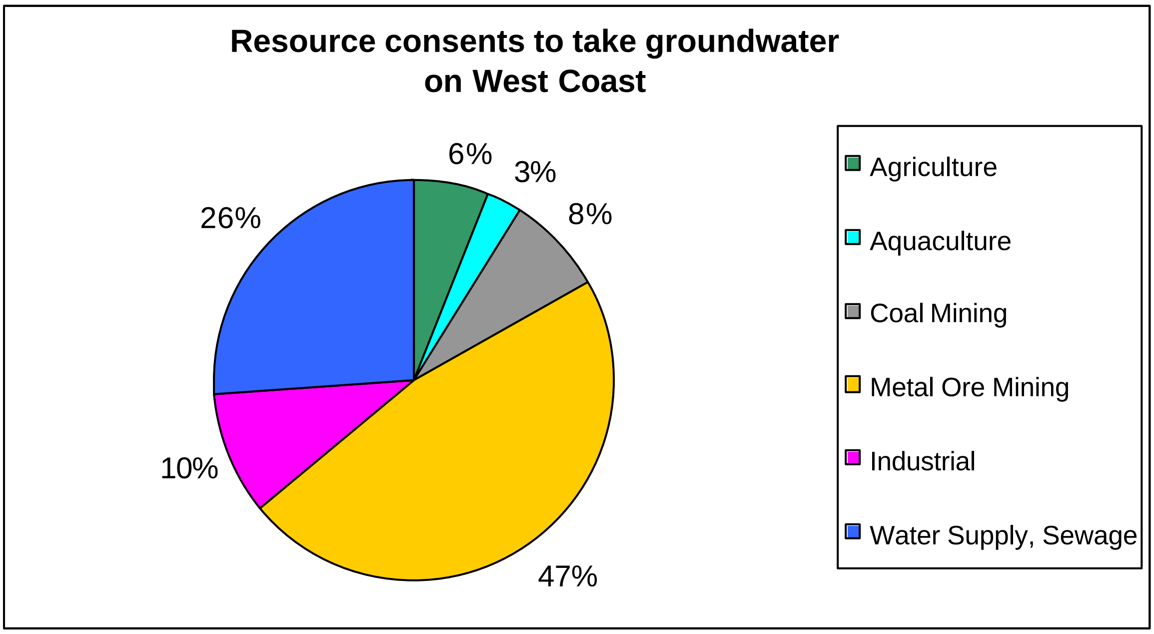


Figure 8. West Coast Region groundwater resource consents by activity.

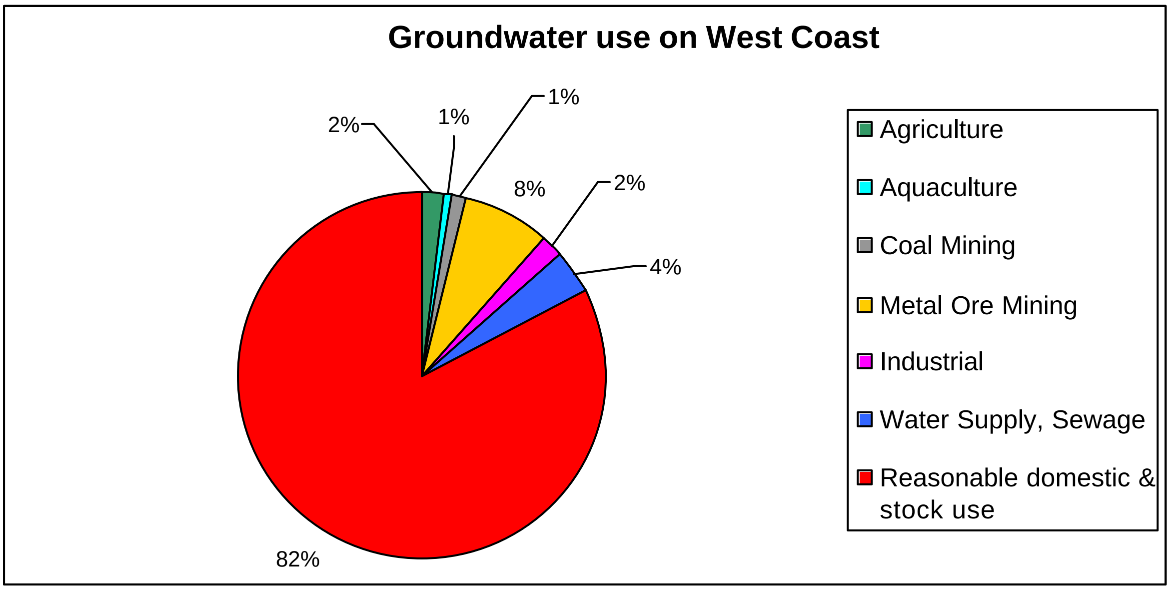


Figure 9. West Coast Region groundwater use.

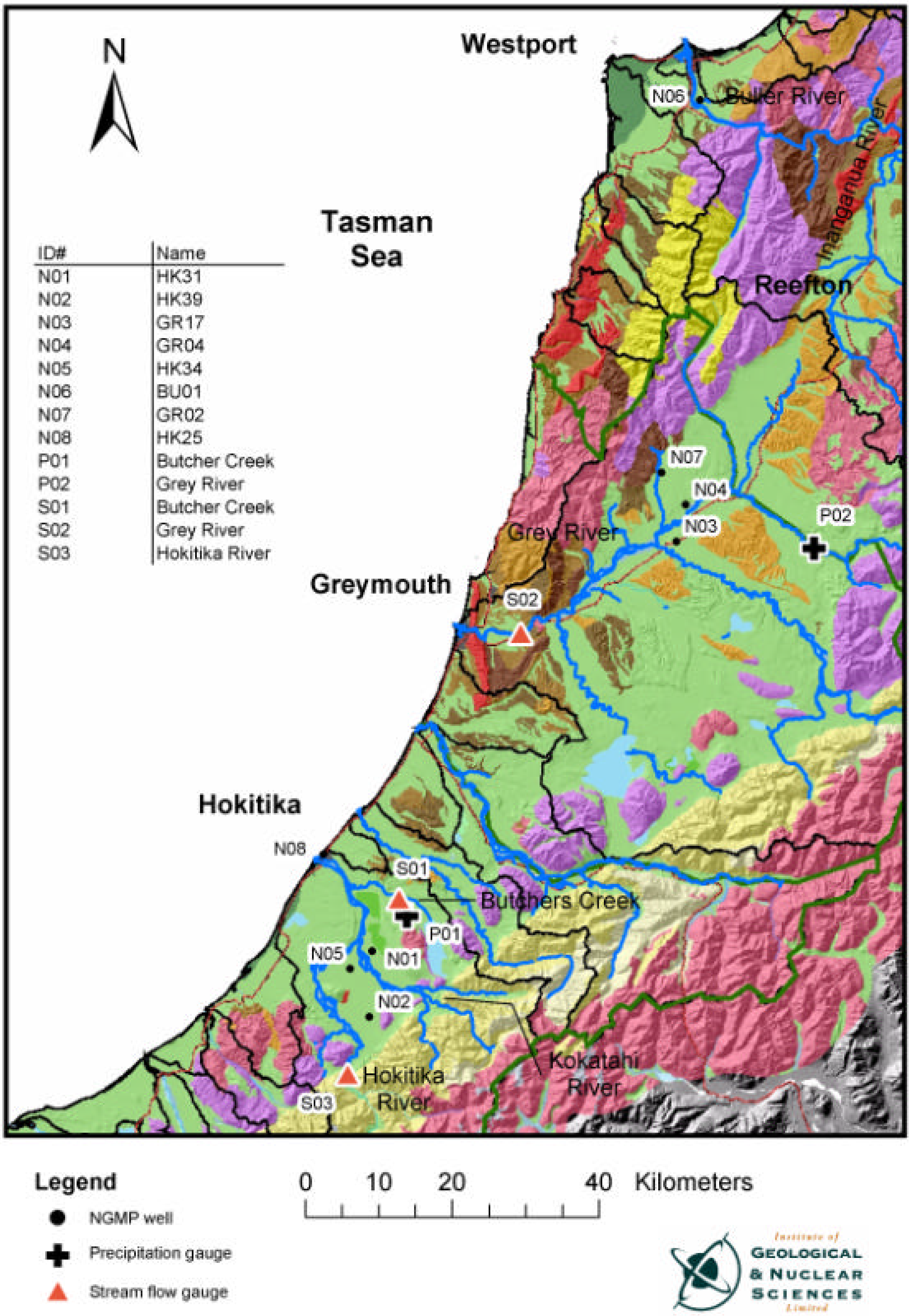


Figure 10. West Coast Region NGMP well locations.

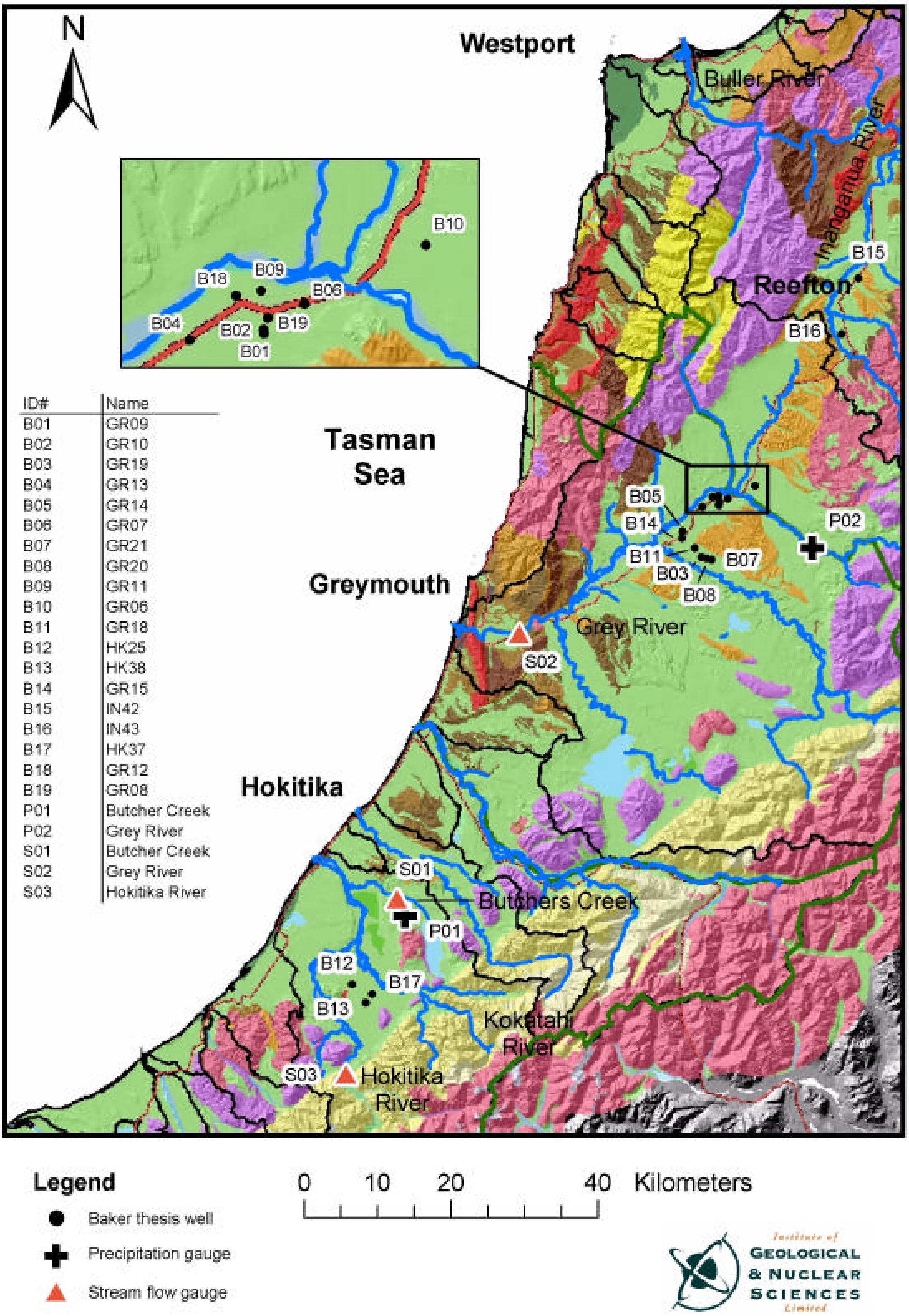


Figure 11. Baker (2004) well locations.

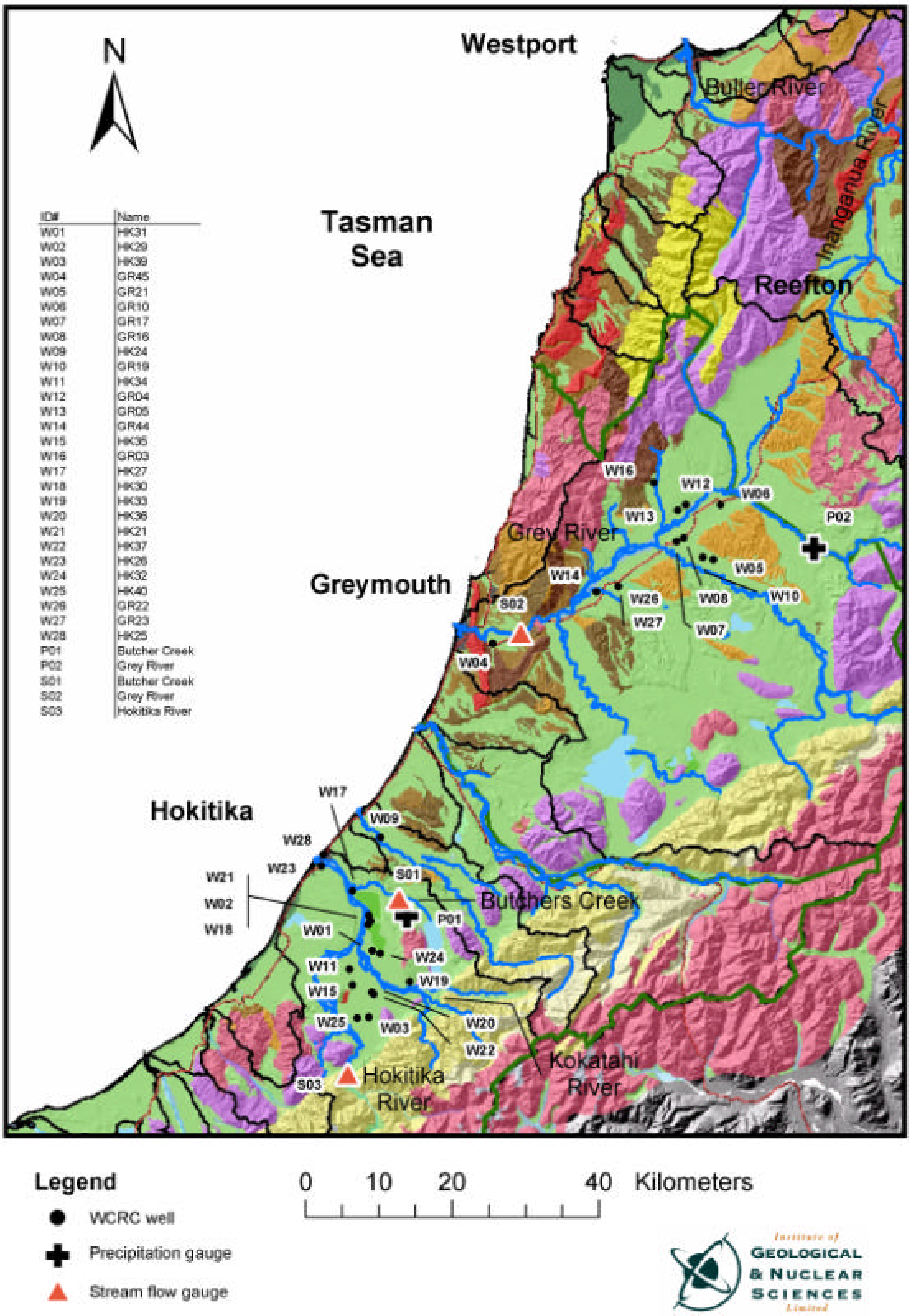


Figure 12. WCRC well locations.

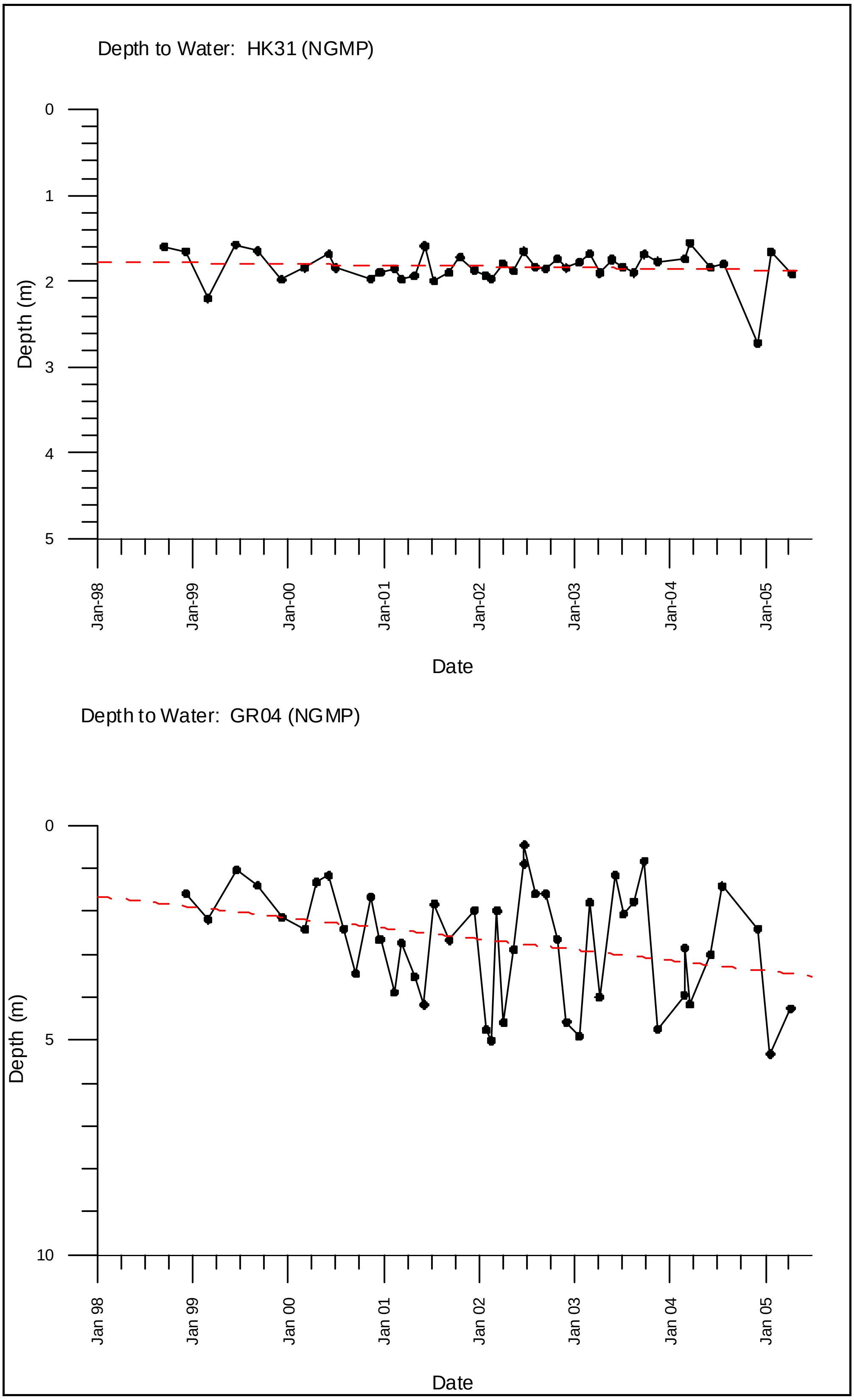


Figure 13. Examples of well water level hydrographs.

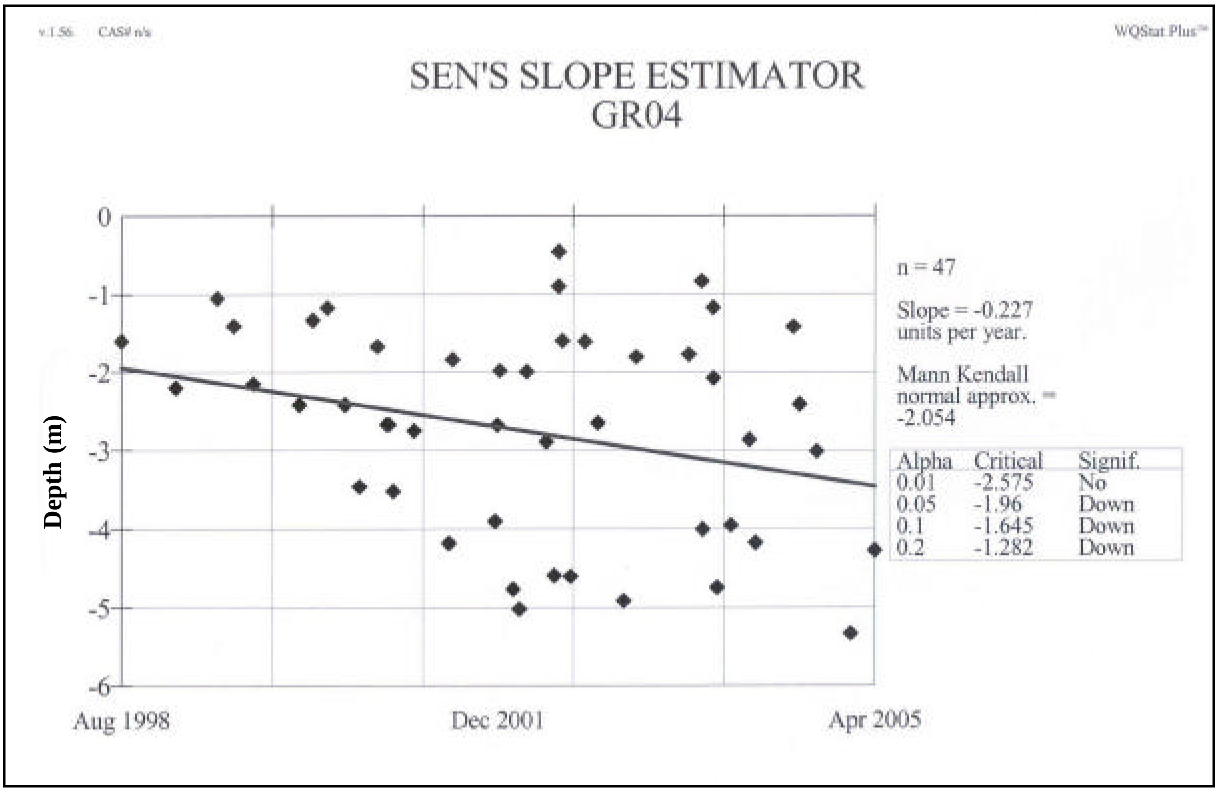


Figure 14. GR04 water level data Sen's Slope Estimator Plot.

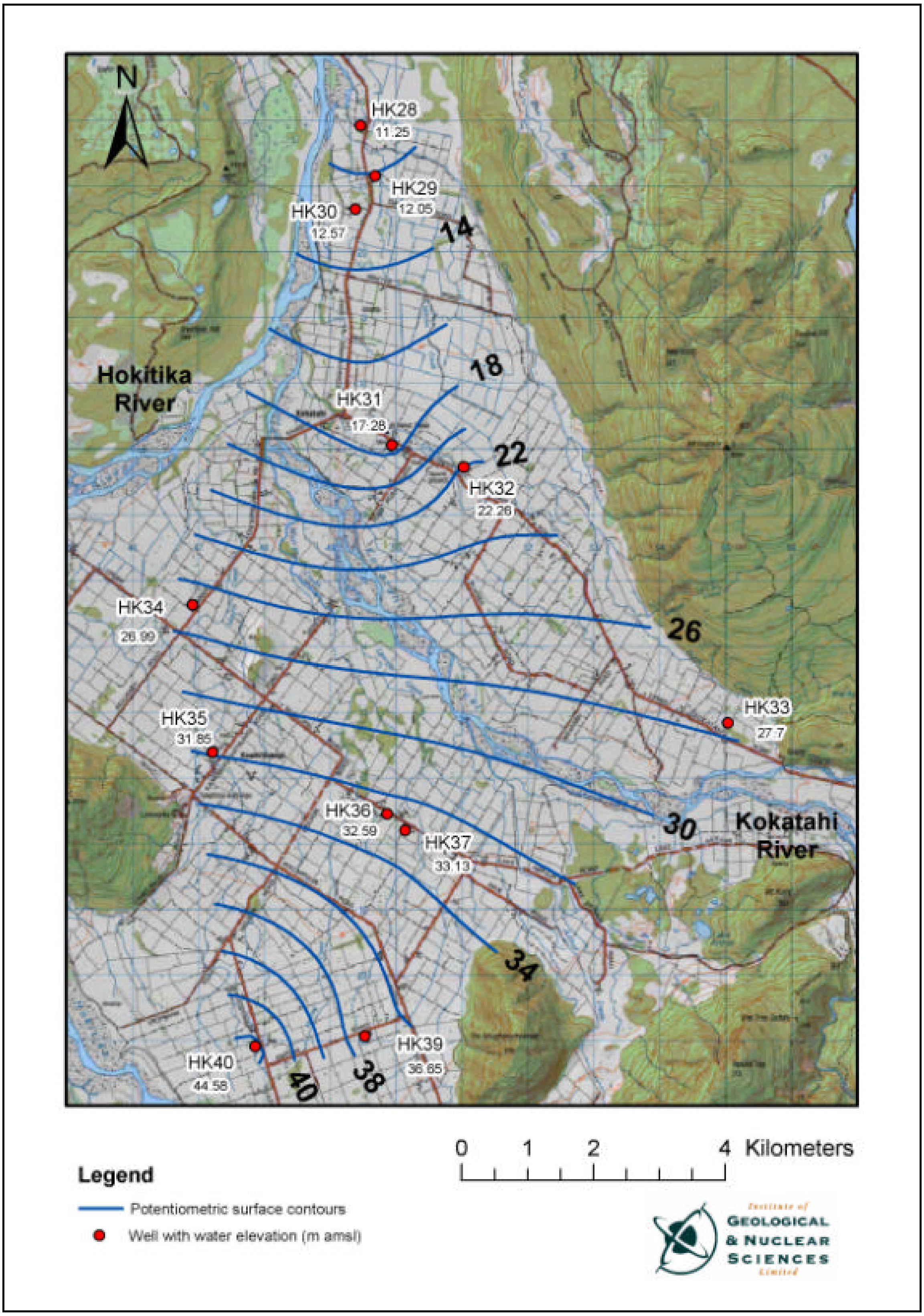


Figure 15. Potentiometric surface - Hokitika River (December 2004 data).

