Water quality study:
Waianakarua River catchment

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Overview

Background

The Otago Regional Council (ORC) is responsible for managing Otago's groundwater and surface-water resources. Although ORC carries out regular and extensive long-term water quality monitoring as part of its State of the environment (SoE) programme, it has not carried out a targeted, short-term monitoring investigation in the Waianakarua River catchment.

Why was this targeted investigation deemed necessary?

This investigation was undertaken to:

- provide a baseline of water quality in the Waianakarua River catchment, including at unaffected (reference) sites.
- compare water quality in the Waianakarua catchment to water quality standards set out in plan change 6A (water quality) (plan change 6A).
- identify any patterns in water quality in the Waianakarua catchment and to relate these to land-use activities, where possible.

What has this study found?

- Both sites in the North Branch had 'very good' water quality. However, water quality in the South Branch declined between the upper site and SH1, and with distance downstream of the confluence, probably because of intensive farming practices.
- Periphyton growth in the South Branch at SH1 and all main stem sites is likely to be phosphorus-limited. However, no nutrient was consistently found to be limiting algal growth at sites in the North Branch and upper South Branch.
- Water quality in the Waianakarua catchment was compared to the receiving water quality standards in plan change 6A. The receiving water quality standard for nitrate-nitrite nitrogen (NNN) (0.075 mg/l) was breached in the South Branch at SH1 and all main stem sites, including Brown's Pump. However, all sites in the catchment are likely to comply with all other standards.
- Benthic cyanobacteria are common in the Waianakarua catchment. Signs are erected at the main public access points warning of the risks that they present to people and animals.
- The Waianakarua River supports a diverse fish community, including several species of conservation concern.

What should be done next?

The results of this study will be used to guide future policy decisions and to promote good practice among the community and other stakeholders to maintain and enhance water quality in the Waianakarua catchment.

Technical summary

The Waianakarua River is a medium-sized river, which rises in the Horse Range and Kakanui Mountains in North Otago. Much of the catchment consists of extensively grazed grasslands and scrub, native forest and plantation forestry. However, the intensification of land use in the lower catchment has the potential to affect water quality in the lower part of the river.

The objectives of this report are to:

- provide a baseline of water quality in the Waianakarua River catchment, including at unimpacted (reference) sites.
- compare water quality in the Waianakarua catchment to water quality standards set out in plan change 6A.
- identify any patterns in water quality in the Waianakarua catchment and to relate these to land-use activities, where possible.

The SoE water quality monitoring site in the Waianakarua River at Brown's Pump showed consistent results between 2001 and 2013, with no trends detected for any of the water quality variables considered. Data on water temperature collected in the Waianakarua River suggests that it provides a highly suitable thermal environment for brown trout and native fish species.

Total nitrogen (TN) and NNN at both sites in the North Branch were very low. TN and NNN concentrations in the upper South Branch were slightly higher, probably due to low nitrogen uptake by algae, as the reach upstream is more heavily shaded than the North Branch sites. TN and NNN concentrations in the South Branch at SH1 were markedly higher than recorded at the upstream site (McKerrow Road, 3.5 km upstream), suggesting that a significant source of nitrogen enters the river between these two sites. Concentrations of TN and NNN increased with distance downstream of the confluence, probably due to intensive farming practices in the lower catchment. Few tributaries enter the lower river, suggesting that nitrogen is entering surface water via leaching to groundwater, then entering the lower river.

Concentrations of dissolved reactive phosphorus (DRP) were generally very low, with the concentration at the majority of samples being below the detection limit at all sites sampled. Nitrogen to phosphorus (N:P) ratios suggest that periphyton in the South Branch at SH1 and all main stem sites are phosphorus-limited. However, ratios in the North Branch and upper South Branch varied markedly, indicating that no one nutrient was consistently limiting algal growth and/or that they may be co-limiting.

Counts of *Escherichia coli (E. coli*) in the catchment were generally low, with the highest median counts observed at the two downstream sites (mid-main stem and Brown's Pump). There was no indication of effluent contamination at any of the sites in the catchment.