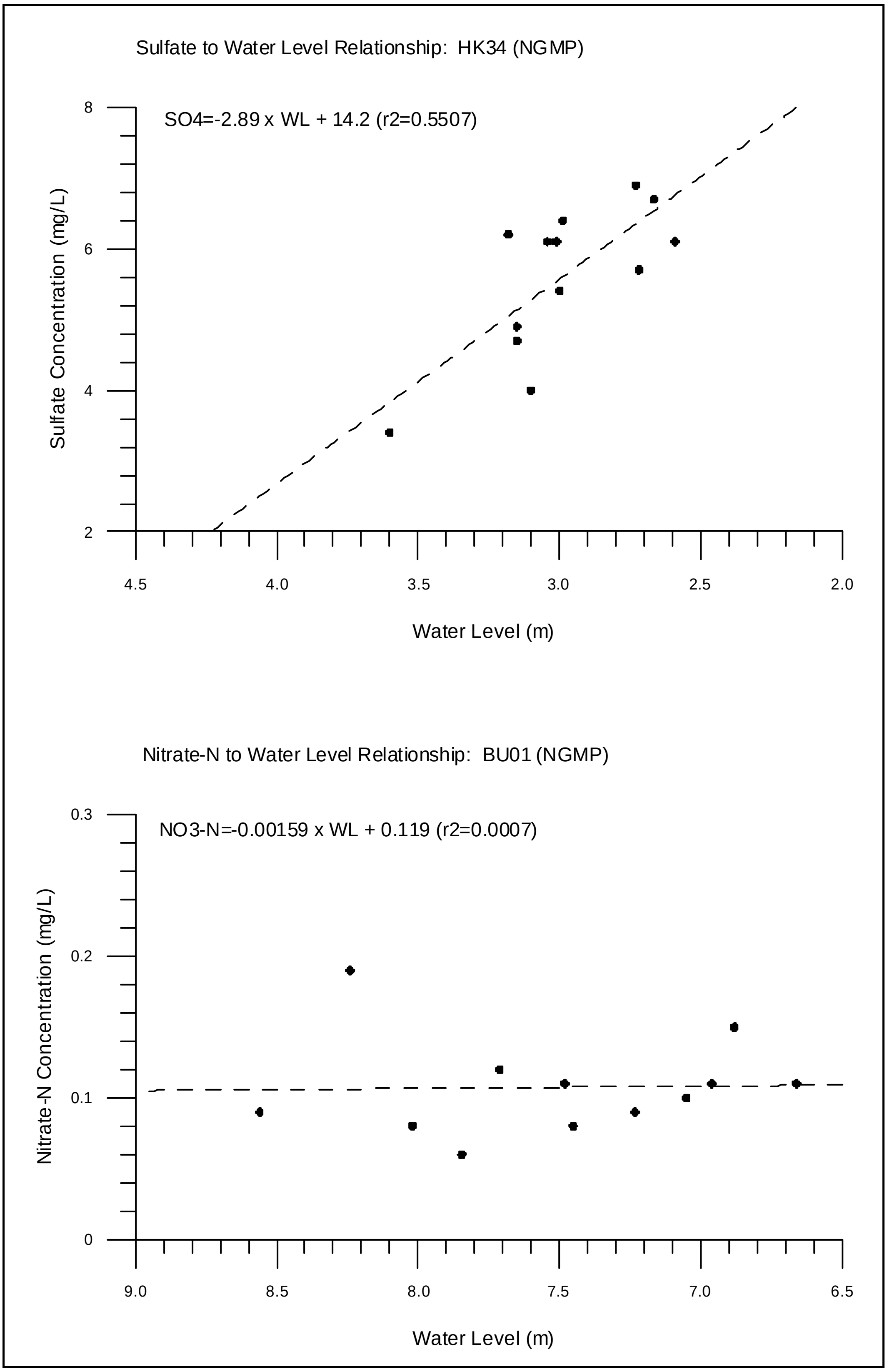


Figure 16. Water level and quality relationships.

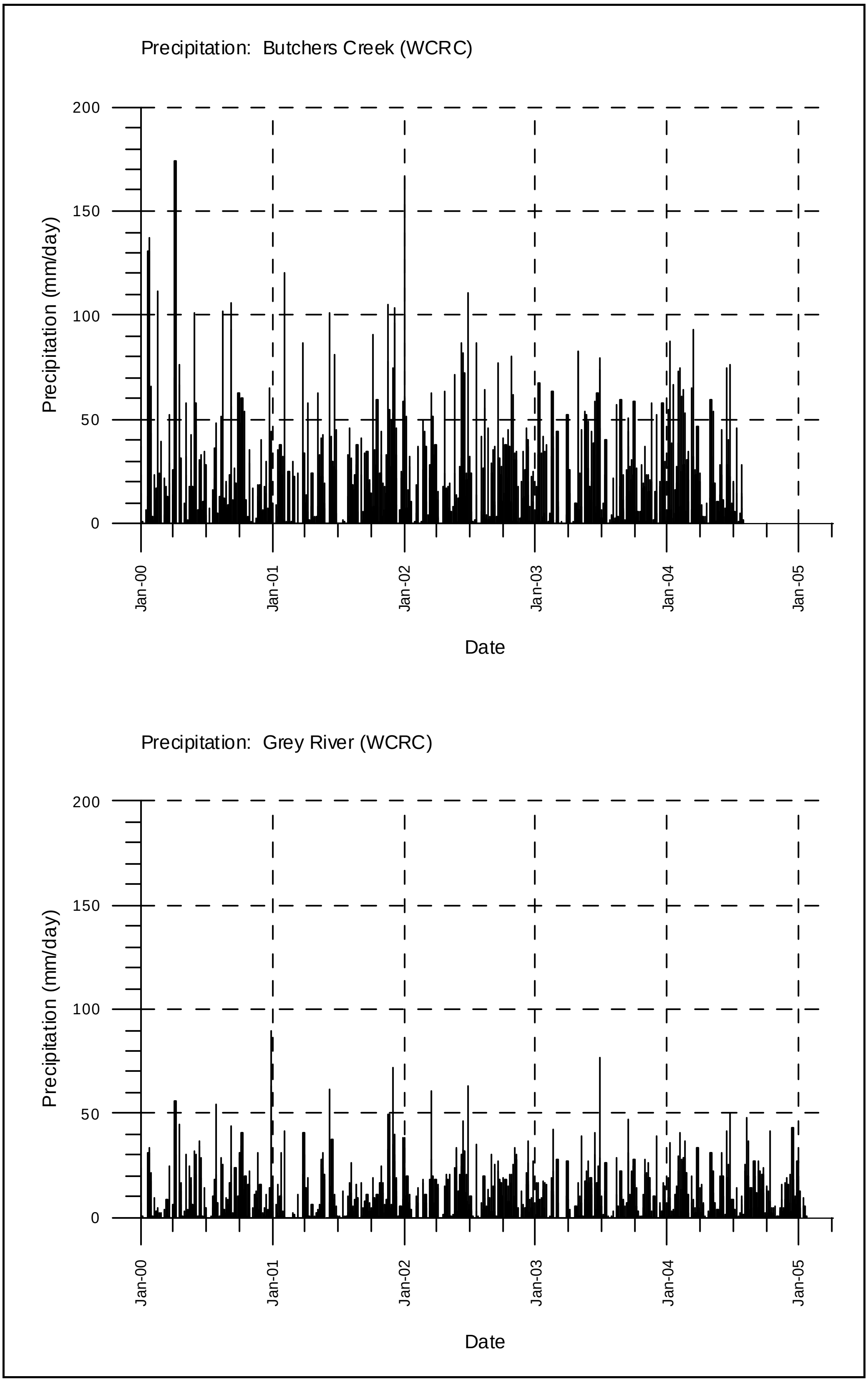


Figure 17. Precipitation gage data plots.

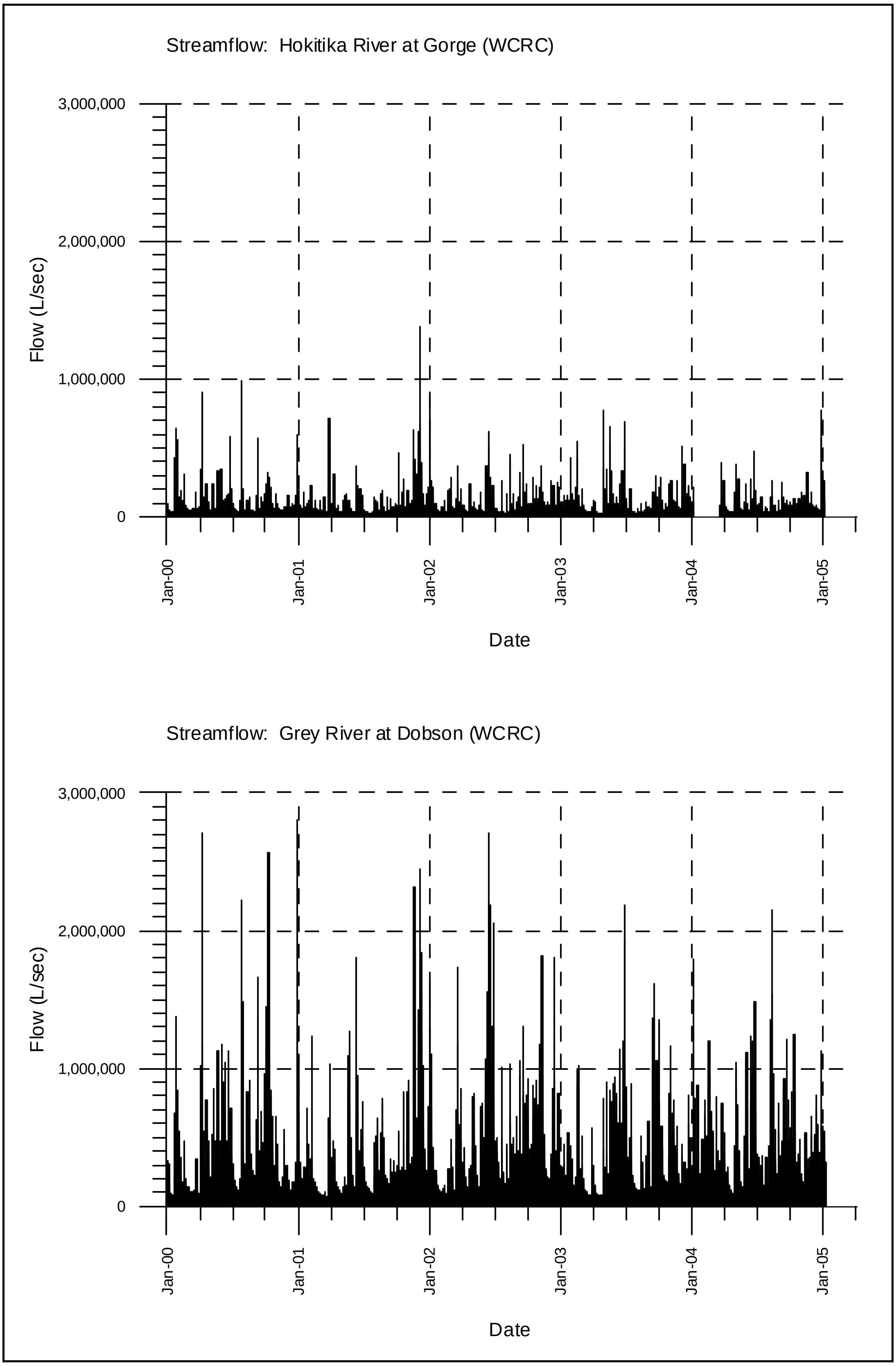


Figure 18. Streamflow gage data plots.

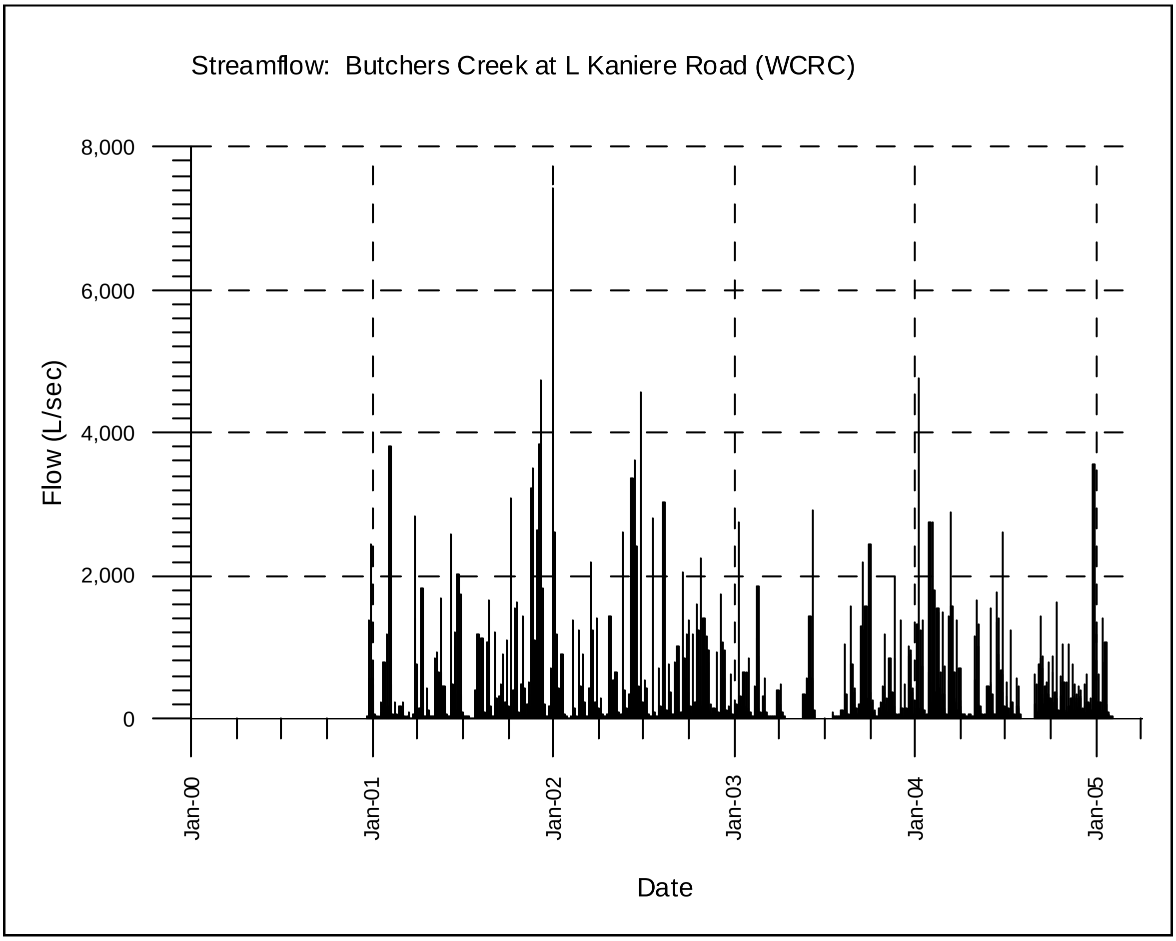


Figure 18 continued. Streamflow gage data plots.

Table 1. West Coast Region well and gage location data.

		Well[1]	Location[2] Area	Drainage	Altitude[3] (m)	Coordinates[4] Easting	Northing	Map Ref[4]	Site ID[5]	UC/C[6]	Multi-Listed[7]
NGMP Wells											
	01	HK31	Kokatahi	Hokitika R.	20	2349941	5817046	J33:499171	170	-	WCRC
	02	HK39	Kowhitirangi	Hokitika R.	45	2349530	5808062	J33:496080	1038	-	WCRC
	03	GR17	Ahaura	Up. Grey R.	110	2391364	5872750	K31:909736	174	-	WCRC
	04	GR04	Ararau	Up. Grey R.	75	2392648	5877766	K31:910765	186	-	WCRC
	05	HK34	Kowhitirangi	Hokitika R.	30	2346916	5814612	J33:468146	178	-	WCRC
	06	BU01	Orowaiti	Buller R.	10	2394615	5932928	K29:945330	189	-	-
	07	GR02	Slaty Ck.	Up. Grey R.	142	2389380	5882150	K31:894822	1309	-	-
	08	HK25	Hokitika	Hokitika R.	15	2343256	5830228	J33:432303	21	Conf.	WCRC
WCRC Precipitation Gages											
	01	Butcher @ Butchers Gully				2354670	5821800	J33:547218			
	02	Grey River @ Waipuna				2410160	5871830	L31:102718			
WCRC Streamflow Gages											
	01	Butcher Creek @ Lake Kaniere				2353570	5824100	J33:536241			
	02	Grey River @ Dobson				2370140	5860170	K31:701602			
	03	Hokitika River @ Gorge				2346570	5800210	J33:466002			

		Well[1]	Location[2]		Altitude[3]	Coordinates[4]		Map Ref[4]	Site ID[5]	UC/C[6]	Multi-Listed[7]
			Area	Drainage	(m)	Easting	Northing				
WCRC Wells											
	01	HK31	Kokatahi	Hokitika R.	20	2349900	5817100	J33:499171	170	-	NGMP
	02	HK29	Kowhitirangi	Hokitika R.	15	2349688	5821140	J33:496211	1035	-	-
	03	HK39	Kowhitirangi	Hokitika R.	45	2349500	5808000	J33:495080	1038	-	NGMP
	04	GR45	Kaiata	L. Grey R.	20	2366330	5858877	J32:663588	1049	Conf.	-
	05	GR21	Ahaura	Up. Grey R.	140	2396401	5870311	K31:964703	1046	-	-
	06	GR10	Totara Flat	Up. Grey R.	90	2397402	5877775	K31:974777	1050	UnConf.	-
	07	GR17	Ahaura	Up. Grey R.	110	2391380	5872765	K31:913727	174	-	NGMP
	08	GR16	Ahaura	Up. Grey R.	110	2392354	5873230	K31:923732	1045	-	-
	09	HK24	Arahura	Arahura R.	15	2351058	5832509	J32:510325	1032	Conf.	-
	10	GR19	Ahaura	Up. Grey R.	135	2394999	5870640	K31:949706	1047	-	-
	11	HK34	Kowhitirangi	Hokitika R.	30	2346800	5814600	J33:468146	178	-	NGMP
	12	GR04	Atarau	Up. Grey R.	75	2392653	5877771	K31:926777	186	-	NGMP
	13	GR05	Atarau	Up. Grey R.	75	2391521	5876996	K31:915769	1044	Conf.	-
	14	GR44	Ngahere	Up. Grey R.	52	2380464	5865936	K31:804659	1048	-	-
	15	HK35	Kowhitirangi	Hokitika R.	35	2347221	5812381	J33:472123	1042	-	-
	16	GR03	Slaty Ck.	Up. Grey R.	110	2388256	5880769	K31:882807	175	Conf.	-
	17	HK27	Kaniere	Hokitika R.	15	2347238	5825217	J33:472252	1033	Conf.	-
	18	HK30	Kowhitirangi	Hokitika R.	15	2349390	5820630	J33:493206	1036	-	-
	19	HK33	Kokatahi	Hokitika R.	35	2355032	5812823	J33:550128	1079	-	-
	20	HK36	Kowhitirangi	Hokitika R.	35	2349870	5811438	J33:498114	1039	-	-
	21	HK28	Kowhitirangi	Hokitika R.	15	2349465	5821906	J33:494219	1034	-	-
	22	HK37	Kowhitirangi	Hokitika R.	35	2350144	5811190	J33:501111	1040	-	-
	23	HK26	Hokitika	Hokitika R.	15	2342954	5828603	J33:429286	1043	UnConf.	-
	24	HK32	Kokatahi	Hokitika R.	25	2351028	5816712	J33:510167	1037	-	-
	25	HK40	Kowhitirangi	Hokitika R.	50	2347868	5807906	J33:478079	1041	-	-
	26	GR22	Ngahere	Up. Grey R.	60	2383452	5866655	K31:834666	1056	Conf.	-
	27	GR23	Ngahere	Up. Grey R.	60	2383449	5866641	K31:834666	1057	-	-

Well[1]			Location[2]		Altitude[3]	Coordinates[4]					Multi-
			Area	Drainage	(m)	Easting	Northing	Map Ref[4]	Site ID[5]	UC/C[6]	Listed[7]
Baker's Thesis Wells											
	01	GR09	Totara Flat	Up. Grey R.	90	2397408	5877655	K31:974777	-	-	-
	02	GR10	Totara Flat	Up. Grey R.	90	2397401	5877776	K31:974778	-	-	WCRC
	03	GR19	Ahaura	Up. Grey R.	135	2395000	5870633	K31:950706	-	-	WCRC
	04	GR13	Totara Flat	Up. Grey R.	79	2395137	5877463	K31:951775	-	-	-
	05	GR14	Ahaura	Up. Grey R.	105	2392464	5874087	K31:925741	-	-	-
	06	GR07	Totara Flat	Up. Grey R.	90	2398650	5878560	K31:987786	-	-	-
	07	GR21	Ahaura	Up. Grey R.	137	2396399	5870303	K31:964703	-	-	WCRC
	08	GR20	Ahaura	Up. Grey R.	133	2395739	5870474	K31:957705	-	-	-
	09	GR11	Totara Flat	Up. Grey R.	87	2397329	5878964	K31:973790	-	-	-
	10	GR06	Ikamatua	Up. Grey R.	135	2402350	5880350	K31:024804	-	-	-
	11	GR18	Ahaura	Up. Grey R.	121	2394116	5871818	K31:941718	-	-	-
	12	HK35	Kowhitirangi	Hokitika R.	35	2347427	5812471	J33:474125	-	-	WCRC
	13	HK38	Kowhitirangi	Hokitika R.	39	2349265	5809973	J33:493100	-	-	-
	14	GR15	Ahaura	Up. Grey R.	110	2392434	5873195	K31:924732	-	-	-
	15	IN42	Cronadun	Inangahua R.	125	2416473	5908630	L30:165086	-	-	-
	16	IN43	Reefton	Inangahua R.	180	2414111	5900980	L30:141010	-	-	-
	17	HK37	Kowhitirangi	Hokitika R.	37	2350144	5811190	J33: 501112	-	-	WCRC
	18	GR12	Totara Flat	Up. Grey R.	84	2396555	5878802	K31:966788	-	-	-

1. *Well data provided by GNS for National Groundwater Monitoring Program (NGMP) wells, WCRC for WCRC wells, and T. Baker for Baker's Thesis wells.*
2. *Area means closest identified area on topographic map. Drainage means stream drainage involved.*
3. *Altitude means approximate ground level at well head in metres above sea level. Altitudes for NGMP and WCRC wells estimated by WCRC from 1:50,000 topo-graphic maps. Altitudes for Baker's Thesis wells estimated from 1:50,000 topographic maps by GNS.*
4. *Coordinates and map references provided by GNS for NGMP wells. Coordinates and map references provided by WCRC for WCRC wells. Coordinates but no map references and in one case a map reference but no coordinates provided by for Baker's Thesis wells by T. Baker. Coordinates or map references for these wells calculated by GNS as appropriate.*
5. *Site ID numbers provided by WCRC.*
6. *Nature of aquifer, that is unconfined (U/C or UnConf.) or confined (C or Conf.), provided by WCRC for those wells where such information is available.*
7. *Some NGMP wells were also listed as WCRC wells and some WCRC wells were also listed as Baker's Thesis wells. These are indicated as multi-listings.*

Table 2. West Coast Region NGMP and Baker (2004) well information.

Well		Use: Type	Use: Frequency	Distance (m)	WH[3] Protection	TD[3] (m)	Casing[3] (mm)	Screen Lithology	Setting
NGMP Wells[1]:									
1	HK31	Domestic	Daily	200	Poor	3	100	-	Septic tanks within 200 m, dairy farm area
2	HK39	Dairy shed	Daily	4	Very poor	~7-10	100	-	DSH disposed of nearby
3	GR17	Dairy shed	Daily	500	Good	37	200	S&G	Upgradient of dairy shed
4	GR04	Dairy shed	Daily	200	Good	5	200	Gravel	Dairy farming and septic tank
5	HK34	Dairy shed	Daily	100	Poor	24	140	S&G	DSE unlined oxidation ponds ~100 m south
6	BU01	Dairy shed	Daily	1	Poor	~7-10	100	-	Downgradient of dairy farm areas and shed
7	GR02	-	-	-	-	-	-	-	-
8	HK25	Commercial water supply	Daily	-	Good	13	200	S&G	Urban
Baker (2004) Wells[2]:									
1	GR09	Stock, domestic, dairy shed	Daily	150	Good	8	250	Gravel	Surrounded by dairy farms, upgradient ponds
2	GR10	Stock, dairy shed	Daily	80	Light cover	7	250	-	Contaminated by DSE
3	GR19	Stock, domestic, dairy shed	Daily	200	Adequate	48	250	-	Upgradient DSE land application
4	GR13	Domestic	Daily	1000	Poor	5	300	-	Upgradient dairy farms, grazing stock at WH
5	GR14	Stock, dairy shed	Daily	50	Poor	12	150	-	-
6	GR07	Stock, dairy shed	Daily	80	Adequate	6	250	Gravel	Pond
7	GR21	Stock, domestic, dairy shed	Daily	100	Adequate	30	200	-	Upgradient DSE land application
8	GR20	Domestic	Monthly	1000	Adequate	30	200	-	Offal pit within 5 m and debris at WH
9	GR11	Stock, domestic, dairy shed	Daily	100	Adequate	6	250	-	Chemicals near WH
10	GR06	Stock, domestic, dairy shed	Daily	120	Good	33	150	-	Upgradient DSE land application
11	GR18	Stock, domestic, dairy shed	Daily	300	Adequate	26.2	200	-	Upgradient dairy farms
12	HK35	Domestic	Seldom	1100	Good	12.5	200	-	Surrounded by dairy farms
13	HK38	Stock, domestic, dairy shed	Daily	500	Poor	10	300	Gravel	Upgradient DSE land application
14	GR15	Stock, domestic, dairy shed	Daily	100	Adequate	5.5	100	-	Poor effluent disposal upgradient
15	IN42	Stock, domestic, dairy shed	Daily	50	Poor	10	200	-	Surrounded by dairy farms
16	IN43	Stock, dairy shed	Daily	12	Good	15	100	-	Upgradient DSE land application
17	HK37	Stock, dairy shed	Daily	30	Poor	10	100	-	Ponds close by
18	GR12	Stock, domestic, dairy shed	Daily	4	Poor	7	200	-	Effluent filled drained near WH

1. *Information from GNS Client Report 2004/156.*
2. *Information from Baker (2004).*
3. *WH means Wellhead, TD means total depth of well, and Casing means nominal casing diameter.*

Table 3. WCRC data water level statistics.