Water quality in the catchment was compared to the receiving water quality standards in plan change 6A. The results showed that:

- all sites in the catchment complied with the receiving water quality standards for ammoniacal nitrogen (NH_4-N) (0.1 mg/l) and DRP (0.01 mg/l)
- turbidity readings at Brown's Pump, taken between 2001 and 2013, complied with the standard (5 NTU)
- the receiving water quality standard for NNN (0.075 mg/l) was breached in the South Branch at SH1 and all main stem sites, including Brown's Pump

- the only site to exceed the receiving water quality standard for *E. coli* (260 cfu/100 ml) was the upper South BranchThis was because of one exceptional value, which is likely to be anomalous.

Benthic cyanobacteria were the dominant (or co-dominant) periphyton taxa at Brown's Pump on most sampling occasions. Benthic cyanobacteria have been associated with dog deaths. Warning signs are erected at the main public access points over the spring-autumn period to educate the public about their presence and the risks that they present to people and animals. This is response is appropriate, given the risk benthic cyanobacteria poses, and it should continue.

The macroinvertebrate community at the Brown's Pump site (2007-2013) indicated that water quality was generally 'good' to 'excellent', while, in 2013, sampling at other sites in the Waianakarua River also indicated 'good' to 'excellent' water quality. Macroinvertebrate community index (MCI) scores in the main stem sites declined from the confluence to Brown's Pump, which is consistent with the decline in water quality (increasing TN, NNN and *E. coli*) observed in the main stem.

The Waianakarua River supports a diverse fish community, with 14 species collected, including seven species classified as 'at risk' and 'declining' under the New Zealand Freshwater Fish Threat Classification. These are the longfin eel, torrentfish, inanga, koaro, lamprey, bluegill bully and redfin bully.

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1 Introduction

The Waianakarua River is a medium-sized river, which rises in the Horse Range and Kakanui Mountains in North Otago. Much of the catchment consists of extensively grazed grasslands and scrub, native forest and plantation forestry. However, the intensification of land use in the lower catchment, with two dairy farms operating near the mouth of the river and proposals for further intensification of land use in areas upstream of State Highway (SH) 1, has the potential to affect water quality in the lower part of the river.

The objectives of this report are to:

1. provide a baseline of water quality in the Waianakarua River catchment, including at unimpacted (reference) sites

2. compare water quality in the Waianakarua catchment to water quality standards set out in plan change 6A

3. identify any patterns in water quality in the Waianakarua catchment and to relate these to land-use activities, where possible.

2 Background information

2.1 Catchment description

The Waianakarua River consists of three branches - South, Middle and North - and has a total catchment area of 262 km^2. The headwaters of the South (35 km^2) and Middle branches (69 km^2) arise in the Horse Range and join about 6 km upstream of SH1 (Figure 2.1). The North Branch (catchment area: 142 km^2) arises in the eastern Kakanui Mountains and joins the South Branch about 1 km downstream of SH1, before entering the Pacific Ocean a further 6 km downstream (Figure 2.1).