Well Identification		Water Levels (m)[2]							Outliers[4]				Trend[5]	
		Min	Median	Mean	Max	Stdev	Count	Seasonality[3]	Date	Dir	Date	Dir	m/year	Alpha
NGMP														
1	HK31	1.55	1.84	1.83	2.72	0.19	45	Yes	Dec-04	Lo	-	-	No	-
2	HK39	1.71	8.16	7.86	9.19	1.20	47	No	Feb-02	Hi	-	-	No	-
3	GR17	Insuf	Insuf	Insuf	Insuf	Insuf	Insuf	Insuf	Insuf	-	-	-	Insuf	-
4	GR04	0.46	2.42	2.70	5.33	1.31	47	No	Jun-02	Hi	-	-	-0.227	0.05
5	HK34	2.10	3.01	2.97	3.60	0.23	47	No	Jul-03	Hi	-	-	0.045	0.01
6	BU01	2.97	7.34	7.17	8.56	1.28	47	Insuf	Mar-02	Hi	-	-	No	-
7	GR02	4.48	Insuf	Insuf	7.00	Insuf	Insuf	Insuf	Insuf	-	-	-	Insuf	-
8	HK25	0.72	2.44	2.42	3.39	0.34	46	No	Dec-04	Hi	-	-	No	-
WCRC														
1	HK29	1.62	3.00	2.98	3.96	0.41	46	No	Jun-02	Hi	-	-	No	
2	GR45	2.47	2.90	2.90	3.57	0.25	16	No	No	-	-	-	0.111	0.01
3	GR21	4.68	11.69	11.48	17.00	3.14	16	Insuf	Insuf	-	-	-	Insuf	-
4	GR10	1.41	2.67	2.57	3.03	0.39	45	Yes	Jun-02	Hi	-	-	No	-
5	GR16	3.89	6.23	6.00	6.74	0.66	45	Yes	Jun-02	Hi	-	-	No	-
6	HK24	2.47	3.48	3.49	4.08	0.40	37	No	No	-	-	-	0.099	0.05
7	GR19	7.04	12.80	12.38	19.00	2.92	37	Insuf	Insuf	-	-	-	Insuf	-
8	GR05	0.40	1.38	1.39	3.11	0.56	34	No	Jun-02	Hi	-	-	No	-
9	GR44	1.30	1.93	1.84	1.99	0.18	34	No	Feb-03	Hi	-	-	-0.090	0.05
10	HK35	2.88	3.51	3.43	4.08	0.31	36	No	No	-	-	-	No	-
11	GR03	1.78	4.02	4.05	7.36	1.20	29	No	No	-	-	-	No	-
12	HK27	2.69	3.32	3.27	3.93	0.31	33	No	No	-	-	-	No	-
13	HK30	2.00	2.53	2.52	2.94	0.25	33	No	No	-	-	-	No	-
14	HK33	3.54	7.06	6.96	8.48	0.74	32	No	Apr-02	Hi	-	-	No	-
15	HK36	1.27	2.07	2.08	2.87	0.25	32	No	Sep-03	Hi	-	-	No	-
16	HK28	1.78	3.83	3.75	4.34	0.42	37	No	Nov-03	Hi	-	-	No	-
17	HK37	1.56	1.87	1.85	2.20	0.13	37	No	No	-	-	-	No	-
18	HK26	3.50	4.43	4.40	5.49	0.30	36	No	Feb-02	Lo	Mar-03	Hi	No	-
19	HK32	1.95	3.06	3.04	4.32	0.37	21	No	Mar-04	Hi	Jul-04	Hi	No	-
20	HK40	3.82	5.83	5.68	6.94	0.64	37	No	Dec-01	Hi	-	-	No	-
21	GR22	1.72	3.21	3.25	4.32	0.46	37	No	Jun-02	Hi	-	-	No	-
22	GR23	1.28	3.10	3.08	4.05	0.52	15	No	Sep-03	Hi	-	-	No	-

1. *"Insuf" means insufficient data for calculation. In the cases of GR17 (NGMP) and GR21 and GR19 (WCRC) this was because the water level was below the measurement capability on a substantial number of occasions. In the case ofGR02, there were only three data points starting in 2003.*
2. *Data used were water levels as reported by the WCRC. These data are below the top of casing measurement reference point which is reportedly within 10 centimetres of ground level. Values calcul ated by Excel spreadsheet computer software. Seasonality, outliers, and trend calculated by WQStat+ computer software.*
3. *Seaonality calculated using the nonparametric Kruskal-Wallis test at the alpha=0.05 significance level.*
4. *Outliers determined by calculation of the outlier test statistic using log-transformed data and a 0.05 significance level for the critical value. In most cases where there was an outlier there was only one for the data set. The HK26 and HK32 wells were exceptions to this rule. The time frame (date) when the outlier was reported and its direction from the data set (i.e., low for a depth lower than the data set and high for a shallower depth).*
5. *Trend determined using the nonparametric Mann/Kendall test (at either the 0.05 or 0.01 significance levels) and the Sen's slope estimator to determine the median slope. Positive trend indicates increasing water table (i.e., decreasing water level depth below top of well casing).*

Table 4. Relationship of WCRC water level data to water quality data.

	Well	Chloride			Nitrate-Nitrogen			Sulfate		
		Coeff Det[1]	Slope[2]	Direction[3]	Coeff Det[1]	Slope[2]	Direction[3]	Coeff Det[1]	Slope[2]	Direction[3]
1	HK31	0.0370	- 0.786	Down	0.3433	- 1.06	Down	0.3034	- 2.31	Down
2	GR04	0.0498	1.38	Up	0.0264	- 0.102	Down	0.0085	- 0.0506	Down
3	HK34	0.2479	- 0.902	Down	0.1870	- 0.46	Down	0.5507	- 2.89	Down
4	BU01	0.0296	0.263	Up	0.0007	- 0.00159	Down	0.2324	- 0.736	Down
5	HK25	0.0732	0.654	Up	0.0273	- 0.0757	Down	0.1425	- 0.836	Down

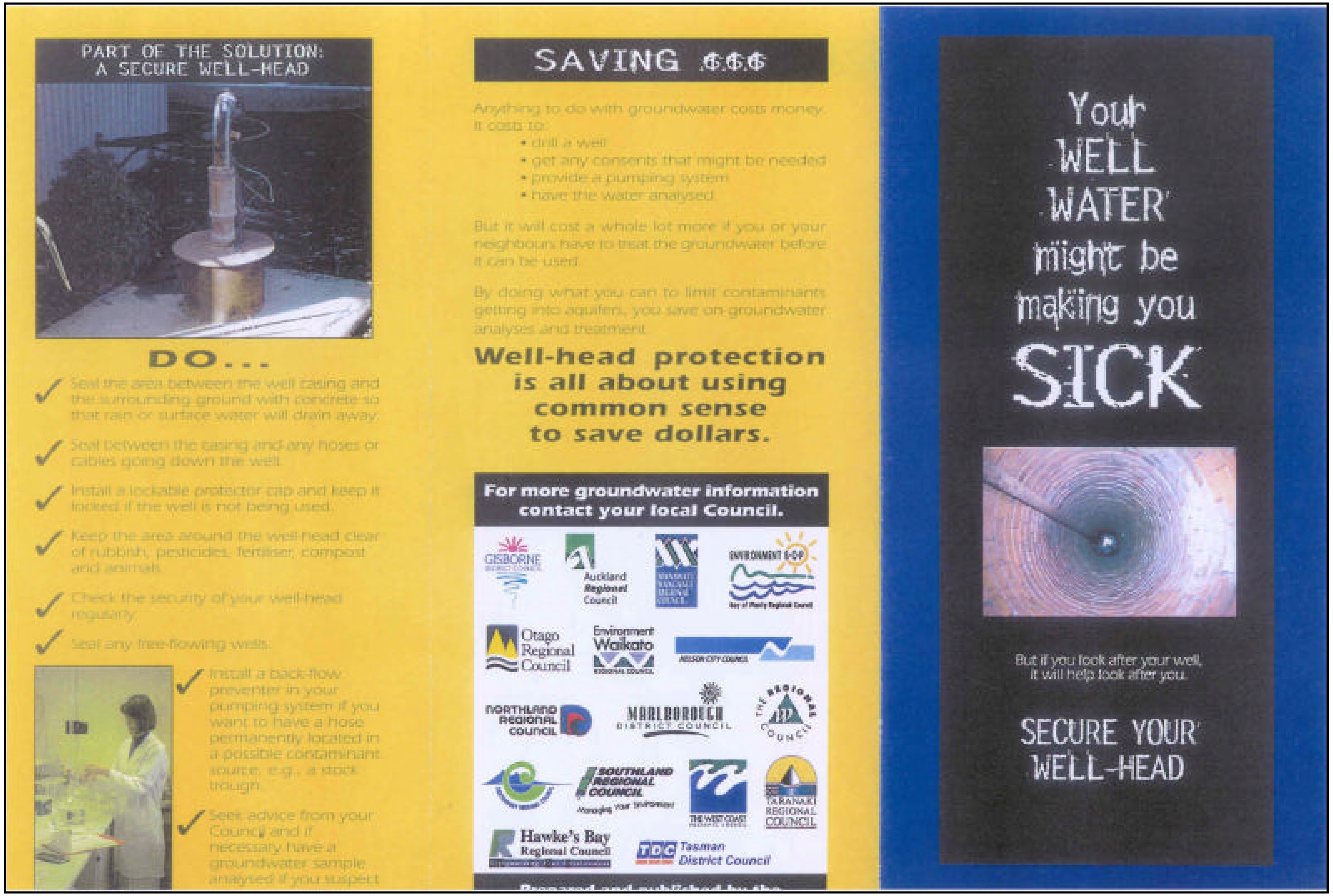
1. *"Coeff Det" means coefficient of determination (r^2) for linear correlation determined by computer program Grapher.*
2. *"Slope" means slope of best fit linear correlation line determined by computer program Grapher. Negative slope means an increasing concentration with decreasing depth below ground of the water table (i.e., the direction is "down" in terms of an increasing depth).*
3. *"Direction" means direction of slope of best fit linear correlation line determined by computer program Grapher. Down means a negative slope in which the magnitude of the variable's concentration increases as water level depth below ground decreases. "Up" means a positive slope in which the magnitude of the variable's concentration increases as water level depth below ground increases.*

Table 5. WCRC precipitation and streamflow data summary/statistics.

Annual Data Summary						
		Precipitation (mm/year)		Streamflow (m^3/year)		
Year	Item	Butchers Creek	Grey River	Butchers Creek	Grey River	Hokitika River
2000	Data	4,059	2,015	565,834	11,318,850,922	3,126,229,085
	Data Points	362	363	10	364	362
	Days No Rain	183	182	-	-	-
2001	Data	3,698	1,656	10,229,414	10,189,872,662	2,958,874,877
	Data Points	364	350	364	365	364
	Days No Rain	187	180	-	-	-
2002	Data	4,005	2,126	11,531,030	13,397,095,440	3,135,435,610
	Data Points	365	361	365	365	365
	Days No Rain	168	173	-	-	-
2003	Data	3,239	1,729	5,984,842	9,977,021,424	2,966,252,227
	Data Points	365	365	292	365	365
	Days No Rain	183	200	-	-	-
2004	Data	2,331	2,080	9,897,293	11,783,337,408	2,120,749,776
	Data Points	217	366	337	364	292
	Days No Rain	93	143	-	-	-
2005	Data	0	39	800,755	356,008,003	152,597,002
	Data Points	0	19	36	12	11
	Days No Rain	-	7	-	-	-

Streamflow Descriptive Statistics (L/sec)					
Category	Min	Median	Mean	Max	Stdev
Butchers Creek	7.	92.	322.	7,428.	597.
Grey River	68,008.	249,300.	359,858.	2,800,110.	336,996.
Hokitika River	20,377.	63,949.	95,201.	1,381,750.	104,566.

Appendix A. Secure your well-head brochure.



PART OF THE SOLUTION:
A SECURE WELL-HEAD

DO...

- Seal the area between the well casing and the surrounding ground with concrete so that rain or surface water will drain away.
- Seal between the casing and any hoses or cables going down the well.
- Install a lockable protector cap and keep it locked if the well is not being used.
- Keep the area around the well-head clear of rubbish, pesticides, fertiliser, compost and animals.
- Check the security of your well-head regularly.
- Seal any free-flowing wells.
- Install a back-flow preventer in your pumping system if you want to have a hose permanently located in a possible contaminant source, e.g., a stock trough.
- Seek advice from your Council and if necessary have a groundwater sample analysed if you suspect

SAVING $$$

Anything to do with groundwater costs money. It costs to:

- drill a well
- get any consents that might be needed
- provide a pumping system
- have the water analysed

But it will cost a whole lot more if you or your neighbours have to treat the groundwater before it can be used.

By doing what you can to limit contaminants getting into aquifers, you save on groundwater analyses and treatment.

Well-head protection is all about using common sense to save dollars.

For more groundwater information contact your local Council.

Your WELL WATER might be making you SICK

But if you look after your well, it will help look after you.

SECURE YOUR WELL-HEAD

THE PROBLEM: GROUNDWATER CONTAMINATION

Would you stir a cup of tea with the same hand that had just mucked out a compost bin? If you are drinking from an unprotected groundwater source, the health effects could be the same.

Groundwater contamination affects human and animal health and can impact on crops and aquatic ecosystems. Protecting your well-head is a basic way to avoid groundwater contamination.

Most people think contaminants move down through the soil and horizontally to an aquifer, where they may be pumped out through a well, but the well itself can be an entry point for nasties.

Contaminants can easily enter unprotected wells.

For example: rain, irrigation and flood waters can pick up bacteria, viruses, and metals, and carry them across the ground and down the sides of well casings. There is no chance for surrounding soil to filter them out, or for them to break down or die off.

Small animals in search of water may fall down large wells and drown. Their carcasses rot and the water is filled with bacteria and viruses. Some people use wells to dispose of rubbish or offal. People can also accidentally contaminate their own well water by back-siphoning contaminants or by dropping things down between pump hoses and well casing. Allowing artesian wells to free-flow increases the risk of contamination by lowering water pressures (and it wastes water).

Contaminants moving down a well can move with the groundwater to be drawn up other wells – all wells need to be protected, whether or not they are in use.

You can reduce the risk of contamination by securing your well-head. It doesn't take much time or money, but it could make all the difference to what you find in your glass of water or cup of tea!

DON'T Leave the water hose in a stock trough, fish pond, or mixing container, otherwise contaminants can be back-siphoned into the well.

DON'T Be fooled into believing that if the groundwater looks clean it is.

DON'T Allow artesian wells to free flow as it increases the risk of contamination by lowering water pressures. It also wastes water.

DON'T Spray weed killers or other chemicals, or store compost, or fertiliser, near your well-head.

DON'T Dump rubbish or offal near or down your well even if the well is no longer used.

DON'T Let surface water run down into the well or down the sides of the well casing.

DON'T Allow grease or petroleum products from pumps or nearby equipment to run down the well casing.

DON'T Allow animals to fall down the well or defecate near it.

DON'T Store or mix chemicals near your well.

#	ID	Name	Date	WL	pH		HCO3	Br	Ca	Cl	F	Fe	Mg	Mn	NH4	NO3	O2	PO4
					Field	Lab												
1	380	HK31	15 Sep 98	1.6	5.94													
	380	HK31	07 Dec 98			6.45	35		9.8	2.5		0.680	0.99	0.0100	<0.010	0.43		
	380	HK31	07 Dec 98	1.65	5.82												5.70	
	380	HK31	01 Mar 99			6.44	31		10.0	4.2		0.250	1.00	<0.0200	<0.010	0.98		
	380	HK31	01 Mar 99	2.2													9.45	
	380	HK31	16 Jun 99			6.13	28	<0.020	10.3	3.9	<0.050	0.090	1.00	<0.0050	<0.010	1.70		<0.030
	380	HK31	16 Jun 99	1.57													7.30	
	380	HK31	08 Sep 99	1.645	6.06	6.41	29	<0.020	9.6	3.3	<0.050	0.076	1.00	<0.0050	<0.010	1.20	10.05	<0.030
	380	HK31	09 Dec 99	1.98	6.05	6.23	33	<0.030	9.1	2.7	<0.050	0.050	0.92	<0.0050	<0.010	0.75	4.52	<0.040
	380	HK31	07 Mar 00	1.845	5.96	6.08	30	<0.030			0.050				<0.010	0.98	2.80	<0.040
	380	HK31	07 Jun 00	1.685	6.48	6.13	29	<0.030	9.8	3.4	0.090	0.070	1.00	<0.0050	<0.010	1.50	6.70	<0.040
	380	HK31	15 Dec 00	1.9	5.77	6.23	32	<0.030	8.8	2.9	0.050	0.230	0.92	0.0080	0.020	0.74	4.19	<0.040
	380	HK31	13 Mar 01	1.98	6.44	5.98	29	<0.030	9.3	4.6	<0.050	0.060	0.94	<0.0050	<0.010	0.93		<0.040
	380	HK31	11 Jun 01	1.59													6.11	
	380	HK31	17 Sep 02	1.852	4.69												4.60	
	380	HK31	04 Dec 02			6.21	32	<0.010	9.2	3.2	0.040	0.096	1.00	0.0070	<0.010	1.30		<0.050
	380	HK31	04 Mar 03			6.09	30	<0.010	10.5	4.5	0.040	0.120	1.10	<0.0050	0.010	1.70		<0.050
	380	HK31	10 Jun 03	1.655	5.63	5.72	27	<0.010	10.3	4.1	0.040	0.054	0.99	<0.0050	<0.010	1.30		<0.050
	380	HK31	29 Sep 03	1.686	6.00	5.87	27	<0.010	9.7	3.8	0.040	0.042	0.95	<0.0050	<0.010	2.60	3.00	<0.050
	380	HK31	17 Dec 03	1.8	8.49	5.93	30	<0.010	9.8	3.3	0.040	0.038	0.94	<0.0050	<0.010	1.00		
	380	HK31	02 Mar 04	1.47	5.75	5.90	30	<0.010	10.1	5.3	0.040	0.055	0.83	<0.0050	<0.010	1.20	3.60	
2	383	HK39	15 Sep 98	8.02	5.90													
	383	HK39	07 Dec 98			6.40	33		8.7	2.0		<0.010	1.10	<0.0100	<0.010	0.75		
	383	HK39	07 Dec 98	8.25	5.57												5.13	
	383	HK39	01 Mar 99	8.8													10.20	
	383	HK39	16 Jun 99			6.48	32	<0.020	8.4	3.0	<0.050	<0.020	1.10	<0.0050	<0.010	1.00		<0.030
	383	HK39	16 Jun 99	7.9													5.21	
	383	HK39	09 Dec 99	6.975	5.78	6.14	33	<0.030	8.6	2.5	0.050	<0.020	1.20	<0.0050	<0.010	0.97	4.10	<0.040
	383	HK39	07 Mar 00			6.07	32	<0.030		2.5	0.025				<0.010	0.90		<0.040
	383	HK39	07 Jun 00			6.11	33	<0.030	8.4	2.4	0.090	0.030	1.20	0.0100	0.010	0.94		<0.040
	383	HK39	18 Sep 00	7.95	5.52	5.90	33	<0.030		2.4	0.050	<0.020	1.20	<0.0050	0.020	1.00	3.92	<0.040
	383	HK39	15 Dec 00	8.78	5.52	5.99	33	<0.030	8.1	1.7	<0.050	0.023	1.10	<0.0050	0.010	0.79	5.85	<0.040
	383	HK39	13 Mar 01	9.05	5.56	5.93	32	<0.030	7.9	2.4	0.070	<0.020	1.10	<0.0050	<0.010	0.85		<0.040
	383	HK39	11 Jun 01	8.35													7.20	
3	382	GR17	14 Sep 98														5.10	
	382	GR17	08 Dec 98			6.50	36		9.2	5.0		0.060	2.30	0.0200	<0.010	1.60		
	382	GR17	02 Mar 99														9.10	
	382	GR17	17 Jun 99			6.16	34	0.060	8.7	5.2	<0.050	<0.020	2.20	0.0050	<0.010	1.50		<0.030
	382	GR17	17 Jun 99	21.6													10.50	
	382	GR17	08 Sep 99	>15.	5.69	6.36	33	0.030	8.1	4.9	<0.050	<0.020	2.10	<0.0050	<0.010	1.40	8.62	0.060
	382	GR17	10 Dec 99	>15.		7.45	35	0.070	8.6	5.3	0.050	<0.020	2.20	<0.0050	<0.010	1.70		0.050
	382	GR17	08 Mar 00	>15.	6.23			0.050		5.8	0.050				<0.010	1.90	9.30	<0.040
	382	GR17	06 Jun 00	>15.	6.52	6.33	33	0.040	8.4	5.3	0.060	0.030	2.20	<0.0050	<0.010	1.80	7.90	<0.040
	382	GR17	19 Sep 00	>15.	6.07												9.74	
	382	GR17	15 Dec 00	>15.	6.21	6.27	37	0.040	9.1	5.1	<0.050	0.046	2.40	0.0080	<0.010	1.80	8.49	<0.040
	382	GR17	14 Mar 01	>15.		6.18	35	0.060	9.0	7.4	<0.050	0.020	2.40	<0.0050	5.400	2.10		0.050
	382	GR17	07 Jun 01	>15.	6.34												11.40	
	382	GR17	12 Sep 01			6.33	35	0.150	8.9	6.0	0.050	0.021	2.40	<0.0050	0.080	2.60		<0.040
	382	GR17	18 Sep 02	>15.	5.64													
	382	GR17	06 Dec 02			6.03	29	<0.100	9.0	7.3	0.060	0.013	2.20	<0.0050	0.100	3.30		<0.050
	382	GR17	03 Mar 03	>15.	6.57	6.18	30	<0.100	9.8	7.5	0.030	<0.020	2.60	<0.0050	<0.010	3.20	4.40	<0.050
	382	GR17	11 Jun 03	>15.	5.97	5.87	29	<0.100	9.6	7.2	0.050	<0.020	2.60	0.0190	<0.010	3.30		<0.050
	382	GR17	30 Sep 03	>15.	5.72												4.00	

#	ID	Name	Date	K	ORP	SiO2	Na	SO4	T Field	Conductivity		Turbidity	
										Field	Lab	Field	Lab
1	380	HK31	15 Sep 98		- 1.1				12.20	90			
	380	HK31	07 Dec 98	2.2		8.8	3.2	3.6			70		
	380	HK31	07 Dec 98		238.				13.23	63			
	380	HK31	01 Mar 99	2.6		9.3	3.4	3.8			50		
	380	HK31	01 Mar 99						16.15	72			
	380	HK31	16 Jun 99	2.6		9.3	3.4	5.0			90		
	380	HK31	16 Jun 99						12.90	73			
	380	HK31	08 Sep 99	2.5	205.8	8.2	3.3	5.4	11.62	65	80		
	380	HK31	09 Dec 99	2.4	335.3	8.1	3.5	4.2	14.22	50	80		
	380	HK31	07 Mar 00	2.4			3.3	4.9	16.01		90		
	380	HK31	07 Jun 00	2.4		7.7	3.1	5.2	12.91	53	90		
	380	HK31	15 Dec 00	2.2		7.0	3.2	4.3	14.68		80	37.6	
	380	HK31	13 Mar 01	2.4		7.6	3.3	5.3	15.47	89	80		-0.6
	380	HK31	11 Jun 01						12.25	66			
	380	HK31	17 Sep 02						11.74				
	380	HK31	04 Dec 02	2.2		7.0	2.7	4.7			90		
	380	HK31	04 Mar 03	2.6		9.0	3.0	5.2			90		
	380	HK31	10 Jun 03	2.1		9.0	2.7	5.9	12.80	85	85		
	380	HK31	29 Sep 03	2.1		7.0	2.6	6.0	10.88		81		
	380	HK31	17 Dec 03	2.1		7.1	2.7	5.9	12.80	84			
	380	HK31	02 Mar 04	2.4	69.7	6.8	3.1	6.1	14.66	68			
2	383	HK39	15 Sep 98		3.2				13.20	80			
	383	HK39	07 Dec 98	2.8		13.3	3.4	3.0			70		
	383	HK39	07 Dec 98		268.				12.68	61			
	383	HK39	01 Mar 99						13.30	62			
	383	HK39	16 Jun 99	2.9		13.9	3.4	5.0			100		
	383	HK39	16 Jun 99						12.85	64			
	383	HK39	09 Dec 99	3.0	368.7	12.8	3.5	3.5	12.99	50	90		
	383	HK39	07 Mar 00	2.8			3.0	3.3			80		
	383	HK39	07 Jun 00	2.9		12.9	3.6	3.2			80		
	383	HK39	18 Sep 00	3.0				3.5	13.09	61	80	10	
	383	HK39	15 Dec 00	2.9		12.9	3.0	2.6	13.43		80	1.8	
	383	HK39	13 Mar 01	2.9		12.5	3.1	3.2	13.20	62	80		14.5
	383	HK39	11 Jun 01						12.40	58			
3	382	GR17	14 Sep 98						13.40	120			
	382	GR17	08 Dec 98	0.66		22.0	8.3	6.8			110		
	382	GR17	02 Mar 99						16.39	92			
	382	GR17	17 Jun 99	0.74		22.0	7.8	7.0			110		
	382	GR17	17 Jun 99						11.21	83			
	382	GR17	08 Sep 99	0.79	241.4	19.5	7.5	7.1	12.65	79	100		
	382	GR17	10 Dec 99	0.77		19.8	7.8	6.9			110		
	382	GR17	08 Mar 00	0.68			7.8	6.5	14.14		120		
	382	GR17	06 Jun 00	0.67		19.2	7.3	6.4	12.90		100		
	382	GR17	19 Sep 00						13.20	78		42	
	382	GR17	15 Dec 00	0.72		18.7	7.8	5.2	16.53		110	-0.7	
	382	GR17	14 Mar 01	1.6		18.8	8.3	6.0	14.01	90	120	8.6	
	382	GR17	07 Jun 01						11.73	65			
	382	GR17	12 Sep 01	1.1		20.0	7.8	6.2			110		
	382	GR17	18 Sep 02						13.00	104			
	382	GR17	06 Dec 02	0.81		19.5	7.1	6.0			310		
	382	GR17	03 Mar 03	1.8		21.0	7.5	5.8	13.50	176	114		
	382	GR17	11 Jun 03	0.79		20.0	7.4	5.9	11.80	112	111		
	382	GR17	30 Sep 03						12.20	109			

					pH													
#	ID	Name	Date	WL	Field	Lab	HCO3	Br	Ca	Cl	F	Fe	Mg	Mn	NH4	NO3	O2	PO4
3	382	GR17	17 Dec 03	>15.	8.50	6.04	29	<0.100	9.7	7.8	<0.030	<0.020	2.50	<0.0050	<0.010	3.50		
	382	GR17	08 Mar 04		5.90	5.89	26	<0.100	8.4	7.6	0.040	<0.020	2.00	<0.0050	<0.010	3.20	6.50	
4	381	GR04	14 Sep 98			6.64	37		7.7	6.0		0.140	1.90	0.0400	0.010	1.14		<0.100
	381	GR04	14 Sep 98														4.90	
	381	GR04	08 Dec 98			6.55	43		8.5	5.7		0.130	2.00	0.0700	<0.010	0.83		
	381	GR04	08 Dec 98	1.6	5.95												7.30	
	381	GR04	02 Mar 99	2.2													9.90	
	381	GR04	17 Jun 99			6.27	37	0.060	8.2	6.8	<0.050	0.125	2.00	0.0400	0.040	2.00		<0.030
	381	GR04	17 Jun 99	1.05													13.10	
	381	GR04	08 Sep 99	1.41	6.08												10.20	
	381	GR04	10 Dec 99	2.15		6.32	43	0.080	8.8	6.3	0.060	0.060	2.20	0.0510	0.020	1.60		<0.040
	381	GR04	08 Mar 00	2.42	6.05	6.17	39	0.080		7.0	0.070				0.070	1.30	2.10	<0.040
	381	GR04	06 Jun 00			6.39	40	0.060	8.5	6.5	0.060	0.060	2.10	0.0500	0.060	2.30		<0.040
	381	GR04	19 Sep 00	3.46	5.77	6.01	42	0.050	9.2	6.9	0.060	0.044	2.30	0.0520	<0.010	2.30	0.38	0.070
	381	GR04	15 Dec 00	2.67	5.69	6.00	34	0.050	7.5	6.1	<0.050	0.260	1.70	0.0540	0.070	0.69	0.38	<0.040
	381	GR04	14 Mar 01	2.75	6.47													
	381	GR04	07 Jun 01			6.14	44	0.060	9.5	8.0	0.060	0.320	2.40	0.0640	0.160	2.40		<0.040
	381	GR04	12 Sep 01	2.68	6.74												9.18	
	381	GR04	17 Dec 01	1.98	6.05	5.85	37	0.030	9.0	7.4	0.040	0.052	2.00	0.0440	0.030	1.90	2.79	<0.040
	381	GR04	14 Mar 02	1.993	5.74	5.90	34	<0.100	8.1	7.6	0.050	0.210	1.70	0.0270	0.040	1.30	3.82	<0.100
	381	GR04	26 Jun 02	0.9	6.16	6.12	37	<0.100	9.0	7.4	0.060	0.060	2.20	0.0210	<0.010	2.70	3.96	<0.100
	381	GR04	18 Sep 02	1.605	5.54	5.98	34	<0.100	8.9	8.0	0.070	0.059	1.90	0.0250	0.020	3.70	3.80	<0.050
	381	GR04	06 Dec 02	4.589	4.90	6.11	36	<0.100	9.0	7.9	0.070	0.063	2.10	0.0280	0.030	2.00	3.80	<0.050
	381	GR04	11 Jun 03	1.172	5.50	5.83	33	<0.100	8.9	8.2	0.060	0.230	2.10	0.0350	0.020	2.10		<0.050
	381	GR04	30 Sep 03	0.834	5.52	5.88	36	<0.100	9.8	7.7	0.060	0.092	2.10	0.0240	0.020	2.90		<0.050
	381	GR04	01 Mar 04	3.95	5.73	5.88	36	<0.100	8.9	7.9	0.060	0.330	1.80	0.0520	0.040	2.00	2.34	
5	379	HK34	15 Sep 98			6.68	48		13.8	2.3		0.020	1.60	<0.0100	<0.010	0.59		<0.100
	379	HK34	15 Sep 98	3.1	6.05													
	379	HK34	07 Dec 98			6.51	47		13.6	2.1		0.050	1.50	<0.0100	<0.010	0.48		
	379	HK34	02 Mar 99			6.41	46		13.3	2.2		0.070	1.50	<0.0200	<0.010	0.52		
	379	HK34	16 Jun 99			8.16	43	0.020	12.7	2.4	<0.050	0.060	1.40	<0.0050	<0.010	0.82		<0.030
	379	HK34	16 Jun 99	3.6													4.00	
	379	HK34	08 Sep 99	3.06													7.01	
	379	HK34	09 Dec 99	3.15	6.08	6.37	43	<0.030	12.3	2.6	<0.050	0.070	1.50	<0.0050	<0.010	0.73	2.90	<0.040
	379	HK34	07 Mar 00	3.105	6.09												0.20	
	379	HK34	07 Jun 00	2.665	6.70	6.29	40	<0.030	12.7	2.8	<0.050	<0.020	1.50	<0.0050	<0.010	1.20	6.10	<0.040
	379	HK34	18 Sep 00	2.97	5.84												2.98	
	379	HK34	15 Dec 00	3.15	5.78	6.22	42	0.120	11.9	2.1	<0.050	0.025	1.40	<0.0050	<0.020	0.65	3.36	<0.040
	379	HK34	13 Mar 01	3.16	6.52													
	379	HK34	11 Jun 01			6.17	40	<0.030	12.0	3.1	0.050	<0.020	1.40	<0.0050	0.020	0.86		<0.040
	379	HK34	11 Sep 01	3.01	6.77	6.25	38	<0.030	12.3	3.5	<0.050	<0.020	1.50	<0.0050	<0.010	1.40	4.80	<0.040
	379	HK34	18 Dec 01	2.8	7.46												2.99	
	379	HK34	14 Mar 02	2.998	5.96	6.04	44	<0.100	13.0	2.4	0.030	<0.020	1.50	<0.0050	<0.010	1.00	2.97	<0.100
	379	HK34	25 Jun 02	2.718	5.93	6.21	40	<0.100	12.5	2.9	<0.030	<0.020	1.50	<0.0050	<0.010	1.20	3.76	<0.100
	379	HK34	17 Sep 02	2.987	4.96	6.12	41	<0.100	13.0	3.3	<0.030	<0.020	1.50	<0.0050	<0.010	1.50	4.40	<0.050
	379	HK34	04 Dec 02	3.042	6.02	6.35	42	<0.100	12.9	3.2	<0.030	<0.020	1.50	<0.0050	<0.010	1.30	3.90	<0.050
	379	HK34	10 Jun 03	2.729	5.92	5.93	40	<0.100	13.4	3.6	0.030	<0.020	1.60	<0.0050	<0.010	1.10		<0.050
	379	HK34	02 Mar 04	2.59	5.97	6.02	42	<0.100	13.1	3.3	0.030	<0.020	1.30	<0.0050	<0.010	1.00	3.60	
6	378	BU01	16 Sep 98	7.2	6.31												1.20	
	378	BU01	07 Apr 99	8.1													0.71	
	378	BU01	15 Sep 99	7.45	5.61	6.27	31	0.040	7.8	6.3	<0.050	0.740	1.10	0.0180	<0.010	0.08	5.03	<0.030
	378	BU01	10 Dec 99	7.845		6.25	29	0.050	7.7	6.6	<0.050	0.110	1.10	0.0140	<0.010	0.06		<0.040
	378	BU01	15 Mar 00	8.02	7.03	6.16	28	0.030		6.8	<0.050				<0.010	0.08	3.80	<0.040

										Conductivity		Turbidity	
#	ID	Name	Date	K	ORP	SiO2	Na	SO4	T Field	Field	Lab	Field	Lab
3	382	GR17	17 Dec 03	0.81		20.0	7.2	5.7	12.90	116			
	382	GR17	08 Mar 04	0.72	192.	18.2	6.9	5.6	13.25	74			
4	381	GR04	14 Sep 98	1.1		14.6	8.5	2.8			100		
	381	GR04	14 Sep 98						12.20	130			
	381	GR04	08 Dec 98	1.2		16.9	9.5	2.5			100		
	381	GR04	08 Dec 98		221.1				14.60	85			
	381	GR04	02 Mar 99						15.97	81			
	381	GR04	17 Jun 99	1.4		16.2	9.6	3.6			110		
	381	GR04	17 Jun 99						12.58	90			
	381	GR04	08 Sep 99		160.9				12.32	86			
	381	GR04	10 Dec 99	1.4		15.3	9.4	3.0			110		
	381	GR04	08 Mar 00	1.3			8.7	2.6	14.84		110		
	381	GR04	06 Jun 00	1.5		15.2	9.0	2.8			110		
	381	GR04	19 Sep 00	1.4		14.2	9.3	2.9	11.40	88	120	42	
	381	GR04	15 Dec 00	1.4		11.9	6.9	2.2	13.78		90	35.5	
	381	GR04	14 Mar 01						14.97	83		1.5	
	381	GR04	07 Jun 01	1.6		19.4	10.1	2.9			120		
	381	GR04	12 Sep 01						12.00	101			
	381	GR04	17 Dec 01	1.7		13.1	7.5	4.0	15.00	107	110		
	381	GR04	14 Mar 02	1.4		12.9	7.5	2.9	14.90	101	100		
	381	GR04	26 Jun 02	1.4		16.2	8.7	3.3	13.08	77	120		
	381	GR04	18 Sep 02	1.4		13.7	7.2	3.7	11.93	99	110		
	381	GR04	06 Dec 02	1.4		14.0	7.3	3.7	12.84	106	120		
	381	GR04	11 Jun 03	1.5		15.8	7.9	4.0	12.90	109	106		
	381	GR04	30 Sep 03	1.4		14.8	7.9	4.4	11.90	118	117		
	381	GR04	01 Mar 04	1.6	69.5	13.9	7.1	4.3	14.72	80			
5	379	HK34	15 Sep 98	2.3		10.0	2.8	4.0			100		
	379	HK34	15 Sep 98		- 7.4				13.20	110			
	379	HK34	07 Dec 98	2.3		9.4	2.9	4.1			90		
	379	HK34	02 Mar 99	2.6		10.3	2.9	4.2			70		
	379	HK34	16 Jun 99	2.5		10.5	2.9	3.4			80		
	379	HK34	16 Jun 99						13.88	83			
	379	HK34	08 Sep 99		196.					12.81			
	379	HK34	09 Dec 99	2.4	354.5	9.3	3.0	4.7	12.85	59	100		
	379	HK34	07 Mar 00						13.80				
	379	HK34	07 Jun 00	2.5		9.1	2.9	6.7	13.94	64	100		
	379	HK34	18 Sep 00						12.60	76		2.4	
	379	HK34	15 Dec 00	2.2		8.7	2.5	4.9	12.51		100	-0.9	
	379	HK34	13 Mar 01						13.42	78			-0.5
	379	HK34	11 Jun 01	2.3		10.0	3.0	6.2			100		
	379	HK34	11 Sep 01	2.1		9.3	3.2	6.1	12.30	99	100		
	379	HK34	18 Dec 01						14.70	101			
	379	HK34	14 Mar 02	2.5		9.1	2.7	5.4	13.80	102	100		
	379	HK34	25 Jun 02	2.4		9.3	2.8	5.7	13.60	95	100		
	379	HK34	17 Sep 02	2.3		8.8	2.7	6.4	12.76		100		
	379	HK34	04 Dec 02	2.6		8.6	2.7	6.1	13.60	106	100		
	379	HK34	10 Jun 03	2.3		10.2	2.8	6.9	13.80	104	105		
	379	HK34	02 Mar 04	2.3	56.6	8.1	2.8	6.1	13.27	72			
6	378	BU01	16 Sep 98		- 22.2				13.80	100			
	378	BU01	07 Apr 99						14.21	59			
	378	BU01	15 Sep 99	1.4	136.	11.1	5.5	4.5	13.57	69	80		
	378	BU01	10 Dec 99	1.1		11.1	6.0	4.7			80		
	378	BU01	15 Mar 00	1.1			5.4	4.5	16.90		80		

					pH													
#	ID	Name	Date	WL	Field	Lab	HCO3	Br	Ca	Cl	F	Fe	Mg	Mn	NH4	NO3	O2	PO4
6	378	BU01	06 Jun 00			6.11	39	<0.030	7.5	6.8	0.090	4.000	1.10	0.0800	0.010	0.05		<0.040
	378	BU01	06 Sep 00	7.48	5.85	5.99	25	0.040	7.0	6.8	<0.050	0.340	1.00	0.0160	<0.010	0.11		<0.040
	378	BU01	12 Dec 00	7.71	5.68	6.24	29	0.030	7.4	6.0	0.060	0.440	1.00	0.0190	<0.010	0.12	0.00	<0.040
	378	BU01	26 Mar 01	8.56	6.83	6.24	30	<0.030	7.5	9.5	<0.050	4.200	2.00	0.1800	<0.010	0.09	11.79	<0.040
	378	BU01	26 Jun 01			6.14	38	0.030	8.5	6.9	<0.050	1.900	1.30	0.0350	<0.010	0.10		<0.040
	378	BU01	18 Sep 01			6.18	26	0.060	7.7	7.2	<0.050	0.140	1.20	0.0190	<0.010	0.09		0.040
	378	BU01	14 Mar 02	2.968	5.62												3.95	
	378	BU01	26 Jun 02	6.29	6.13												0.95	
	378	BU01	11 Sep 02	6.88	6.20	6.20	28	<0.100	8.0	7.6	0.040	<0.020	1.10	0.0200	<0.010	0.15	0.56	<0.050
	378	BU01	18 Dec 02	6.96	5.72	6.16	29	<0.100	7.8	7.5	0.050	0.900	1.20	0.0240	<0.010	0.11	0.40	<0.050
	378	BU01	24 Mar 03	8.24	5.85	5.86	31	<0.100	9.1	7.3	0.040	0.360	1.40	0.0200	<0.010	0.19	1.58	<0.050
	378	BU01	18 Sep 03	7.232	5.78	5.87	31	<0.100	9.0	7.6	0.030	0.750	1.30	0.0270	<0.010	0.09	3.70	<0.050
	378	BU01	21 Jan 04	7.05		6.12	31	<0.100	9.2	7.5	0.040	0.260	1.30	0.0240	<0.010	0.10		
	378	BU01	03 Mar 04	6.66	5.83	5.98	32	<0.100	8.8	7.5	0.030	0.290	1.10	0.0220	<0.010	0.11	0.00	
7	1993	GR02	25 Jun 03		3.88	5.37	14	0.220	8.1	6.1	<0.030	0.027	1.00	0.0710	<0.010	1.80		<0.050
	1993	GR02	30 Sep 03	4.5	5.08												3.90	
	1993	GR02	17 Dec 03	7.0	8.49													
	1993	GR02	01 Mar 04	4.475	5.28	5.45	15	0.180	9.2	8.1	<0.030	0.035	1.00	0.0580	0.030	2.70	3.40	
8	384	HK25	15 Sep 98	2.4	5.98													
	384	HK25	07 Dec 98			6.51	33		6.1	10.7		<0.010	3.00	<0.0100	<0.010	0.80		
	384	HK25	16 Jun 99			6.36	32	0.090	5.8	9.7	0.080	<0.020	2.90	<0.0050	<0.010	0.76		<0.030
	384	HK25	16 Jun 99	2.4													4.49	
	384	HK25	08 Sep 99	2.267	6.02	6.37	32	0.050	5.7	9.7	0.130	<0.020	2.90	0.0050	<0.010	0.71	8.03	<0.030
	384	HK25	09 Dec 99	2.605	6.07	6.29	34	0.070	5.9	10.3	0.090	<0.020	3.00	0.0050	<0.010	0.78	5.13	<0.040
	384	HK25	07 Jun 00	2.45	6.57	6.23	34	0.050	5.6	9.7	0.130	<0.020	3.00	<0.0050	<0.010	0.72	7.00	<0.040
	384	HK25	18 Sep 00	2.5	5.68												8.70	
	384	HK25	15 Dec 00	2.34	5.66	6.18	34	0.030	5.7	9.5	0.120	<0.020	2.90	0.0050	0.010	0.79	2.05	0.050
	384	HK25	13 Mar 01	2.44	6.54													
	384	HK25	11 Sep 01	2.76	6.17												6.54	
	384	HK25	18 Dec 01	2.5	7.37	5.94	36	0.040	5.9	10.9	0.110	<0.020	3.10	<0.0050	0.020	0.77	3.24	<0.040
	384	HK25	17 Sep 02	2.466	4.80												2.50	
	384	HK25	04 Dec 02			6.23	30	<0.100	5.7	10.2	0.100	<0.020	2.60	0.0050	<0.010	0.87		<0.050
	384	HK25	04 Mar 03	2.104	6.53	5.85	32	<0.100	6.0	10.3	0.090	<0.020	2.80	<0.0050	<0.010	0.82	3.10	<0.050
	384	HK25	10 Jun 03	2.272	5.62	5.81	29	<0.100	5.9	9.8	0.090	<0.020	2.80	<0.0050	<0.010	0.88		<0.050
	384	HK25	29 Sep 03	2.1	5.91	5.78	27	<0.100	5.8	9.9	0.120	<0.020	2.60	<0.0050	<0.010	0.86	1.86	<0.050
	384	HK25	17 Dec 03	2.57	8.47	6.03	29	<0.100	5.8	10.5	0.070	<0.020	2.70	<0.0050	<0.010	0.89		
	384	HK25	02 Mar 04	2.24	5.70	5.88	29	<0.100	5.5	10.6	0.080	<0.020	2.40	<0.0050	<0.010	1.00	1.80	

										Conductivity		Turbidity	
#	ID	Name	Date	K	ORP	SiO2	Na	SO4	T Field	Field	Lab	Field	Lab
6	378	BU01	06 Jun 00	1.1		10.7	5.2	3.9			80		
	378	BU01	06 Sep 00	1.1	126.5	10.7	5.6	5.0	13.91	63	80		
	378	BU01	12 Dec 00	1.1		11.6	5.4	4.9	14.68		80	-0.7	
	378	BU01	26 Mar 01	1.2		9.0	5.6	5.4	15.77	109	100	-0.2	
	378	BU01	26 Jun 01	1.2		12.4	5.9	5.2			110		
	378	BU01	18 Sep 01	1.3		11.4	5.7	5.4			80		
	378	BU01	14 Mar 02						14.70	85			
	378	BU01	26 Jun 02						14.02	67			
	378	BU01	11 Sep 02	1.2	302.5	12.0	5.2	5.9	15.86		90		
	378	BU01	18 Dec 02	1.1		11.3	5.5	6.2	14.40	94	90		
	378	BU01	24 Mar 03	1.2	531.	12.2	5.4	6.3	14.35	149	130		
	378	BU01	18 Sep 03	1.3		12.3	5.6	6.9	13.98	168	92		
	378	BU01	21 Jan 04	1.2	135.3	12.7	5.4	6.7	14.58	92			
	378	BU01	03 Mar 04	1.2	63.1	10.2	5.6	6.5	14.41	66			
7	1993	GR02	25 Jun 03	1.6		3.6	3.0	6.5	9.02	84	82		
	1993	GR02	30 Sep 03						11.90	78			
	1993	GR02	17 Dec 03						12.80	73			
	1993	GR02	01 Mar 04	1.9	96.	3.4	3.4	6.1	14.16	66			
8	384	HK25	15 Sep 98		- 2.7				15.40	110			
	384	HK25	07 Dec 98	1.8		18.2	10.4	5.5			100		
	384	HK25	16 Jun 99	2.1		17.3	9.4	5.8			100		
	384	HK25	16 Jun 99						14.12	91			
	384	HK25	08 Sep 99	2.1	232.	17.3	9.3	5.5	14.36	86	100		
	384	HK25	09 Dec 99	2.0	272.5	17.2	10.0	5.3	14.67	71	110		
	384	HK25	07 Jun 00	1.9		17.4	9.2	4.9	14.25	69	100		
	384	HK25	18 Sep 00						14.20	106			
	384	HK25	15 Dec 00	1.9		16.6	9.4	5.3	14.34		110	0.8	
	384	HK25	13 Mar 01						14.82	92			-0.7
	384	HK25	11 Sep 01						14.60	108			
	384	HK25	18 Dec 01	2.4		17.8	8.9	4.7	15.60	105	120		
	384	HK25	17 Sep 02						14.60				
	384	HK25	04 Dec 02	2.1		16.5	8.1	5.8			100		
	384	HK25	04 Mar 03	2.2		16.4	8.5	5.6	14.50	169	104		
	384	HK25	10 Jun 03	2.0		16.4	7.7	5.8	14.70	103	102		
	384	HK25	29 Sep 03	1.9		16.5	7.7	6.1	14.66	100	101		
	384	HK25	17 Dec 03	2.0		16.7	7.9	5.7	14.40	101			
	384	HK25	02 Mar 04	1.9	70.8	15.3	8.2	5.6	15.08	76			

Appendix B-1 Footnotes

1. *Units for variables listed in table are as follows:*
    - *a. Water level (WL) - meters below reference point (i.e., top of well casing and approximately ground level).*
    - *b. pH - standard units.*
    - *c. Chemical concentrations (HCO3 through SO4) - mg/L.*
    - *d. Temperature - ^{o}C.*
    - *e. Conductivity - uS/cm.*
    - *f. Turbidity - NTUs.*

Appendix B-2. WCRC water level data base.

#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL
1	HK31	07 Jun 00	1.685	2	HK29	18 Feb 00	2.57	3	HK39	18 Feb 00	8.05	4	GR45	20 Apr 00	2.96
	HK31	03 Jul 00	1.845		HK29	18 Apr 00	3.02		HK39	18 Apr 00	7.9		GR45	06 Jun 00	2.895
	HK31	15 Nov 00	1.97		HK29	07 Jun 00	2.705		HK39	07 Jun 00	6.68		GR45	15 Nov 00	3.05
	HK31	22 Dec 00	1.9		HK29	03 Jul 00	3.185		HK39	03 Jul 00	8.198		GR45	22 Dec 00	3.32
	HK31	13 Feb 01	1.85		HK29	15 Nov 00	3.28		HK39	15 Nov 00	7.74		GR45	12 Feb 01	3.14
	HK31	13 Mar 01	1.98		HK29	22 Dec 00	3.35		HK39	22 Dec 00	8.78		GR45	14 Mar 01	3.57
	HK31	30 Apr 01	1.94		HK29	13 Feb 01	3.3		HK39	13 Feb 01	8.52		GR45	01 May 01	3.27
	HK31	08 Jun 01	1.59		HK29	13 Mar 01	3.57		HK39	13 Mar 01	9.05		GR45	07 Jun 01	3.08
	HK31	16 Jul 01	2.0		HK29	30 Apr 01	3.24		HK39	30 Apr 01	8.66		GR45	17 Jul 01	2.95
	HK31	10 Sep 01	1.9		HK29	08 Jun 01	2.82		HK39	08 Jun 01	8.35		GR45	12 Sep 01	3.17
	HK31	23 Oct 01	1.72		HK29	16 Jul 01	3.32		HK39	16 Jul 01	8.0		GR45	26 Oct 01	2.99
	HK31	18 Dec 01	1.87		HK29	23 Oct 01	2.71		HK39	10 Sep 01	8.47		GR45	17 Dec 01	2.61
	HK31	29 Jan 02	1.93		HK29	18 Dec 01	2.77		HK39	23 Oct 01	8.1		GR45	30 Jan 02	3.1
	HK31	19 Feb 02	1.966		HK29	29 Jan 02	3.222		HK39	18 Dec 01	5.0		GR45	19 Feb 02	3.218
	HK31	04 Apr 02	1.795		HK29	19 Feb 02	3.56		HK39	29 Jan 02	6.121		GR45	08 Apr 02	3.0
	HK31	16 May 02	1.879		HK29	04 Apr 02	2.865		HK39	19 Feb 02	1.709		GR45	17 May 02	2.863
	HK31	25 Jun 02	1.648		HK29	16 May 02	3.135		HK39	04 Apr 02	7.82		GR45	28 May 02	2.856
	HK31	06 Aug 02	1.83		HK29	25 Jun 02	1.618		HK39	16 May 02	8.287		GR45	27 Jun 02	2.471
	HK31	17 Sep 02	1.852		HK29	06 Aug 02	3.121		HK39	11 Jun 02	8.455		GR45	07 Aug 02	2.781
	HK31	31 Oct 02	1.739		HK29	17 Sep 02	2.995		HK39	25 Jun 02	7.266		GR45	18 Sep 02	2.645
	HK31	04 Dec 02	1.845		HK29	31 Oct 02	2.836		HK39	06 Aug 02	7.846		GR45	30 Oct 02	2.657
	HK31	22 Jan 03	1.782		HK29	04 Dec 02	3.164		HK39	17 Sep 02	8.16		GR45	06 Dec 02	2.619
	HK31	04 Mar 03	1.68		HK29	22 Jan 03	2.989		HK39	31 Oct 02	7.562		GR45	03 Mar 03	2.676
	HK31	11 Apr 03	1.904		HK29	04 Mar 03	3.956		HK39	04 Dec 02	7.694		GR45	10 Apr 03	3.093
	HK31	27 May 03	1.746		HK29	11 Apr 03	3.246		HK39	22 Jan 03	8.202		GR45	11 Jul 03	2.692
	HK31	09 Jul 03	1.832		HK29	27 May 03	2.67		HK39	04 Mar 03	8.31		GR45	20 Aug 03	2.995
	HK31	19 Aug 03	1.901		HK29	09 Jul 03	2.87		HK39	11 Apr 03	9.193		GR45	30 Sep 03	2.578
	HK31	29 Sep 03	1.686		HK29	19 Aug 03	3.2		HK39	27 May 03	8.386		GR45	20 Nov 03	2.762
	HK31	19 Nov 03	1.769		HK29	29 Sep 03	2.737		HK39	09 Jul 03	6.95		GR45	03 Mar 04	2.515
	HK31	04 Mar 04	1.741		HK29	19 Nov 03	2.918		HK39	19 Aug 03	8.602		GR45	23 Mar 04	2.744
	HK31	22 Mar 04	1.55		HK29	04 Mar 04	3.2		HK39	29 Sep 03	8.5		GR45	10 Jun 04	2.742
	HK31	09 Jun 04	1.84		HK29	22 Mar 04	2.2		HK39	29 Nov 03	8.406		GR45	23 Jul 04	2.898
	HK31	28 Jul 04	1.801		HK29	09 Jun 04	2.86		HK39	04 Mar 04	7.777		GR45	08 Dec 04	2.91
	HK31	07 Dec 04	2.72		HK29	28 Jul 04	3.172		HK39	22 Mar 04	6.31		GR45	12 Apr 05	2.631
	HK31	26 Jan 05	1.66		HK29	07 Dec 04	2.951		HK39	09 Jun 04	8.123				
	HK31	18 Apr 05	1.911		HK29	26 Jan 05	2.75		HK39	28 Jul 04	8.146				
					HK29	18 Apr 05	2.331		HK39	07 Dec 04	8.35				
									HK39	26 Jan 05	8.35				
									HK39	18 Apr 05	8.461				

#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL
5	GR21	06 Jun 00	7.55	6	GR10	15 Nov 00	2.7	7	GR16	20 Apr 00	5.99	8	HK24	18 Feb 00	2.99
	GR21	03 Aug 00	>15		GR10	22 Dec 00	2.94		GR16	03 Aug 00	6.28		HK24	18 Apr 00	3.55
	GR21	15 Nov 00	11.69		GR10	12 Feb 01	2.95		GR16	15 Nov 00	6.3		HK24	07 Jun 00	3.075
	GR21	22 Dec 00	14.76		GR10	14 Mar 01	3.03		GR16	22 Dec 00	6.6		HK24	03 Jul 00	3.815
	GR21	12 Feb 01	>15		GR10	01 May 01	2.97		GR16	12 Feb 01	6.53		HK24	15 Nov 00	3.98
	GR21	14 Mar 01	>15		GR10	07 Jun 01	2.4		GR16	14 Mar 01	6.39		HK24	22 Dec 00	3.87
	GR21	01 May 01	>15		GR10	17 Jul 01	2.63		GR16	01 May 01	6.34		HK24	13 Feb 01	3.56
	GR21	07 Jun 01	11.1		GR10	12 Sep 01	2.68		GR16	07 Jun 01	5.9		HK24	13 Mar 01	4.08
	GR21	17 Jul 01	11.28		GR10	26 Oct 01	2.86		GR16	17 Jul 01	6.29		HK24	30 Apr 01	3.88
	GR21	12 Sep 01	11.54		GR10	17 Dec 01	1.9		GR16	12 Sep 01	6.26		HK24	08 Jun 01	3.25
	GR21	26 Oct 01	>15		GR10	30 Jan 02	2.725		GR16	26 Oct 01	6.15		HK24	16 Jul 01	3.94
	GR21	17 Dec 01	5.38		GR10	19 Feb 02	2.988		GR16	17 Dec 01	4.4		HK24	10 Sep 01	3.8
	GR21	30 Jan 02	10.431		GR10	08 Apr 02	2.663		GR16	30 Jan 02	6.538		HK24	23 Oct 01	3.22
	GR21	19 Feb 02	13.542		GR10	17 May 02	2.609		GR16	19 Feb 02	6.74		HK24	18 Dec 01	3.08
	GR21	04 Apr 02	>15		GR10	28 May 02	2.407		GR16	08 Apr 02	6.2		HK24	29 Jan 02	3.727
	GR21	17 May 02	12.531		GR10	27 Jun 02	1.405		GR16	17 May 02	6.103		HK24	19 Feb 02	3.935
	GR21	28 May 02	15.173		GR10	18 Sep 02	2.399		GR16	28 May 02	5.52		HK24	04 Apr 02	3.48
	GR21	27 Jun 02	4.684		GR10	30 Oct 02	2.091		GR16	27 Jun 02	3.885		HK24	25 Jun 02	3.061
	GR21	07 Aug 02	10.03		GR10	06 Dec 02	2.548		GR16	07 Aug 02	6.188		HK24	07 Aug 02	3.74
	GR21	18 Sep 02	9.924		GR10	23 Jan 03	2.742		GR16	18 Sep 02	5.988		HK24	17 Sep 02	3.538
	GR21	30 Oct 02	12.146		GR10	03 Mar 03	2.668		GR16	30 Oct 02	5.414		HK24	30 Oct 02	3.334
	GR21	06 Dec 02	14.562		GR10	10 Apr 03	2.91		GR16	06 Dec 02	6.302		HK24	04 Dec 02	3.973
	GR21	23 Jan 03	13.337		GR10	11 Jul 03	2.003		GR16	23 Jan 03	6.508		HK24	22 Jan 03	3.76
	GR21	03 Mar 03	14.332		GR10	20 Aug 03	2.652		GR16	03 Mar 03	6.19		HK24	04 Mar 03	3.712
	GR21	10 Apr 03	>15		GR10	30 Sep 03	1.87		GR16	10 Apr 03	6.475		HK24	11 Apr 03	3.949
	GR21	11 Jul 03	6.01		GR10	20 Nov 03	2.733		GR16	11 Jul 03	5.024		HK24	27 May 03	3.253
	GR21	20 Aug 03	11.97		GR10	03 Mar 04	2.984		GR16	20 Aug 03	6.38		HK24	09 Jul 03	3.323
	GR21	30 Sep 03	6.777		GR10	23 Mar 04	2.71		GR16	30 Sep 03	4.627		HK24	19 Aug 03	3.88
	GR21	20 Nov 03	10.405		GR10	10 Jun 04	2.337		GR16	20 Nov 03	5.877		HK24	29 Sep 03	3.209
	GR21	03 Mar 04	14.321		GR10	23 Jul 04	2.51		GR16	03 Mar 04	80.0		HK24	19 Nov 03	3.462
	GR21	23 Mar 04	12.952		GR10	08 Dec 04	2.01		GR16	23 Mar 04	26.391		HK24	04 Mar 04	3.124
	GR21	10 Jun 04	10.012		GR10	25 Jan 05	2.88		GR16	10 Jun 04	80.0		HK24	22 Mar 04	3.31
	GR21	23 Jul 04	10.013		GR10	13 Apr 05	2.811		GR16	23 Jul 04	80.0		HK24	09 Jun 04	2.472
	GR21	08 Dec 04	15.113						GR16	08 Dec 04	5.95		HK24	28 Jul 04	3.451
	GR21	25 Jan 05	14.31						GR16	25 Jan 05	6.41		HK24	07 Dec 04	2.541
	GR21	12 Apr 05	17.003						GR16	13 Apr 05	6.345		HK24	26 Jan 05	3.45
													HK24	18 Apr 05	3.199

#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL
9	GR19	20 Apr 00	>15	10	HK34	07 Jun 00	2.665	11	GR04	20 Apr 00	1.33	12	GR05	20 Apr 00	0.87
	GR19	06 Jun 00	9.25		HK34	03 Jul 00	3.105		GR04	06 Jun 00	1.175		GR05	06 Jun 00	0.758
	GR19	03 Aug 00	>15		HK34	15 Nov 00	3.14		GR04	03 Aug 00	2.42		GR05	03 Aug 00	1.578
	GR19	15 Nov 00	14.46		HK34	22 Dec 00	3.15		GR04	19 Sep 00	3.46		GR05	15 Nov 00	1.35
	GR19	22 Dec 00	>15		HK34	13 Feb 01	2.91		GR04	15 Nov 00	1.67		GR05	22 Dec 00	1.52
	GR19	12 Feb 01	>15		HK34	13 Mar 01	3.16		GR04	22 Dec 00	2.67		GR05	12 Feb 01	1.46
	GR19	14 Mar 01	>15		HK34	30 Apr 01	3.04		GR04	12 Feb 01	3.9		GR05	14 Mar 01	1.69
	GR19	01 May 01	>15		HK34	08 Jun 01	3.18		GR04	14 Mar 01	2.75		GR05	01 May 01	1.61
	GR19	07 Jun 01	12.8		HK34	16 Jul 01	3.15		GR04	01 May 01	3.52		GR05	07 Jun 01	1.2
	GR19	17 Jul 01	12.64		HK34	10 Sep 01	3.01		GR04	07 Jun 01	4.18		GR05	17 Jul 01	1.3
	GR19	12 Sep 01	14.07		HK34	18 Dec 01	2.8		GR04	17 Jul 01	1.84		GR05	12 Sep 01	1.39
	GR19	26 Oct 01	>15		HK34	29 Jan 02	3.04		GR04	12 Sep 01	2.68		GR05	26 Oct 01	1.43
	GR19	17 Dec 01	8.82		HK34	19 Feb 02	3.162		GR04	17 Dec 01	1.98		GR05	17 Dec 01	0.71
	GR19	30 Jan 02	14.425		HK34	08 Apr 02	2.8		GR04	30 Jan 02	4.765		GR05	30 Jan 02	1.378
	GR19	19 Feb 02	>15		HK34	16 May 02	2.99		GR04	19 Feb 02	5.017		GR05	19 Feb 02	1.567
	GR19	17 May 02	>15		HK34	25 Jun 02	2.718		GR04	08 Apr 02	4.6		GR05	08 Apr 02	1.25
	GR19	28 May 02	>15		HK34	06 Aug 02	3.057		GR04	17 May 02	2.891		GR05	17 May 02	1.392
	GR19	27 Jun 02	7.037		HK34	17 Sep 02	2.987		GR04	27 Jun 02	0.458		GR05	28 May 02	1.098
	GR19	07 Aug 02	13.279		HK34	31 Oct 02	2.802		GR04	07 Aug 02	1.599		GR05	27 Jun 02	0.402
	GR19	18 Sep 02	12.36		HK34	04 Dec 02	3.042		GR04	18 Sep 02	1.605		GR05	07 Aug 02	1.277
	GR19	30 Oct 02	8.9		HK34	22 Jan 03	2.988		GR04	30 Oct 02	2.651		GR05	18 Sep 02	1.047
	GR19	06 Dec 02	11.768		HK34	04 Mar 03	2.908		GR04	06 Dec 02	4.589		GR05	30 Oct 02	0.785
	GR19	23 Jan 03	>15		HK34	11 Apr 03	3.046		GR04	23 Jan 03	4.913		GR05	06 Dec 02	1.317
	GR19	03 Mar 03	>15		HK34	27 May 03	2.682		GR04	03 Mar 03	1.804		GR05	23 Jan 03	1.475
	GR19	10 Apr 03	>15		HK34	09 Jul 03	2.098		GR04	10 Apr 03	4.001		GR05	03 Mar 03	1.46
	GR19	11 Jul 03	8.262		HK34	19 Aug 03	3.058		GR04	11 Jul 03	2.076		GR05	10 Apr 03	1.648
	GR19	20 Aug 03	>15		HK34	29 Sep 03	2.794		GR04	20 Aug 03	1.774		GR05	11 Jul 03	0.847
	GR19	30 Sep 03	9.776		HK34	19 Nov 03	2.977		GR04	30 Sep 03	0.834		GR05	20 Aug 03	1.223
	GR19	20 Nov 03	12.973		HK34	04 Mar 04	3.051		GR04	20 Nov 03	4.742		GR05	30 Sep 03	0.572
	GR19	03 Mar 04	>15		HK34	22 Mar 04	2.55		GR04	03 Mar 04	2.864		GR05	20 Nov 03	1.069
	GR19	23 Mar 04	14.411		HK34	09 Jun 04	2.804		GR04	23 Mar 04	4.171		GR05	03 Mar 04	1.482
	GR19	10 Jun 04	12.632		HK34	28 Jul 04	3.094		GR04	10 Jun 04	3.012		GR05	23 Mar 04	3.11
	GR19	23 Jul 04	13.011		HK34	07 Dec 04	3.01		GR04	23 Jul 04	1.417		GR05	10 Jun 04	2.865
	GR19	08 Dec 04	13.146		HK34	26 Jan 05	2.92		GR04	08 Dec 04	2.413		GR05	23 Jul 04	1.302
	GR19	25 Jan 05	17.03		HK34	18 Apr 05	3.114		GR04	25 Jan 05	5.33		GR05	08 Dec 04	1.948
	GR19	12 Apr 05	19.0						GR04	13 Apr 05	4.271		GR05	25 Jan 05	1.41
													GR05	13 Apr 05	2.631

#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL
13	GR44	20 Apr 00	1.3	14	HK35	18 Feb 00	3.05	15	GR03	20 Apr 00	3.1	16	HK27	18 Feb 00	2.685
	GR44	06 Jun 00	1.61		HK35	18 Apr 00	3.44		GR03	06 Jun 00	2.765		HK27	18 Apr 00	3.029
	GR44	03 Aug 00	1.85		HK35	07 Jun 00	2.95		GR03	03 Aug 00	4.09		HK27	07 Jun 00	2.85
	GR44	15 Nov 00	1.93		HK35	03 Jul 00	3.613		GR03	15 Nov 00	6.91		HK27	03 Jul 00	3.24
	GR44	22 Dec 00	1.87		HK35	15 Nov 00	3.77		GR03	22 Dec 00	4.37		HK27	15 Nov 00	3.82
	GR44	12 Feb 01	1.81		HK35	22 Dec 00	4.05		GR03	12 Feb 01	4.02		HK27	22 Dec 00	3.2
	GR44	14 Mar 01	1.94		HK35	13 Feb 01	3.52		GR03	14 Mar 01	4.55		HK27	13 Feb 01	3.24
	GR44	01 May 01	1.93		HK35	13 Mar 01	4.08		GR03	01 May 01	4.3		HK27	13 Mar 01	3.93
	GR44	07 Jun 01	1.96		HK35	30 Apr 01	3.7		GR03	07 Jun 01	3.7		HK27	30 Apr 01	3.41
	GR44	17 Jul 01	1.99		HK35	08 Jun 01	3.31		GR03	17 Jul 01	4.08		HK27	08 Jun 01	2.87
	GR44	12 Sep 01	1.95		HK35	16 Jul 01	3.8		GR03	12 Sep 01	4.19		HK27	16 Jul 01	3.48
	GR44	26 Oct 01	1.84		HK35	10 Sep 01	3.6		GR03	26 Oct 01	6.35		HK27	10 Sep 01	3.33
	GR44	17 Dec 01	1.68		HK35	23 Oct 01	3.22		GR03	17 Dec 01	3.12		HK27	23 Oct 01	2.85
	GR44	30 Jan 02	1.965		HK35	18 Dec 01	3.11		GR03	30 Jan 02	4.334		HK27	18 Dec 01	2.74
	GR44	19 Feb 02	1.949		HK35	29 Jan 02	3.548		GR03	19 Feb 02	7.359		HK27	29 Jan 02	3.068
					HK35	19 Feb 02	3.793		GR03	08 Apr 02	3.575		HK27	19 Feb 02	3.179
					HK35	04 Apr 02	3.197		GR03	17 May 02	3.851		HK27	04 Apr 02	3.6
					HK35	16 May 02	3.544		GR03	27 Jun 02	1.777		HK27	16 May 02	3.542
					HK35	25 Jun 02	3.09		GR03	07 Aug 02	3.745		HK27	25 Jun 02	3.089
					HK35	06 Aug 02	3.614		GR03	18 Sep 02	3.726		HK27	06 Aug 02	3.418
					HK35	17 Sep 02	3.506		GR03	31 Oct 02	3.206		HK27	17 Sep 02	3.448
					HK35	31 Oct 02	3.227		GR03	06 Dec 02	4.46		HK27	31 Oct 02	3.408
					HK35	04 Dec 02	3.639		GR03	23 Jan 03	3.768		HK27	04 Dec 02	3.503
					HK35	22 Jan 03	3.62		GR03	03 Mar 03	5.741		HK27	22 Jan 03	3.442
					HK35	04 Mar 03	3.592		GR03	10 Apr 03	4.52		HK27	04 Mar 03	3.253
					HK35	11 Apr 03	3.789		GR03	30 Sep 03	2.731		HK27	11 Apr 03	3.741
					HK35	27 May 03	2.98		GR03	20 Nov 03	3.642		HK27	27 May 03	3.327
					HK35	09 Jul 03	3.266		GR03	03 Mar 04	4.551		HK27	09 Jul 03	3.516
					HK35	19 Aug 03	3.648		GR03	10 Jun 04	3.419		HK27	19 Aug 03	3.756
					HK35	29 Sep 03	3.168		GR03	23 Jul 04	3.091		HK27	29 Sep 03	3.325
					HK35	19 Nov 03	3.468		GR03	08 Dec 04	4.211		HK27	19 Nov 03	3.5
					HK35	04 Mar 04	3.705		GR03	25 Jan 05	4.25		HK27	04 Mar 04	2.893
					HK35	22 Mar 04	2.96		GR03	13 Apr 05	1.987		HK27	22 Mar 04	2.735
					HK35	09 Jun 04	3.241						HK27	09 Jun 04	3.128
					HK35	09 Aug 04	2.883						HK27	28 Jul 04	3.319
					HK35	07 Dec 04	3.154						HK27	07 Dec 04	3.25
					HK35	26 Jan 05	3.51						HK27	18 Apr 05	2.948
					HK35	18 Apr 05	2.988								

#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL
17	HK30	18 Feb 00	2.8	18	HK33	18 Apr 00	6.695	19	HK36	18 Apr 00	2.07	20	HK28	18 Feb 00	3.75
	HK30	18 Apr 00	2.51		HK33	07 Jun 00	6.3		HK36	07 Jun 00	1.96		HK28	18 Apr 00	3.87
	HK30	07 Jun 00	2.195		HK33	03 Jul 00	7.195		HK36	03 Jul 00	2.75		HK28	07 Jun 00	3.665
	HK30	03 Jul 00	2.685		HK33	15 Nov 00	7.59		HK36	15 Nov 00	2.08		HK28	03 Jul 00	3.98
	HK30	15 Nov 00	2.94		HK33	22 Dec 00	7.42		HK36	22 Dec 00	2.12		HK28	15 Nov 00	4.05
	HK30	22 Dec 00	2.74		HK33	13 Feb 01	7.07		HK36	13 Feb 01	2.16		HK28	22 Dec 00	4.34
	HK30	13 Feb 01	2.53		HK33	13 Mar 01	7.58		HK36	13 Mar 01	2.26		HK28	13 Feb 01	3.9
	HK30	13 Mar 01	2.82		HK33	30 Apr 01	7.35		HK36	30 Apr 01	2.2		HK28	13 Mar 01	4.1
	HK30	30 Apr 01	2.72		HK33	08 Jun 01	7.05		HK36	08 Jun 01	2.07		HK28	30 Apr 01	4.01
	HK30	08 Jun 01	2.22		HK33	16 Jul 01	7.54		HK36	16 Jul 01	2.19		HK28	08 Jun 01	3.5
	HK30	16 Jul 01	2.83		HK33	10 Sep 01	7.49		HK36	10 Sep 01	2.2		HK28	16 Jul 01	4.1
	HK30	10 Sep 01	2.66		HK33	23 Oct 01	6.74		HK36	23 Oct 01	2.1		HK28	10 Sep 01	3.92
	HK30	23 Oct 01	2.18		HK33	18 Dec 01	6.25		HK36	18 Dec 01	1.91		HK28	23 Oct 01	3.59
	HK30	18 Dec 01	2.29		HK33	29 Jan 02	7.231		HK36	29 Jan 02	1.973		HK28	18 Dec 01	3.69
	HK30	29 Jan 02	2.752		HK33	19 Feb 02	7.43		HK36	19 Feb 02	2.058		HK28	29 Jan 02	4.025
	HK30	19 Feb 02	2.842		HK33	04 Apr 02	3.544		HK36	04 Apr 02	2.02		HK28	19 Feb 02	4.017
	HK30	04 Apr 02	2.525		HK33	16 May 02	6.958		HK36	16 Apr 02	2.099		HK28	04 Apr 02	3.812
	HK30	16 May 02	2.706		HK33	11 Jun 02	6.793		HK36	25 Jun 02	1.93		HK28	16 May 02	3.992
	HK30	11 Jun 02	2.161		HK33	25 Jun 02	6.222		HK36	06 Aug 02	2.069		HK28	11 Jun 02	3.318
	HK30	25 Jun 02	2.129		HK33	06 Aug 02	7.254		HK36	17 Sep 02	2.115		HK28	25 Jun 02	3.555
	HK30	06 Aug 02	2.544		HK33	17 Sep 02	6.996		HK36	31 Oct 02	1.999		HK28	06 Aug 02	3.893
	HK30	17 Sep 02	2.469		HK33	31 Oct 02	6.861		HK36	04 Dec 02	2.034		HK28	17 Sep 02	3.923
	HK30	31 Oct 02	2.329		HK33	04 Dec 02	7.283		HK36	22 Jan 03	2.105		HK28	31 Oct 02	3.761
	HK30	04 Dec 02	2.603		HK33	22 Jan 03	7.101		HK36	04 Mar 03	1.944		HK28	04 Dec 02	4.07
	HK30	22 Jan 03	2.486		HK33	04 Mar 03	7.128		HK36	11 Apr 03	2.161		HK28	22 Jan 03	3.845
	HK30	04 Mar 03	2.403		HK33	11 Apr 03	7.503		HK36	27 May 03	2.087		HK28	04 Mar 03	3.678
	HK30	11 Apr 03	2.74		HK33	27 May 03	6.4		HK36	09 Jul 03	2.033		HK28	11 Apr 03	4.078
	HK30	27 May 03	2.136		HK33	09 Jul 03	6.596		HK36	19 Aug 03	2.257		HK28	27 May 03	3.646
	HK30	09 Jul 03	2.38		HK33	19 Aug 03	7.509		HK36	29 Sep 03	1.272		HK28	09 Jul 03	1.779
	HK30	19 Aug 03	2.748		HK33	29 Sep 03	6.599		HK36	19 Nov 03	2.073		HK28	19 Aug 03	4.035
	HK30	29 Sep 03	2.185		HK33	19 Nov 03	6.944		HK36	04 Mar 04	1.909		HK28	29 Sep 03	3.604
	HK30	19 Nov 03	2.403		HK33	04 Mar 04	7.368		HK36	22 Mar 04	1.78		HK28	19 Nov 03	3.76
	HK30	04 Mar 04	2.568		HK33	22 Mar 04	6.32		HK36	09 Jun 04	1.943		HK28	04 Mar 04	2.883
	HK30	22 Mar 04	2.0		HK33	09 Jun 04	6.889		HK36	28 Jul 04	2.871		HK28	22 Mar 04	3.31
	HK30	09 Jun 04	2.371		HK33	28 Jul 04	6.551		HK36	07 Dec 04	2.413		HK28	09 Jun 04	3.735
	HK30	28 Jul 04	2.66		HK33	07 Dec 04	7.3		HK36	18 Apr 05	1.841		HK28	28 Jul 04	3.881
	HK30	07 Dec 04	2.435		HK33	26 Jan 05	7.0						HK28	07 Dec 04	3.755
	HK30	18 Apr 05	2.931		HK33	18 Apr 05	8.476						HK28	18 Apr 05	3.813

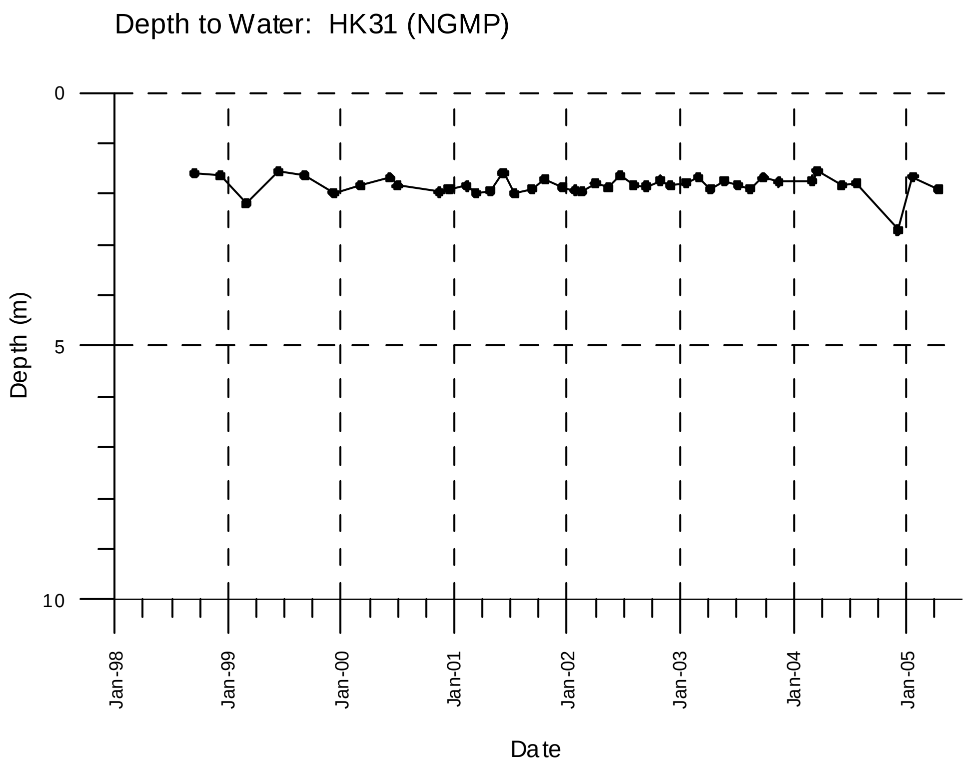
#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL
21	HK37	18 Apr 00	1.88	22	HK26	18 Feb 00	4.26	23	HK32	18 Feb 00	2.69	24	HK40	18 Feb 00	5.5
	HK37	07 Jun 00	1.7		HK26	18 Apr 00	4.389		HK32	18 Apr 00	3.55		HK40	18 Apr 00	5.6
	HK37	03 Jul 00	1.89		HK26	07 Jun 00	4.15		HK32	03 Jul 00	3.21		HK40	07 Jun 00	4.46
	HK37	15 Nov 00	1.9		HK26	03 Jul 00	4.54		HK32	15 Nov 00	3.16		HK40	03 Jul 00	5.98
	HK37	22 Dec 00	2.04		HK26	15 Nov 00	4.5		HK32	22 Dec 00	4.32		HK40	15 Nov 00	5.81
	HK37	13 Mar 01	2.2		HK26	22 Dec 00	4.47		HK32	13 Feb 01	3.04		HK40	22 Dec 00	6.44
	HK37	30 Apr 01	2.03		HK26	13 Feb 01	4.48		HK32	13 Mar 01	3.15		HK40	13 Feb 01	6.03
	HK37	08 Jun 01	1.85		HK26	13 Mar 01	4.59		HK32	30 Apr 01	3.1		HK40	13 Mar 01	6.94
	HK37	16 Jul 01	2.0		HK26	30 Apr 01	4.6		HK32	08 Jun 01	2.83		HK40	30 Apr 01	6.3
	HK37	10 Sep 01	1.99		HK26	08 Jun 01	4.33		HK32	16 Jul 01	3.18		HK40	08 Jun 01	5.93
	HK37	23 Oct 01	1.88		HK26	16 Jul 01	4.57		HK32	10 Sep 01	3.06		HK40	16 Jul 01	6.05
	HK37	18 Dec 01	1.56		HK26	10 Sep 01	4.48		HK32	23 Oct 01	2.91		HK40	10 Sep 01	6.19
	HK37	29 Jan 02	1.661		HK26	23 Oct 01	4.3		HK32	18 Dec 01	2.98		HK40	23 Oct 01	5.5
	HK37	19 Feb 02	1.844		HK26	18 Dec 01	4.2		HK32	29 Jan 02	3.08		HK40	18 Dec 01	3.82
	HK37	04 Apr 02	1.765		HK26	29 Jan 02	4.468		HK32	19 Feb 02	3.155		HK40	29 Jan 02	4.706
	HK37	16 May 02	1.9		HK26	19 Feb 02	5.485		HK32	04 Apr 02	2.958		HK40	19 Feb 02	5.837
	HK37	25 Jun 02	1.659		HK26	04 Apr 02	4.365		HK32	16 May 02	3.052		HK40	04 Apr 02	5.467
	HK37	06 Aug 02	1.823		HK26	16 May 02	4.462		HK32	11 Jun 02	2.725		HK40	16 May 02	6.068
	HK37	17 Sep 02	1.903		HK26	25 Jun 02	4.135		HK32	25 Jun 02	2.837		HK40	11 Jun 02	5.631
	HK37	31 Oct 02	1.747		HK26	06 Aug 02	4.494		HK32	06 Aug 02	3.062		HK40	25 Jun 02	5.335
	HK37	04 Dec 02	1.809		HK26	17 Sep 02	4.444		HK32	17 Sep 02	3.046		HK40	06 Aug 02	5.925
	HK37	22 Jan 03	1.819		HK26	31 Oct 02	4.345		HK32	31 Oct 02	2.898		HK40	17 Sep 02	5.866
	HK37	04 Mar 03	1.765		HK26	04 Dec 02	4.458		HK32	04 Dec 02	3.298		HK40	31 Oct 02	5.53
	HK37	11 Apr 03	2.028		HK26	22 Jan 03	4.4		HK32	22 Jan 03	3.332		HK40	04 Dec 02	4.788
	HK37	27 May 03	1.872		HK26	04 Mar 03	3.5		HK32	04 Mar 03	3.159		HK40	22 Jan 03	5.988
	HK37	09 Jul 03	1.779		HK26	11 Apr 03	4.629		HK32	11 Apr 03	3.303		HK40	04 Mar 03	5.629
	HK37	19 Aug 03	2.003		HK26	27 May 03	4.389		HK32	27 May 03	2.959		HK40	11 Apr 03	6.82
	HK37	29 Sep 03	1.865		HK26	09 Jul 03	4.345		HK32	09 Jul 03	3.3		HK40	27 May 03	5.46
	HK37	19 Nov 03	1.879		HK26	19 Aug 03	4.45		HK32	19 Aug 03	3.134		HK40	09 Jul 03	4.978
	HK37	04 Mar 04	1.682		HK26	29 Sep 03	4.102		HK32	29 Sep 03	2.908		HK40	19 Aug 03	6.421
	HK37	22 Mar 04	1.62		HK26	19 Nov 03	4.537		HK32	19 Nov 03	3.237		HK40	29 Sep 03	5.834
	HK37	09 Jun 04	1.893		HK26	04 Mar 04	4.432		HK32	04 Mar 04	3.015		HK40	19 Nov 03	5.935
	HK37	28 Jul 04	1.954		HK26	22 Mar 04	4.225		HK32	22 Mar 04	1.95		HK40	04 Mar 04	5.911
	HK37	07 Dec 04	1.871		HK26	09 Jun 04	3.721		HK32	09 Jun 04	2.999		HK40	22 Mar 04	4.26
	HK37	26 Jan 05	1.86		HK26	28 Jul 04	4.111		HK32	28 Jul 04	2.031		HK40	09 Jun 04	5.751
	HK37	18 Apr 05	1.755		HK26	07 Dec 04	4.94		HK32	07 Dec 04	2.741		HK40	28 Jul 04	6.139
					HK26	26 Jan 05	4.42		HK32	26 Jan 05	2.93		HK40	07 Dec 04	5.416
					HK26	18 Apr 05	4.322		HK32	18 Apr 05	3.112		HK40	26 Jan 05	5.84
													HK40	18 Apr 05	5.499

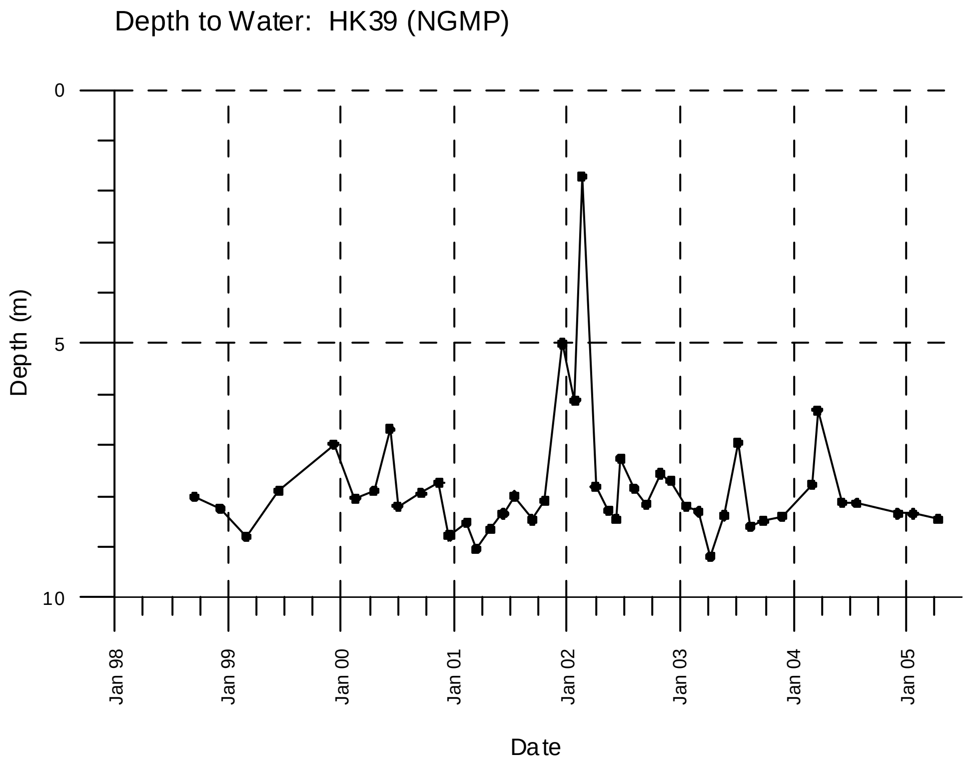
#	Well	Date	WL	#	Well	Date	WL	#	Well	Date	WL
25	GR22	20 Apr 00	3.05	26	GR23	20 Apr 00	2.74	27	HK25	07 Jun 00	2.45
	GR22	06 Jun 00	2.8		GR23	06 Jun 00	2.49		HK25	03 Jul 00	2.635
	GR22	03 Aug 00	3.515		GR23	03 Aug 00	3.46		HK25	15 Nov 00	2.2
	GR22	15 Nov 00	3.2		GR23	15 Nov 00	3.08		HK25	22 Dec 00	2.34
	GR22	22 Dec 00	3.6		GR23	22 Dec 00	3.62		HK25	13 Feb 01	2.45
	GR22	12 Feb 01	3.67		GR23	12 Feb 01	3.65		HK25	13 Mar 01	2.44
	GR22	14 Mar 01	4.32		GR23	14 Mar 01	3.93		HK25	30 Apr 01	2.57
	GR22	01 May 01	3.93		GR23	01 May 01	4.05		HK25	08 Jun 01	2.62
	GR22	07 Jun 01	3.39		GR23	07 Jun 01	3.29		HK25	16 Jul 01	2.58
	GR22	17 Jul 01	3.16		GR23	17 Jul 01	2.96		HK25	10 Sep 01	2.76
	GR22	12 Sep 01	3.35		GR23	12 Sep 01	3.12		HK25	23 Oct 01	2.43
	GR22	26 Oct 01	4.03		GR23	26 Oct 01	3.46		HK25	18 Dec 01	2.5
	GR22	17 Dec 01	2.46		GR23	17 Dec 01	2.18		HK25	29 Jan 02	2.432
	GR22	30 Jan 02	3.052		GR23	30 Jan 02	2.903		HK25	19 Feb 02	2.442
	GR22	19 Feb 02	3.416		GR23	19 Feb 02	3.389		HK25	04 Apr 02	2.345
	GR22	08 Apr 02	3.695		GR23	08 Apr 02	3.082		HK25	16 May 02	2.351
	GR22	08 Apr 02	3.082		GR23	17 May 02	3.082		HK25	25 Jun 02	2.191
	GR22	17 May 02	3.203		GR23	27 Jun 02	1.283		HK25	06 Aug 02	2.443
	GR22	27 Jun 02	1.72		GR23	07 Aug 02	2.906		HK25	17 Sep 02	2.466
	GR22	07 Aug 02	3.079		GR23	18 Sep 02	2.787		HK25	31 Oct 02	2.56
	GR22	18 Sep 02	2.964		GR23	30 Oct 02	2.461		HK25	04 Dec 02	2.615
	GR22	30 Oct 02	2.738		GR23	06 Dec 02	3.021		HK25	22 Jan 03	2.31
	GR22	06 Dec 02	3.679		GR23	23 Jan 03	3.237		HK25	04 Mar 03	2.104
	GR22	23 Jan 03	3.301		GR23	03 Mar 03	3.534		HK25	11 Apr 03	2.626
	GR22	03 Mar 03	3.437		GR23	10 Apr 03	3.68		HK25	27 May 03	2.495
	GR22	10 Apr 03	3.68		GR23	30 Sep 03	2.468		HK25	09 Jul 03	2.461
	GR22	30 Sep 03	2.973		GR23	20 Nov 03	2.921		HK25	19 Aug 03	2.33
	GR22	20 Nov 03	3.082		GR23	03 Mar 04	3.332		HK25	29 Sep 03	2.1
	GR22	03 Mar 04	3.451		GR23	23 Mar 04	3.112		HK25	19 Nov 03	2.574
	GR22	23 Mar 04	2.973		GR23	10 Jun 04	2.941		HK25	04 Mar 04	2.391
	GR22	10 Jun 04	3.004		GR23	23 Jul 04	2.801		HK25	22 Mar 04	2.095
	GR22	23 Jul 04	2.988		GR23	08 Dec 04	3.311		HK25	09 Jun 04	3.391
	GR22	08 Dec 04	3.33		GR23	25 Jan 05	3.14		HK25	07 Dec 04	0.722
	GR22	25 Jan 05	3.21		GR23	12 Apr 05	3.203		HK25	26 Jan 05	2.56
	GR22	12 Apr 05	3.205						HK25	18 Apr 05	2.397

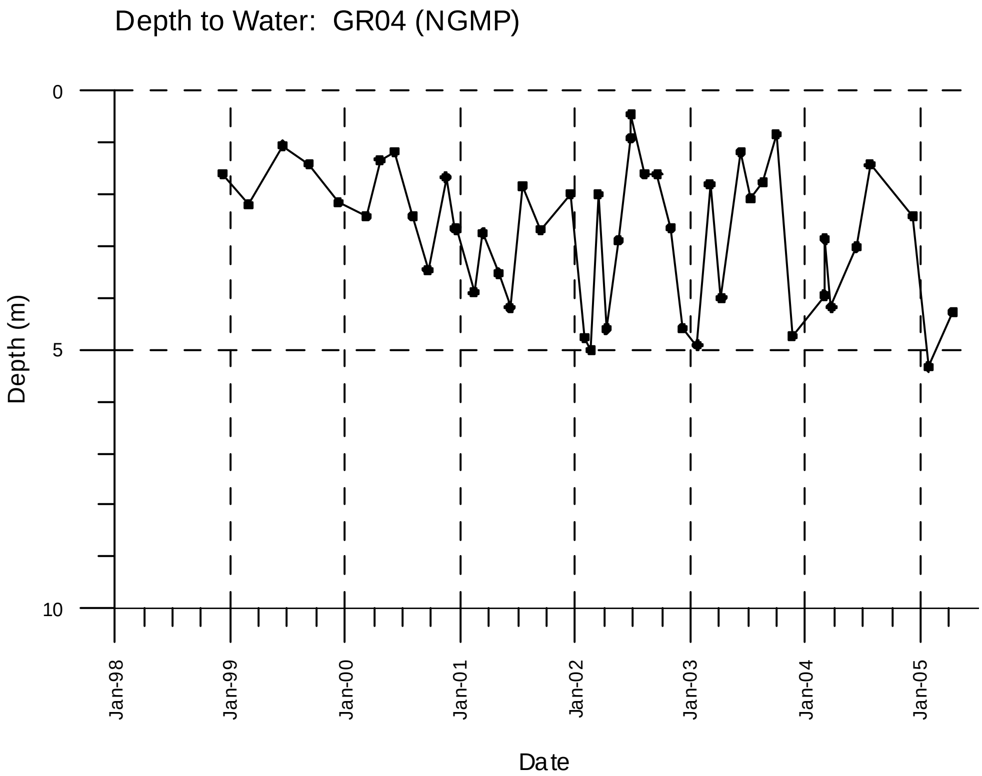
Appendix B-2 Footnotes

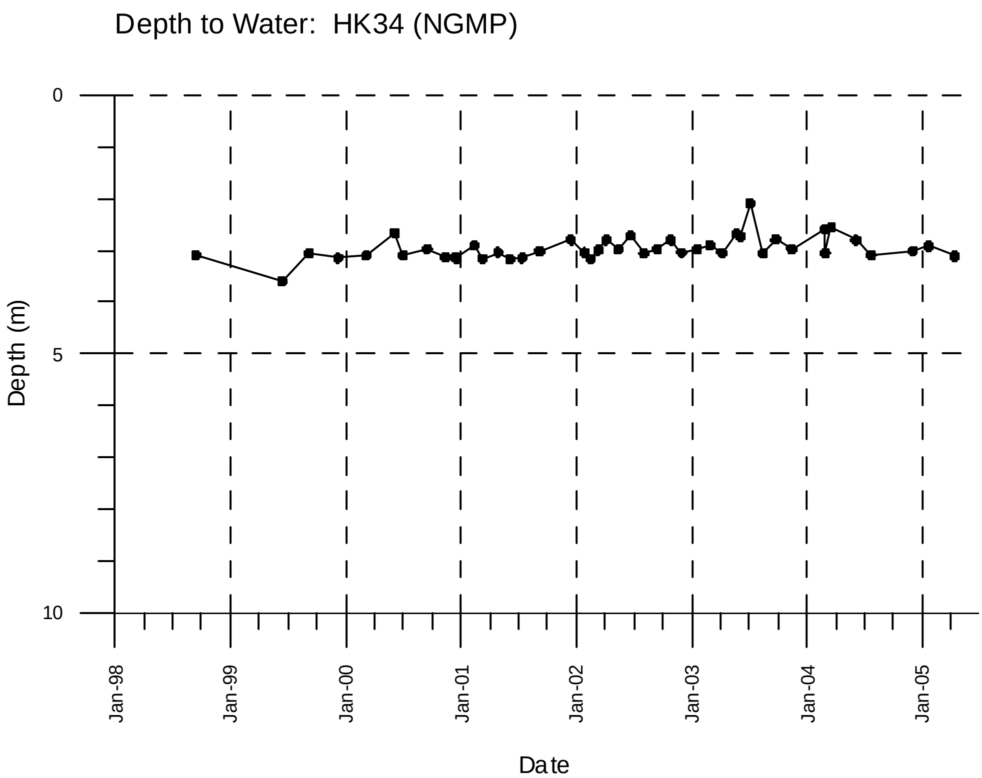
1. *Units for water level (WL) are meters below reference point (i.e., top of well casing and approximatel y ground level).*
2. *Data for March-July 2004 in well GR16 provided by the WCRC are inconsistent with historic and later values.*

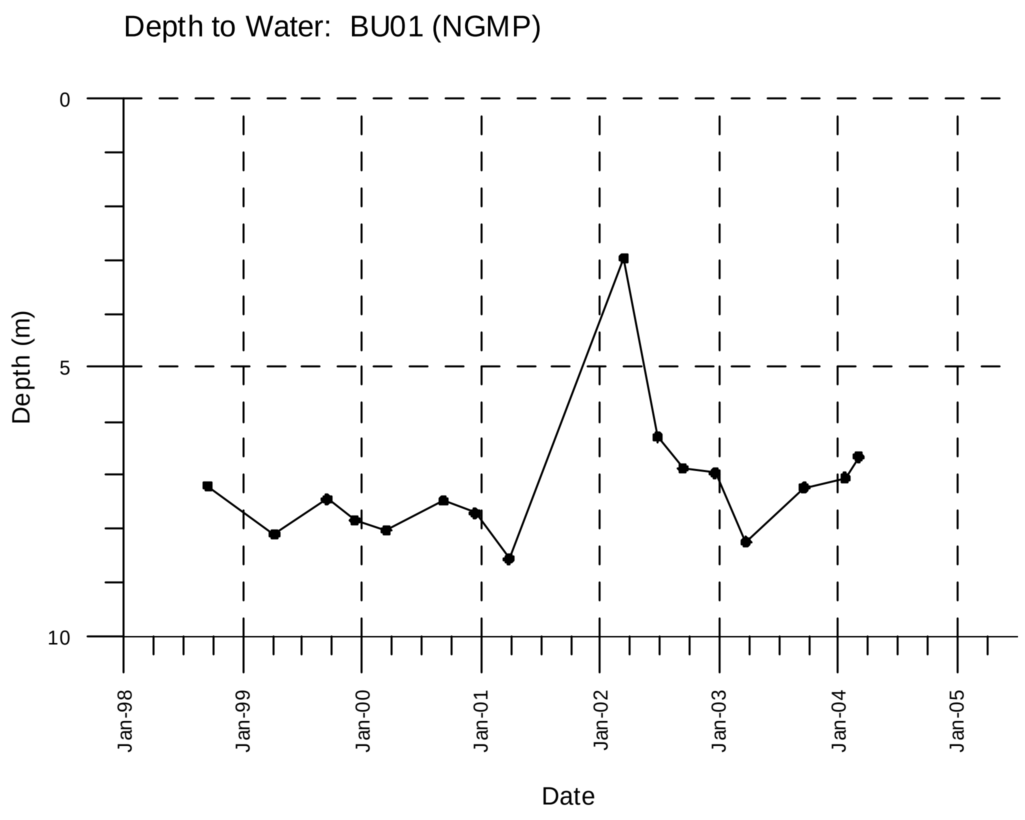
Appendix C. WCRC well hydrographs.

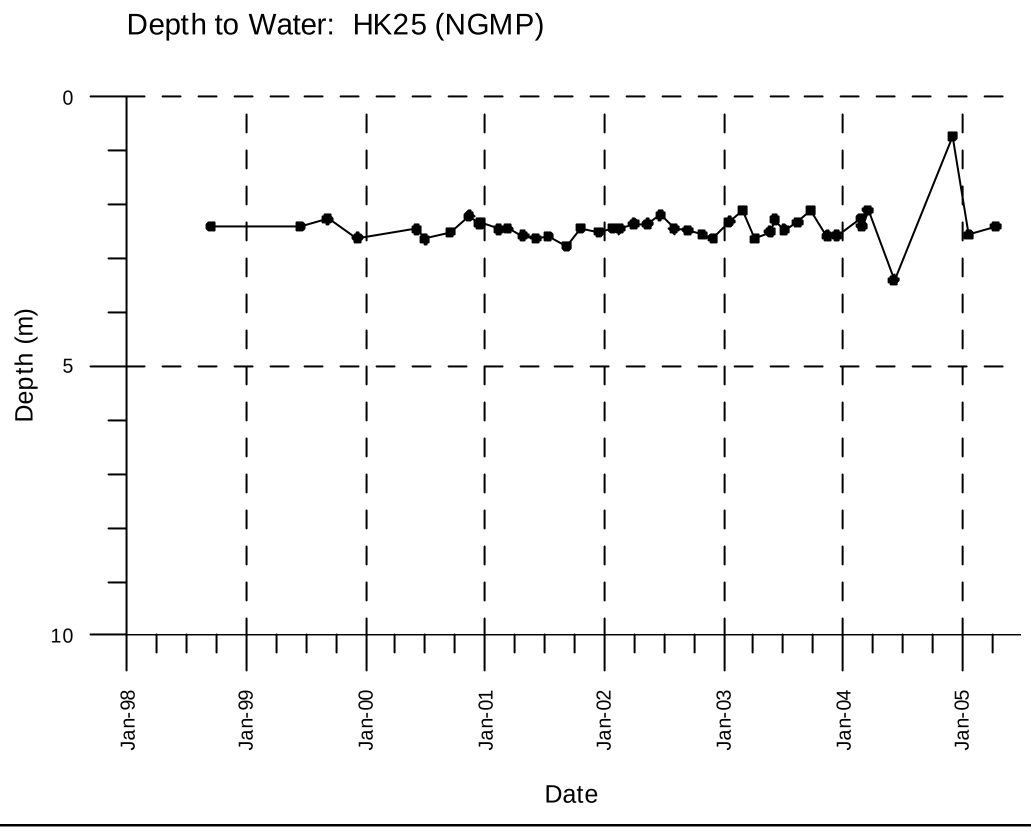


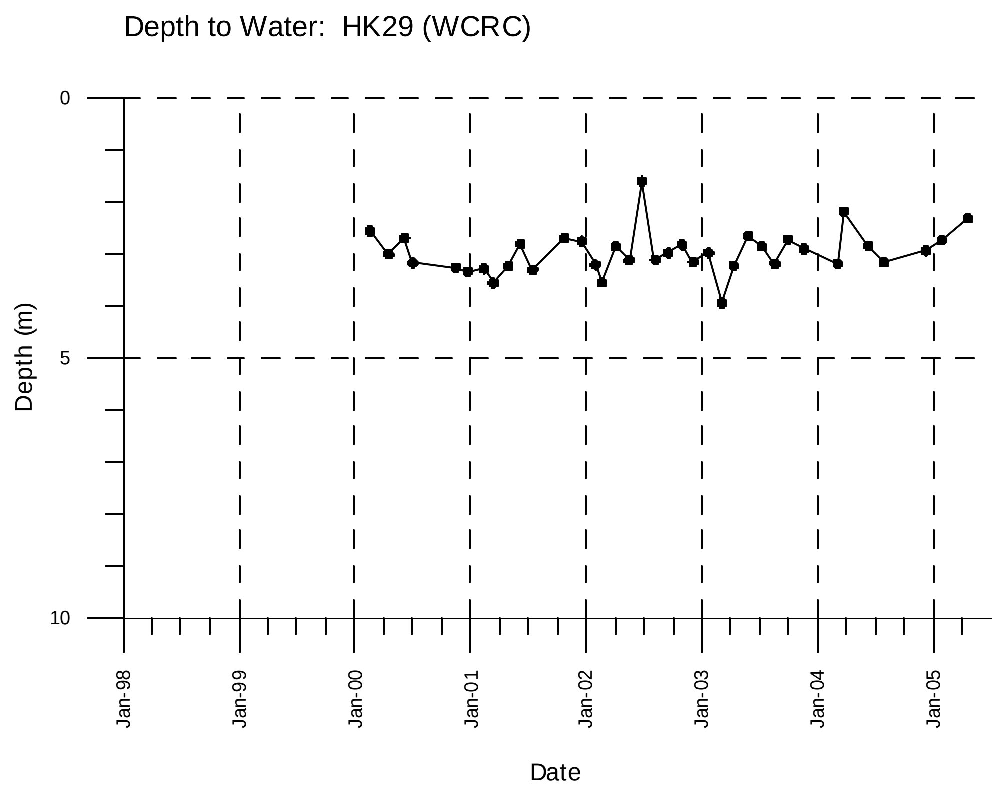



Depth to Water: GR04 (NGMP)
Depth (m)
0
5
10
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

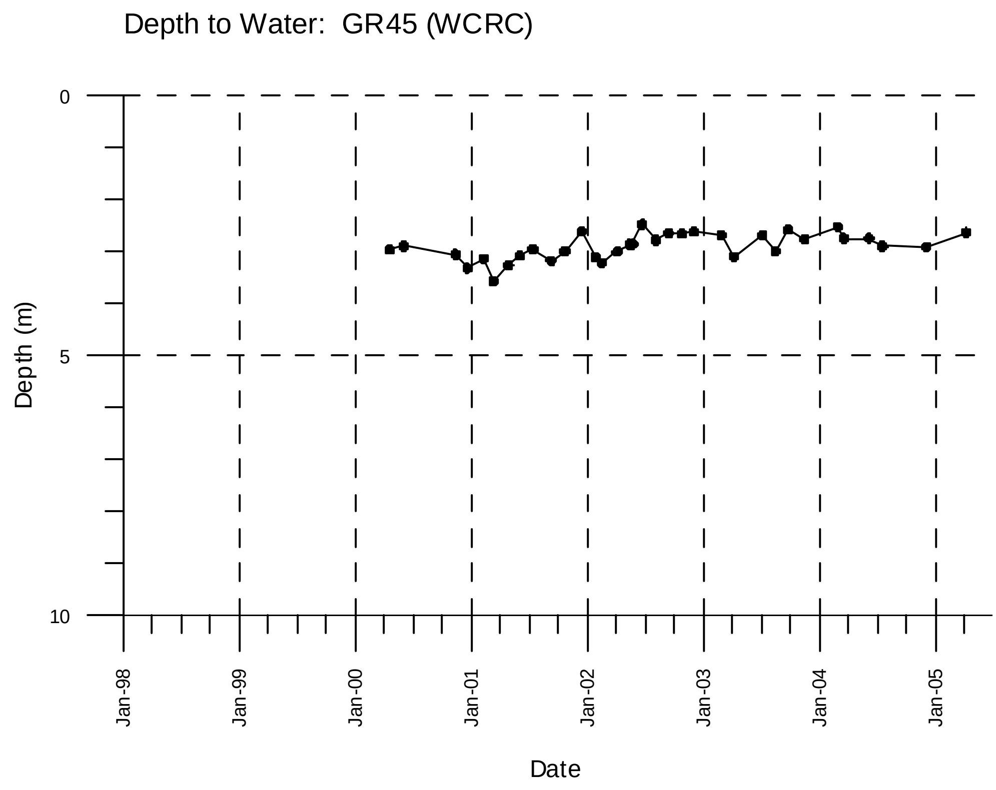

Depth to Water: HK34 (NGMP)
Depth (m)
0
5
10
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date


Depth to Water: BU01 (NGMP)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

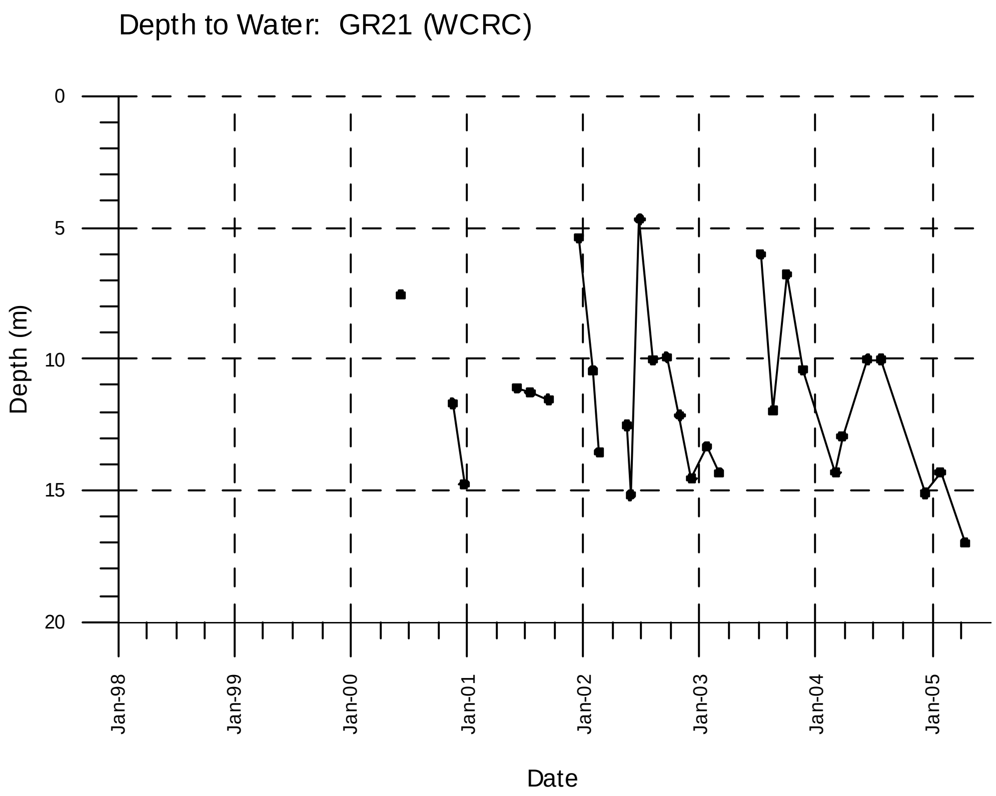

Depth to Water: HK25 (NGMP)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

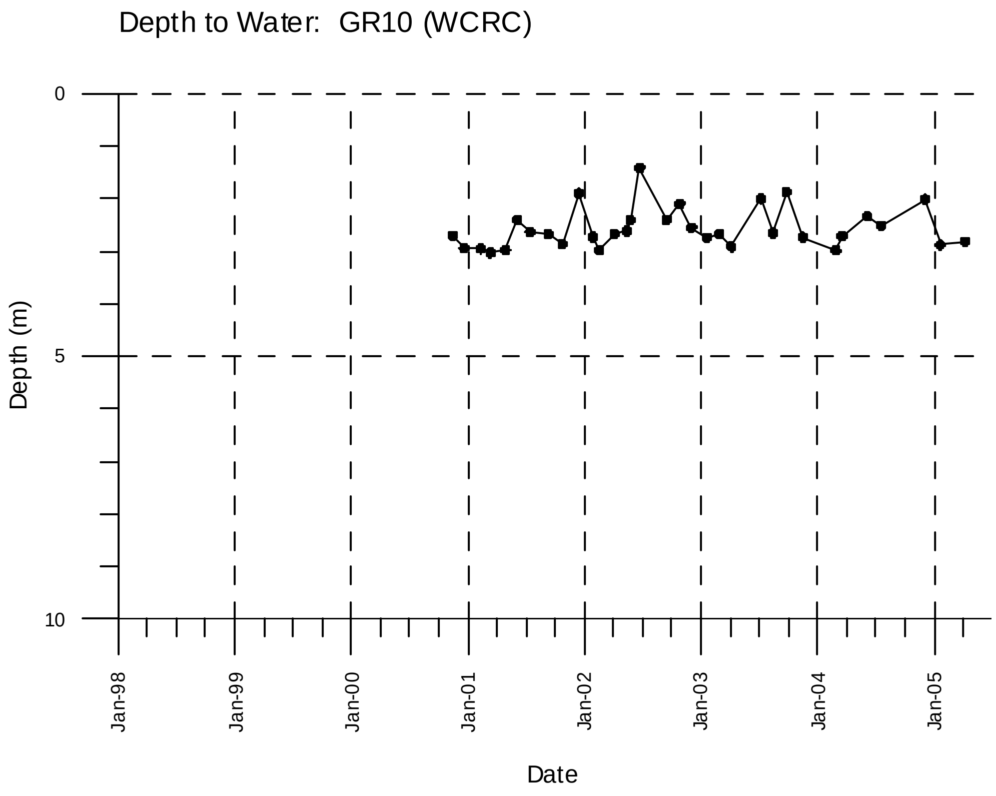


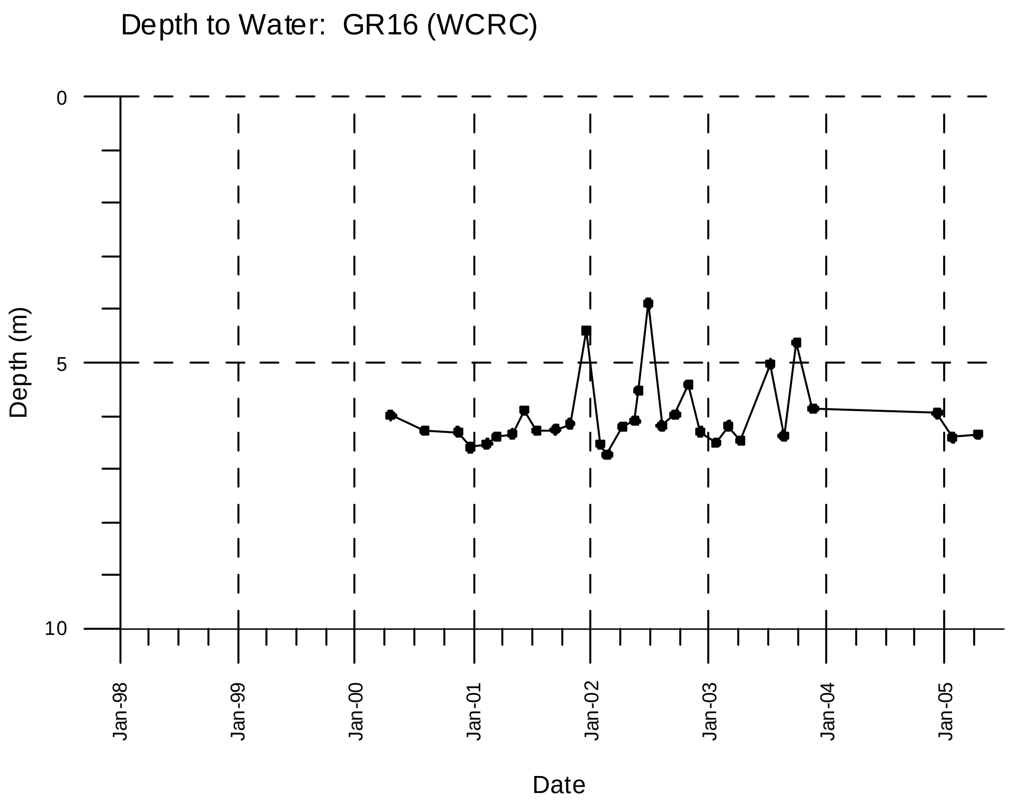
Depth to Water: HK29 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

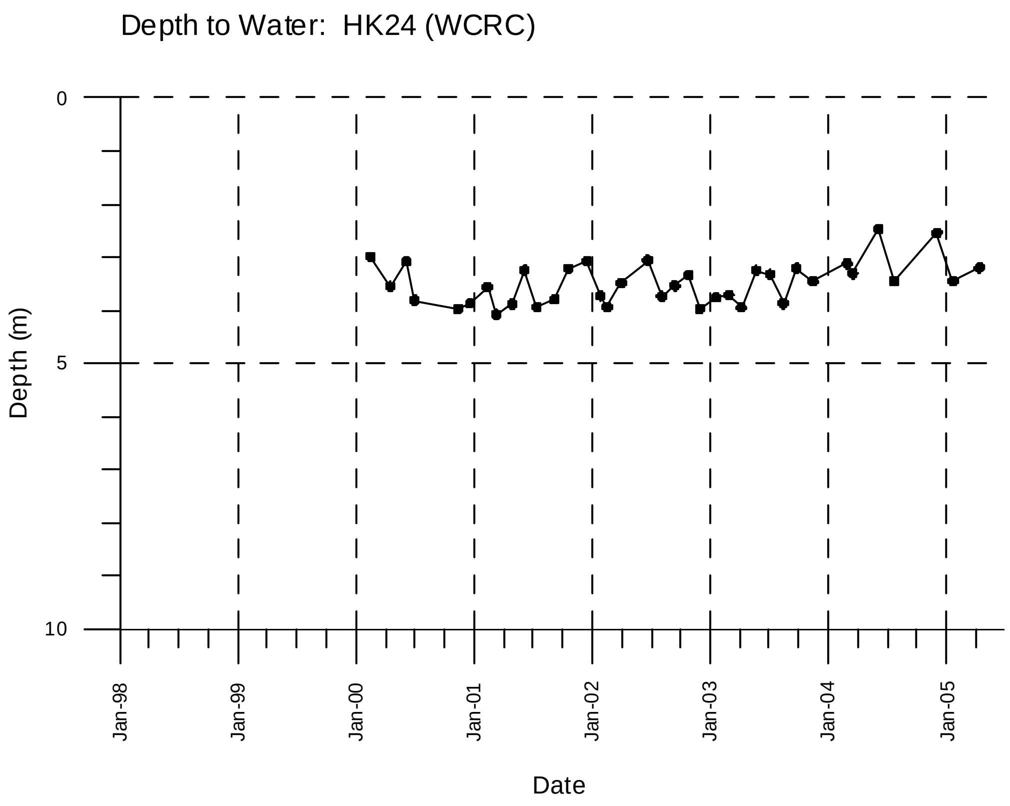


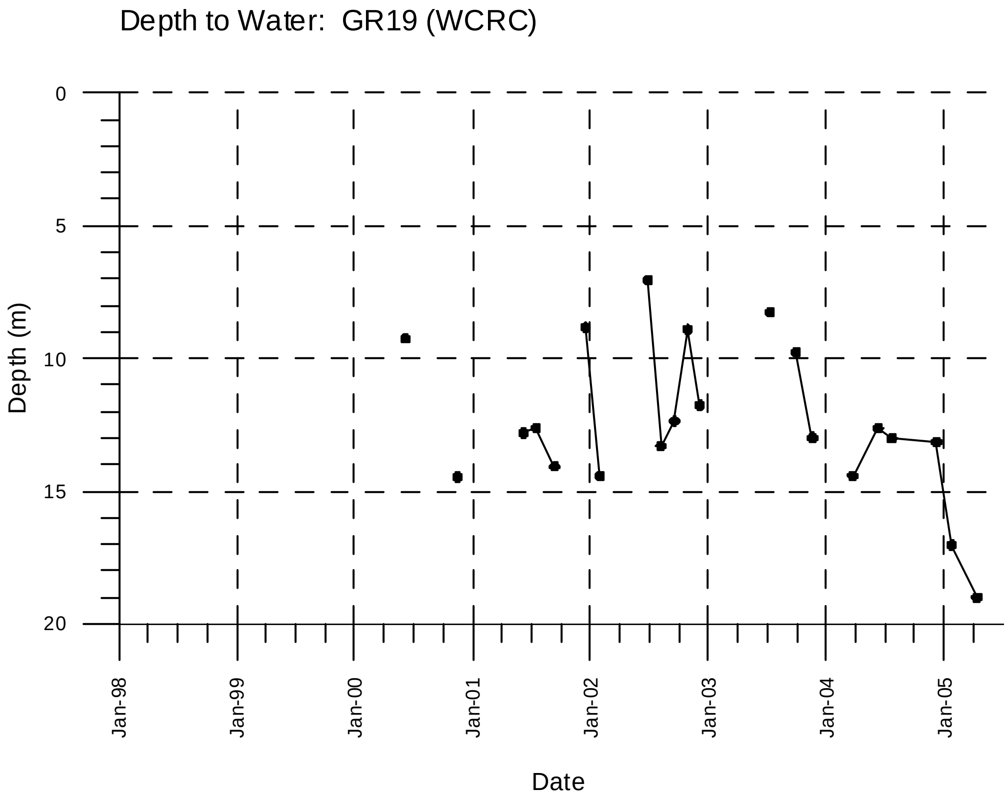
Depth to Water: GR45 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

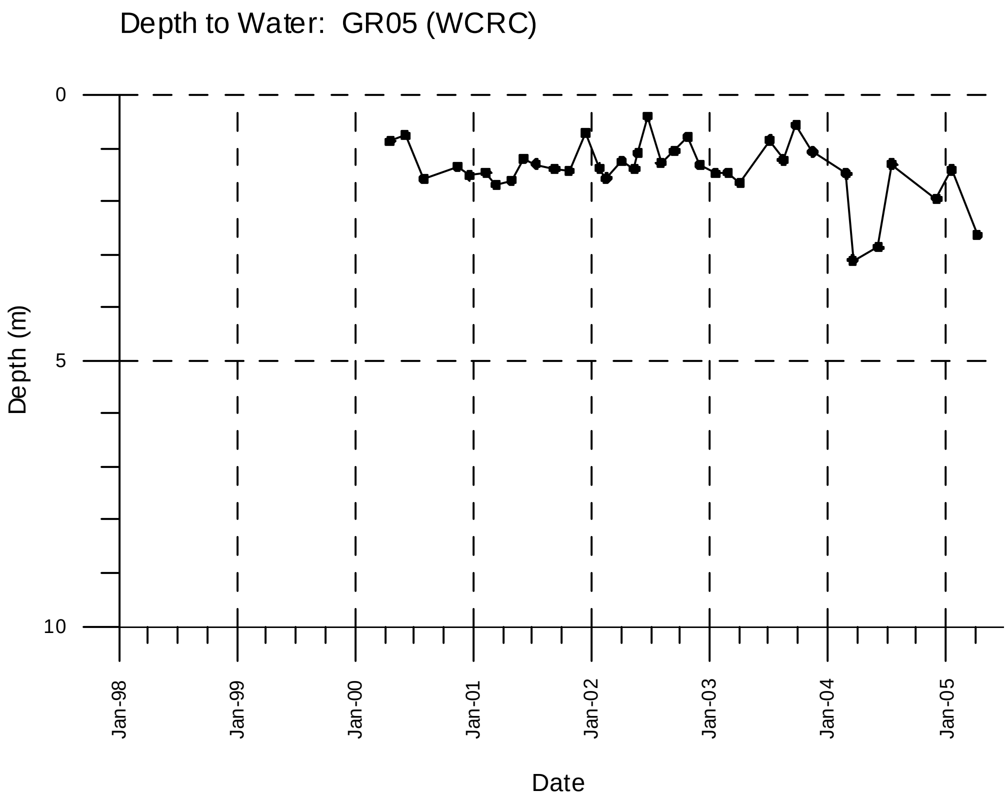

Depth to Water: GR21 (WCRC)
Depth (m)
0
5
10
15
20
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

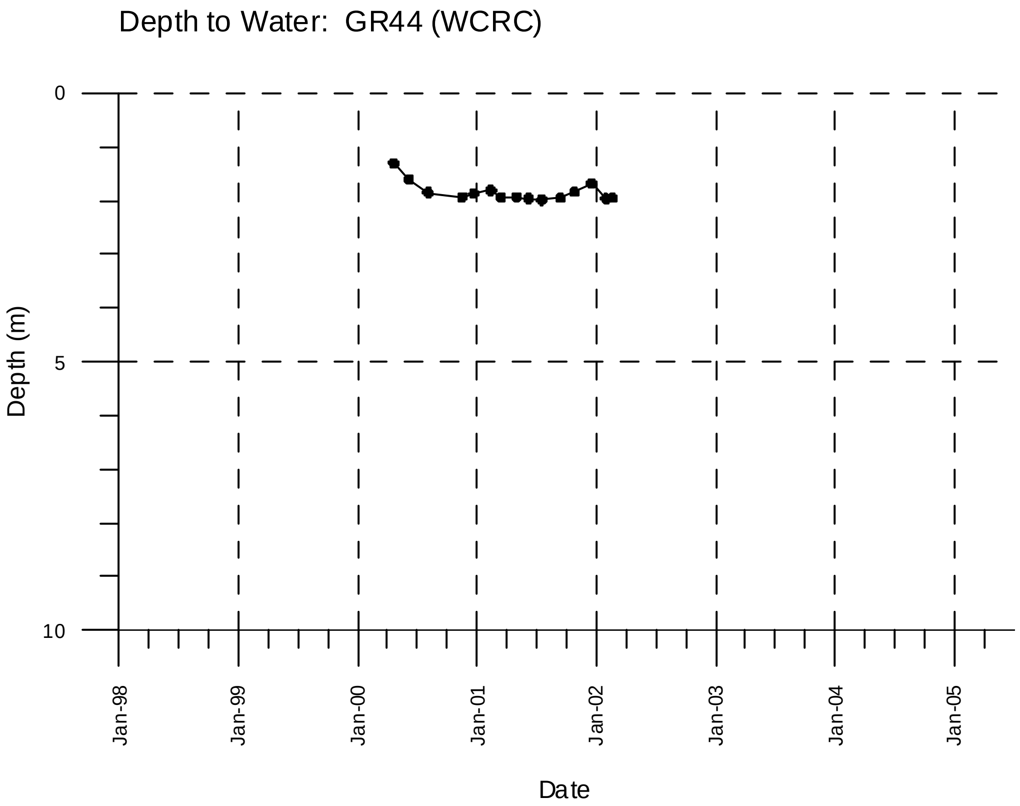

Depth to Water: GR10 (WCRC)
Depth (m)
0
5
10
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

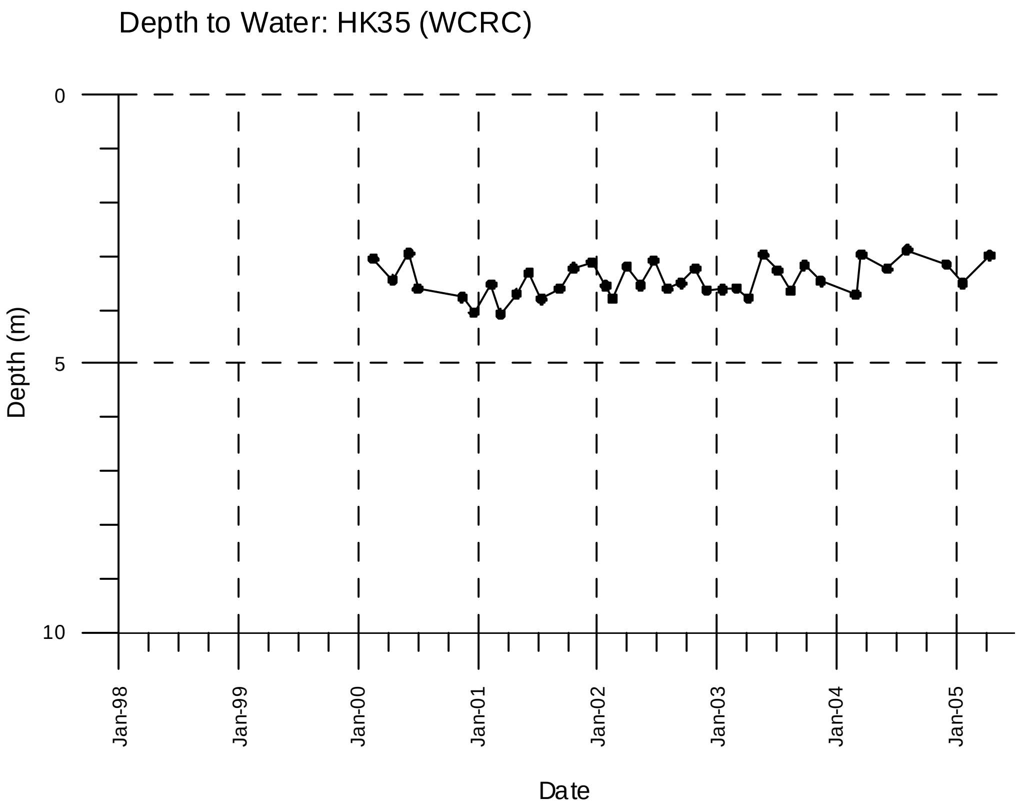

Depth to Water: GR16 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date


Depth to Water: HK24 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

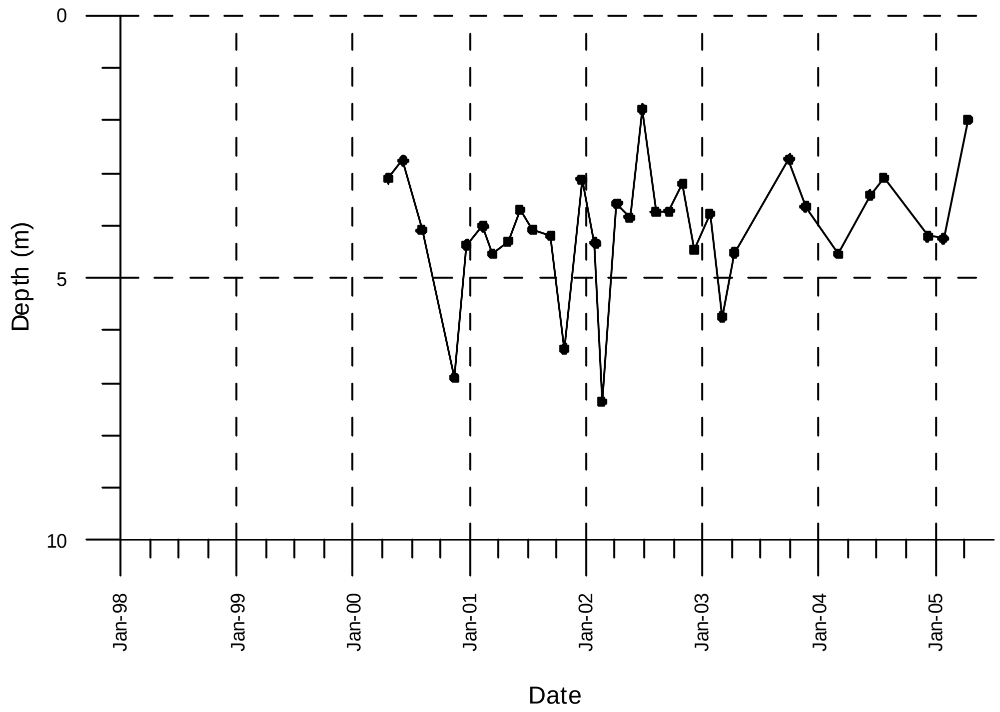

Depth to Water: GR19 (WCRC)
0
5
10
15
20
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date


Depth to Water: GR05 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

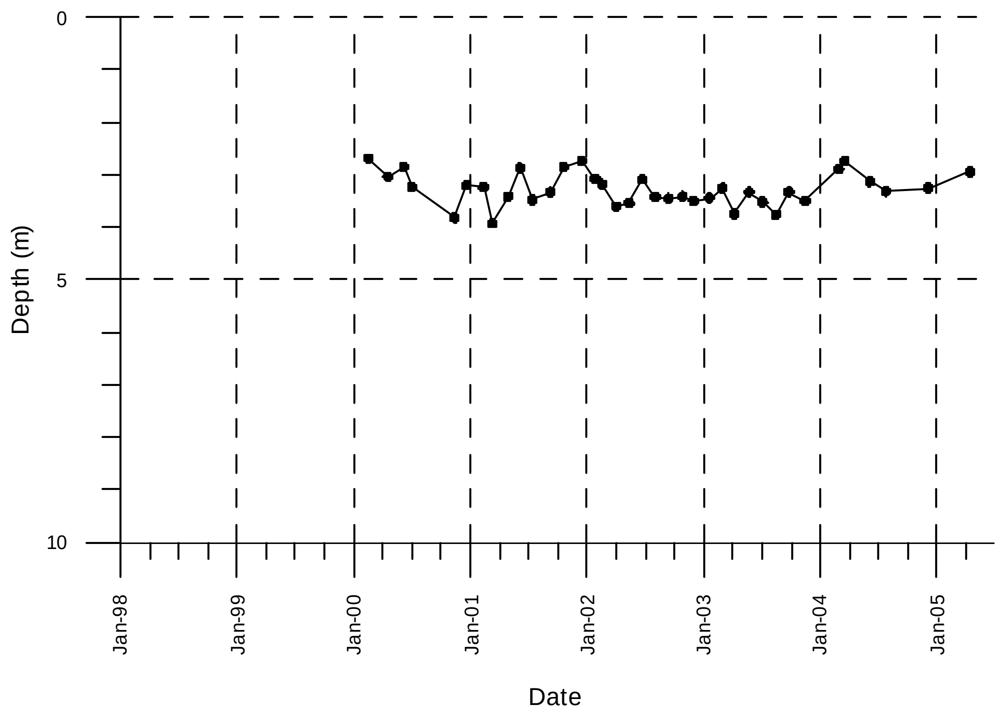

Depth to Water: GR44 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date


Depth to Water: HK35 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

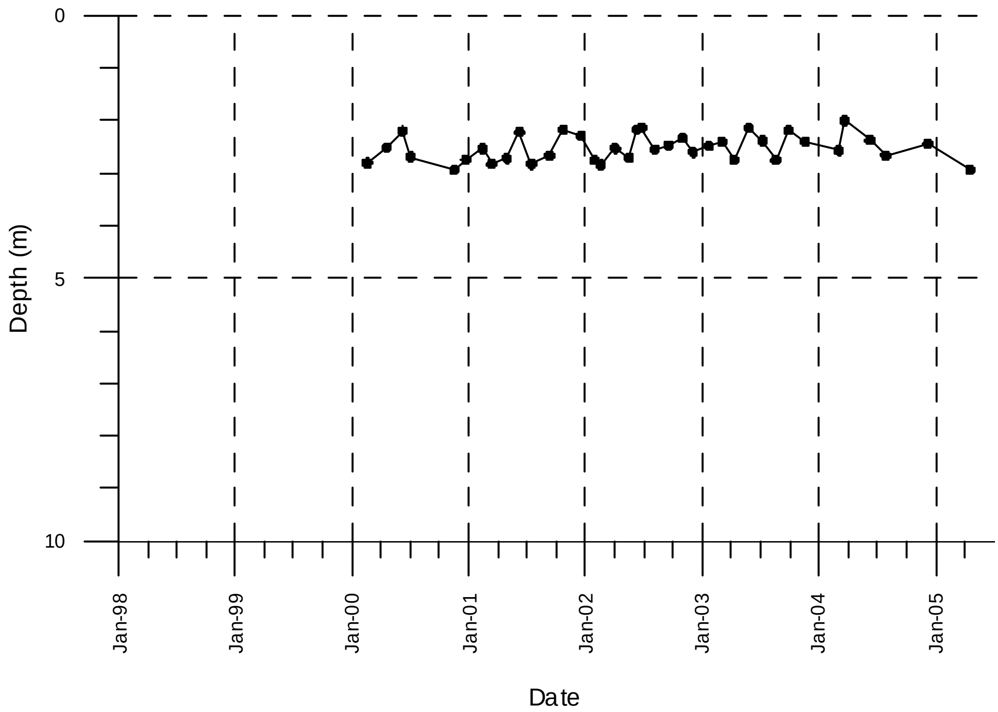
Depth to Water: GR03 (WCRC)



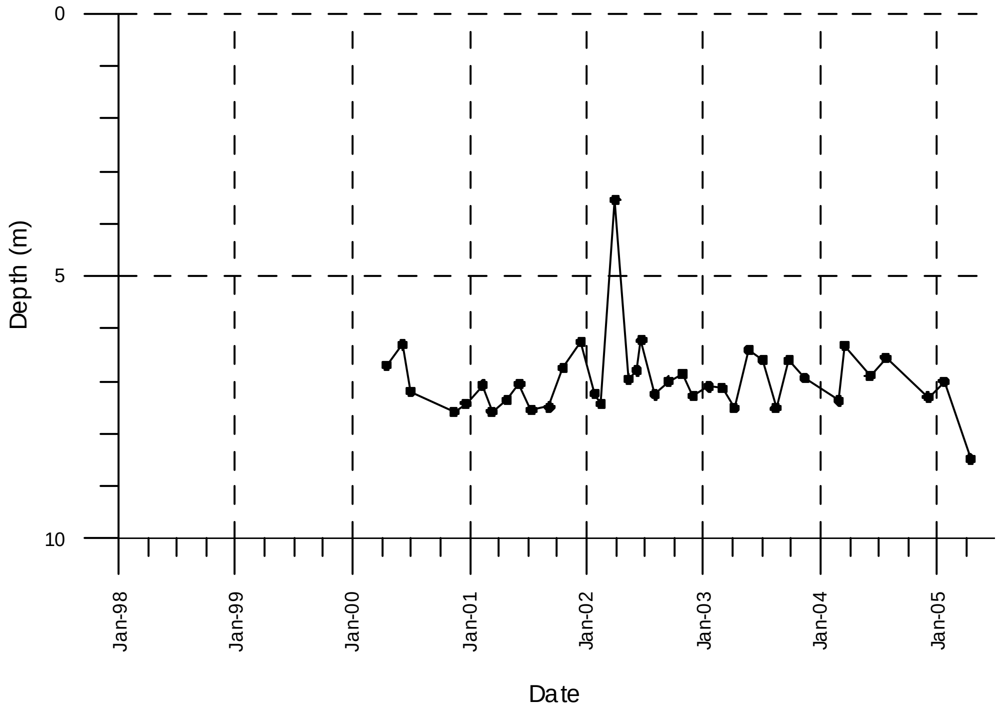
Depth to Water: HK27 (WCRC)

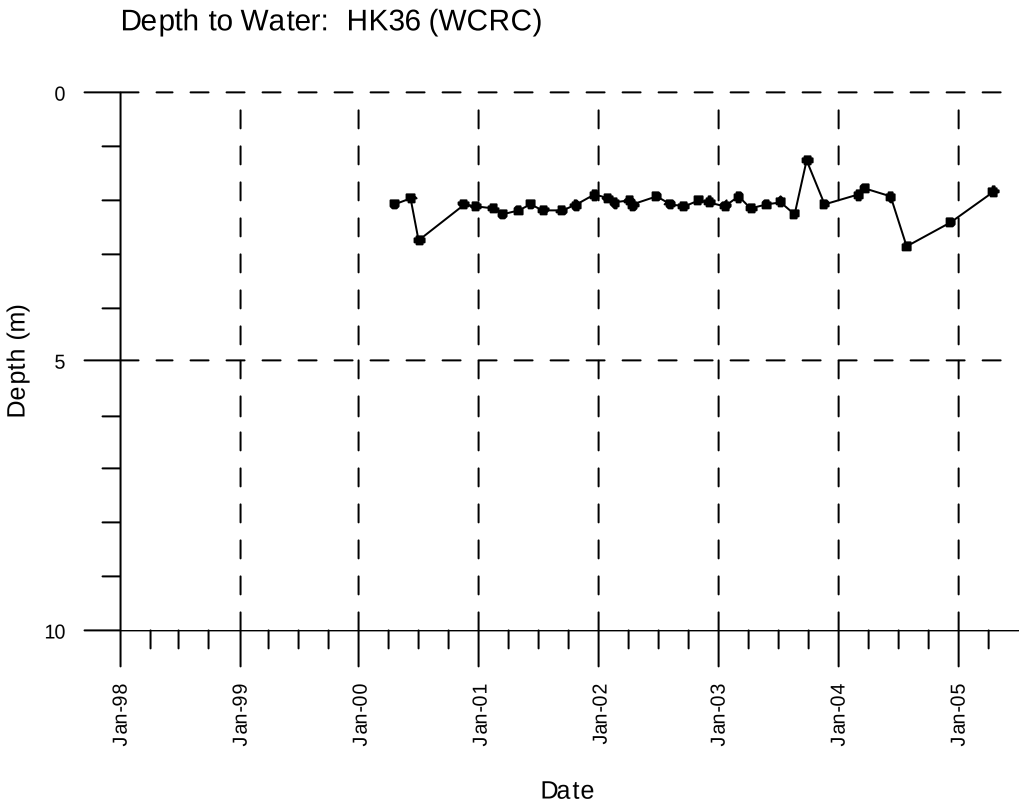


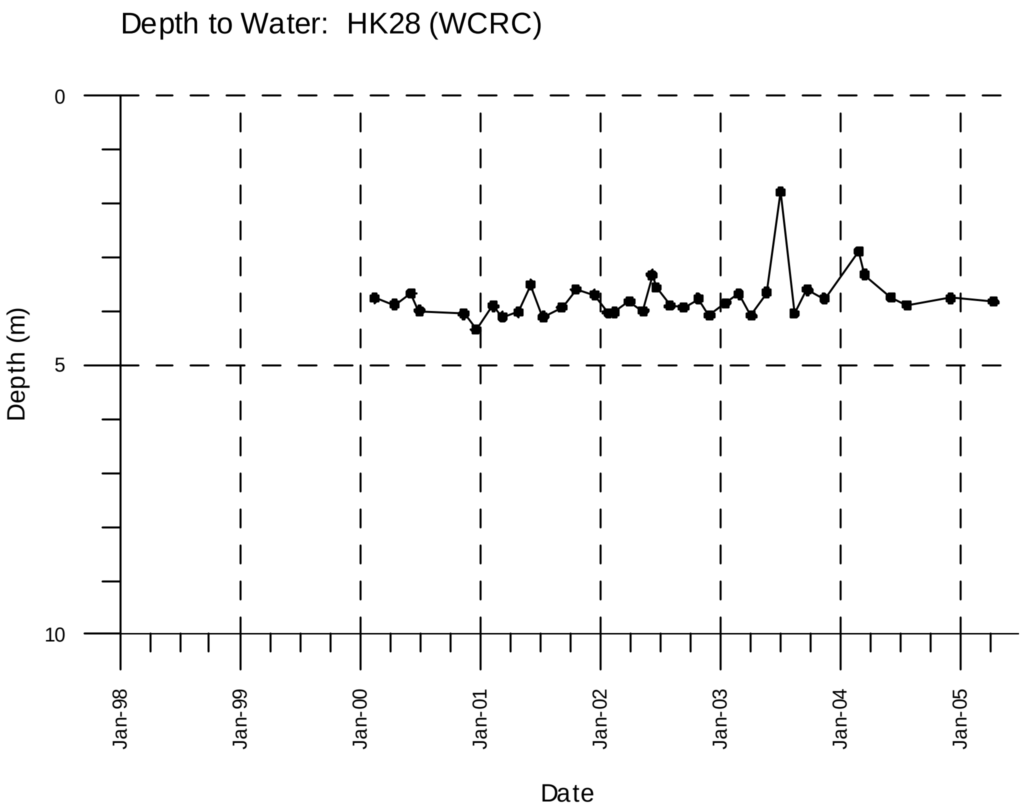
Depth to Water: HK30 (WCRC)

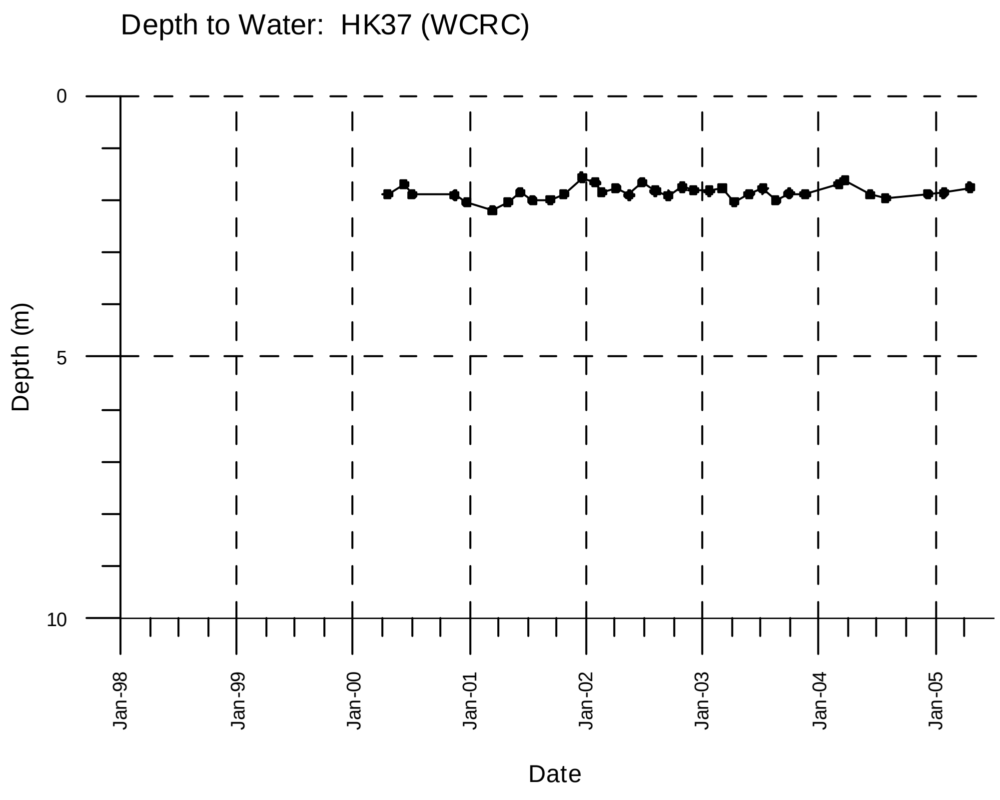


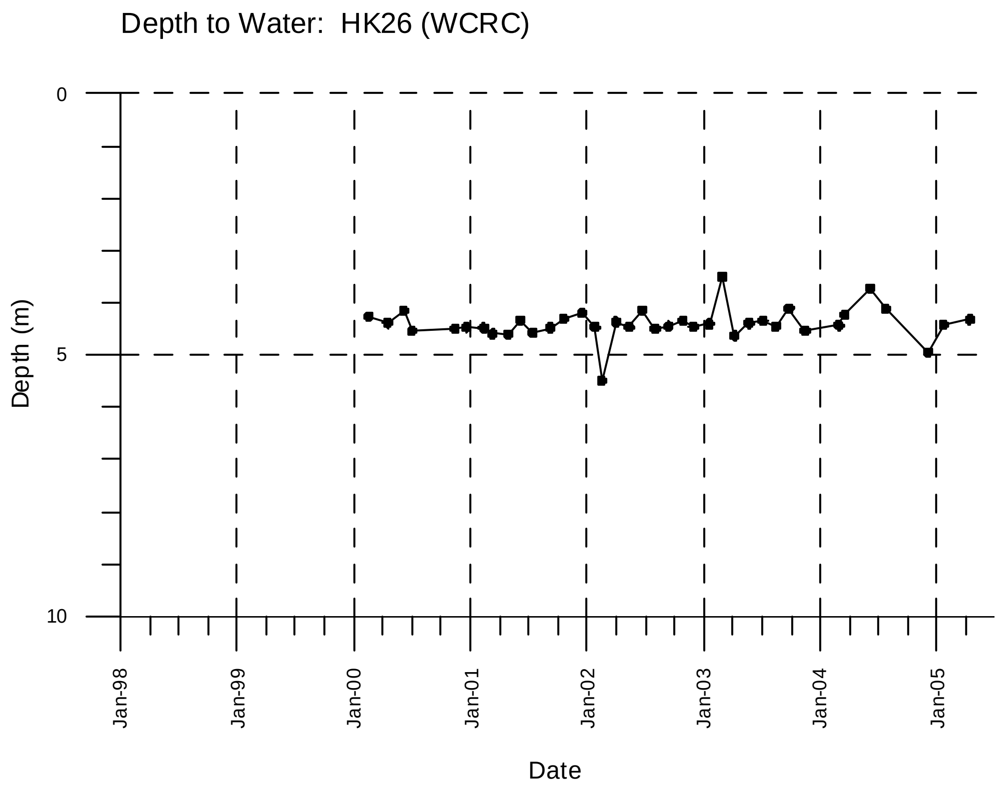
Depth to Water: HK33 (WCRC)

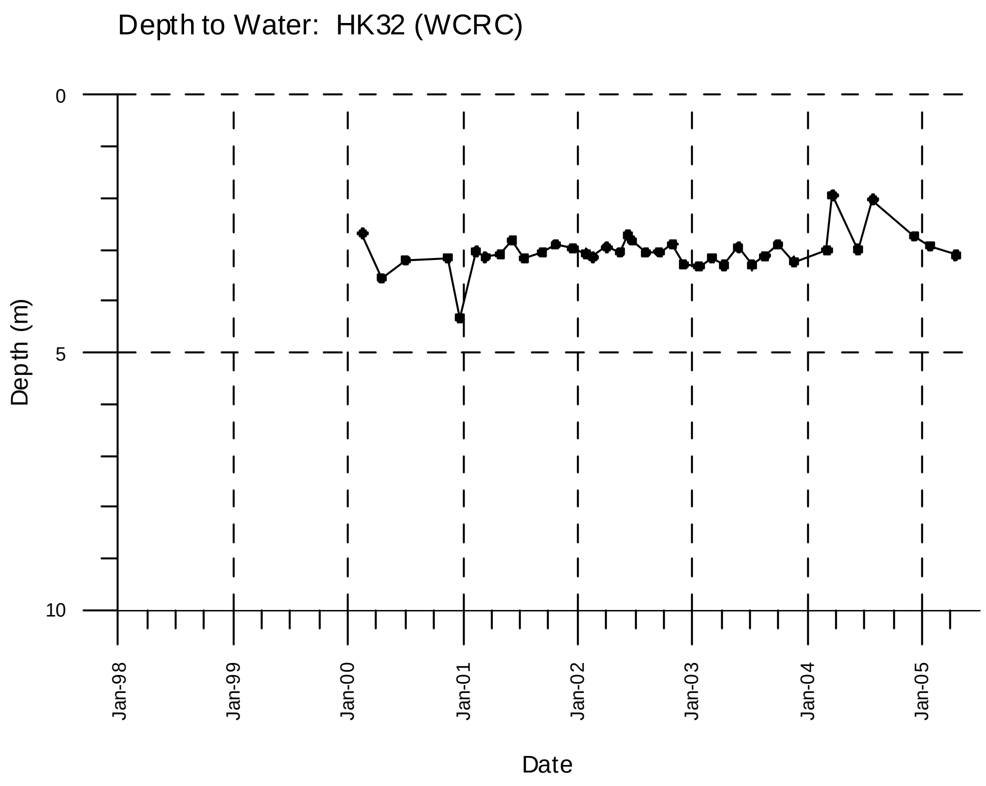


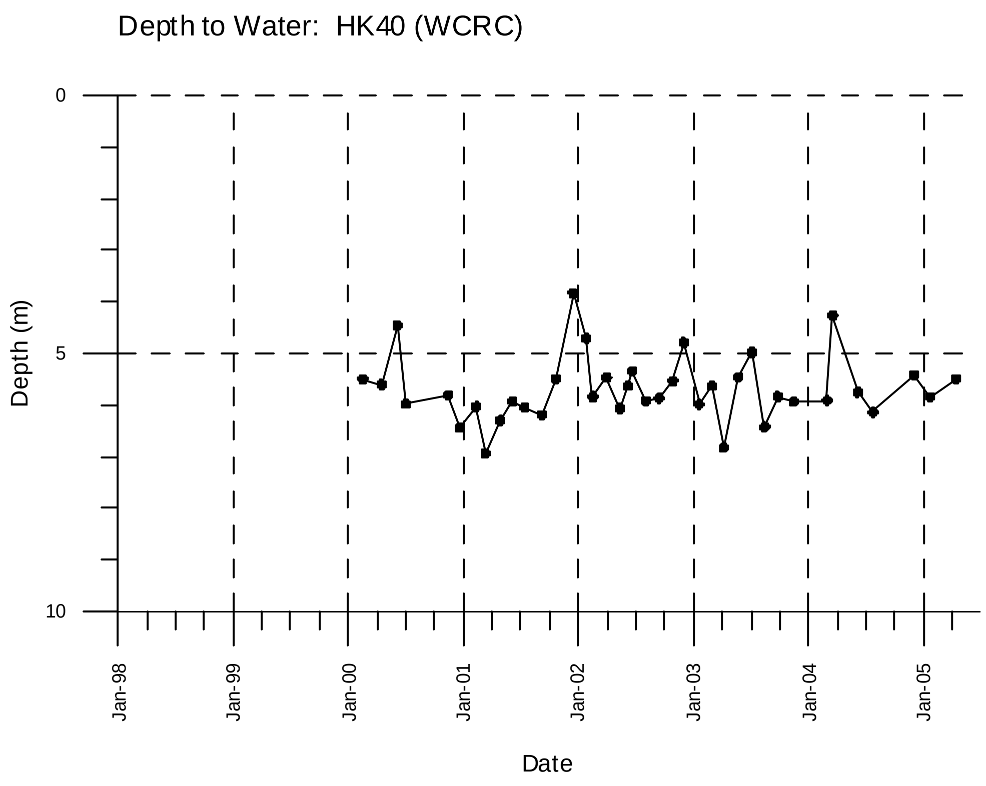

Depth to Water: HK36 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

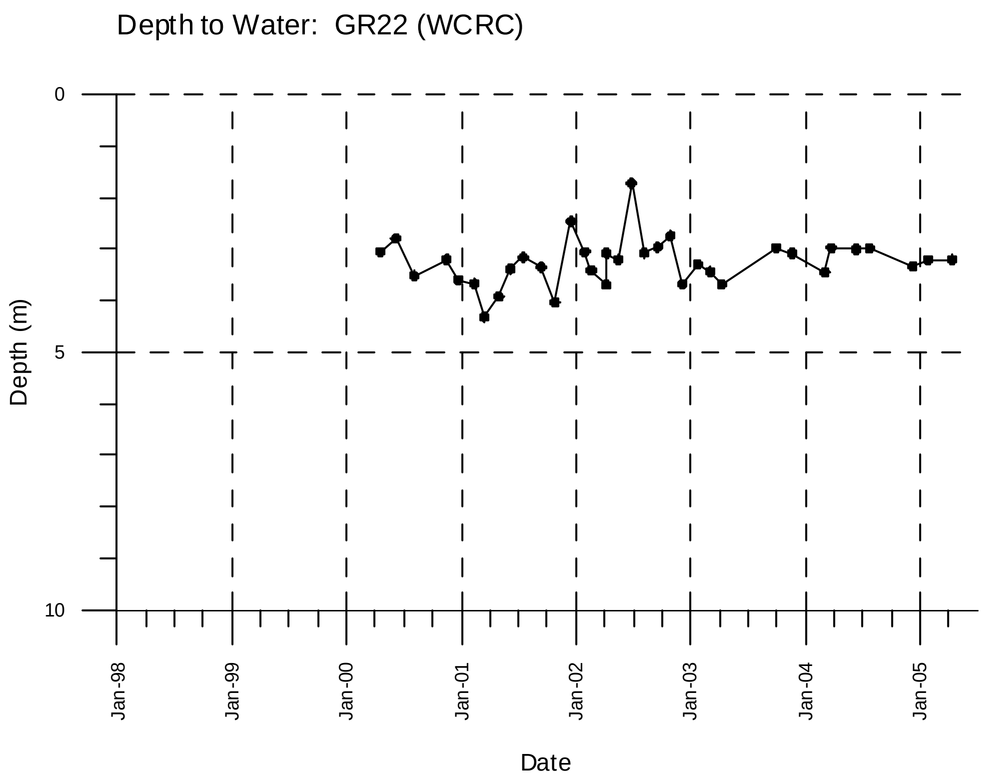

Depth to Water: HK28 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date


Depth to Water: HK37 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date

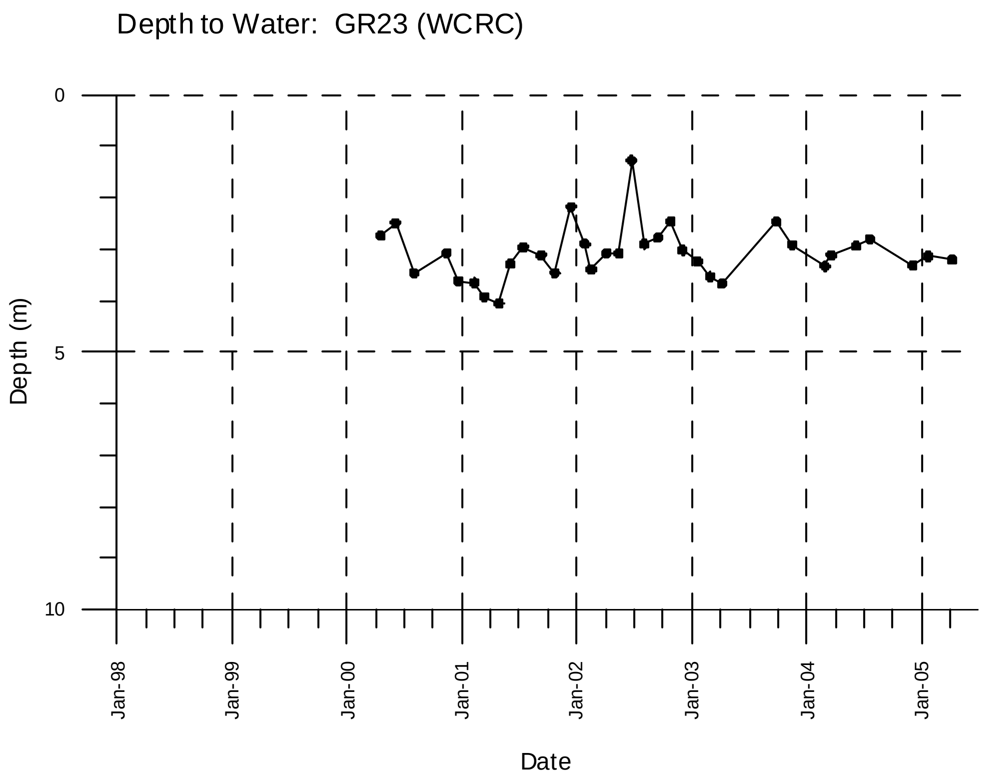

Depth to Water: HK26 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date


Depth to Water: HK32 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date


Depth to Water: HK40 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date



Depth to Water: GR22 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date



Depth to Water: GR23 (WCRC)
0
5
10
Depth (m)
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Date