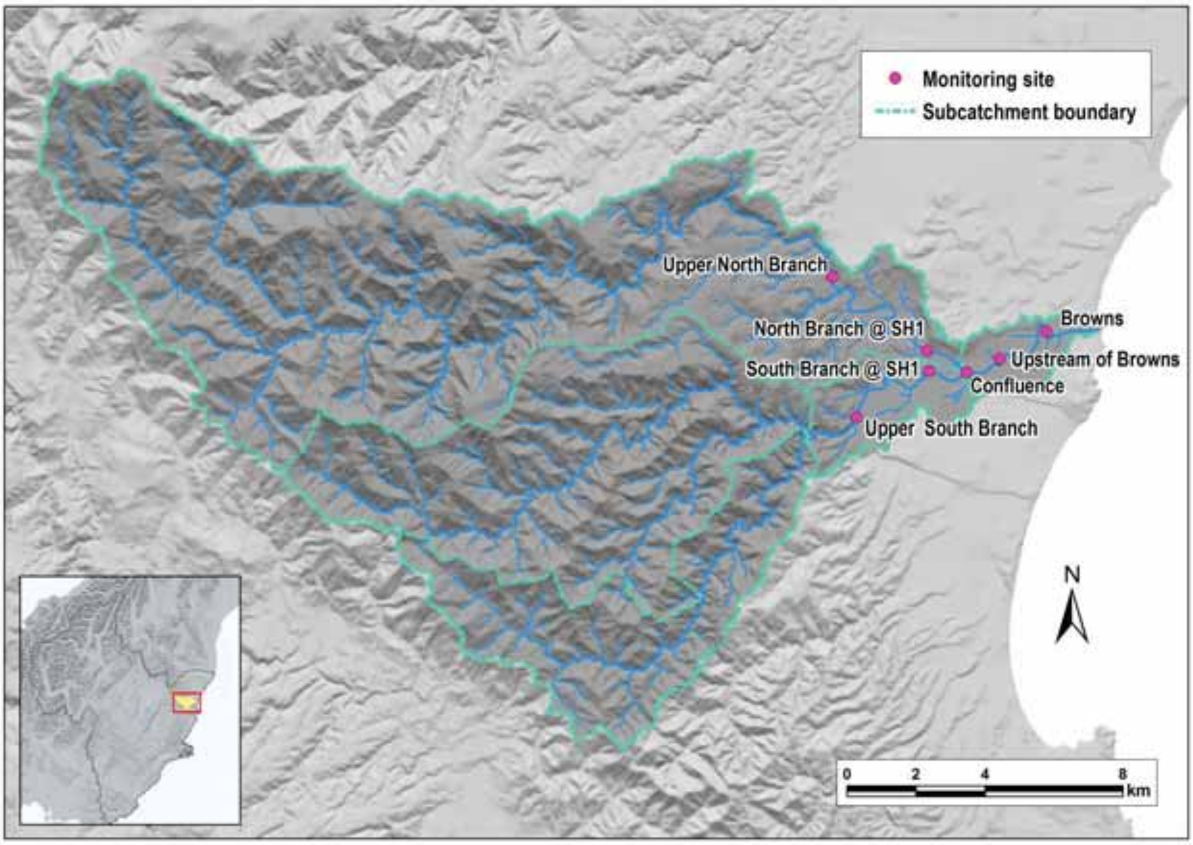

Figure 2.1 Map of the Waianakarua catchment showing monitoring sites and sub-catchment boundaries

2.1.1 *Climate*

The climate within the Waianakarua catchment is classified as either ‘cool-dry’ (mean annual temperature <12°C, mean annual effective precipitation ≤500 mm) or ‘cool-wet’ (mean annual temperature <12°C, mean annual effective precipitation 500-1500 mm) (River Environment Classification, Ministry for the Environment & NIWA, 2004). There is a strong gradient in rainfall within the catchment, with an excess of a metre of rain falling in the higher elevation areas in the upper catchment (

Table 2.1, Figure 2.2). The mean annual air temperature at Herbert Forest (1981-2010) was 10.4°C (Figure 2.2).

Table 2.1 Monthly rainfall statistics (minimum, mean, maximum) for The Dasher, Grandview and Glenrowan

	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Kauru at The Dasher (E2327200 N5556500)													
Mean	91	83	45	54	45	43	67	53	54	63	59	72	**722**
Min.	20	10	8	8	18	8	9	9	10	22	19	12	**473**
Max.	552	346	113	136	99	172	197	342	208	124	120	150	**1159**
Kakanui at Grandview (E2357000 N5561400)													
Mean	55	48	38	41	48	38	42	49	40	41	48	63	**548**
Min.	11	11	5	1	9	9	10	4	4	7	16	0	**355**
Max.	139	149	165	129	226	134	123	194	96	104	103	126	**798**
Kakanui at Glenrowan (E2340800 N5555700)													
Mean	63	60	49	51	54	39	48	48	37	45	47	56	**602**
Min.	15	12	6	10	7	5	8	6	9	7	7	0	**376**
Max.	195	197	211	142	277	149	125	280	111	112	100	127	**933**

Table 2.2 Mean temperature statistics (mean, minimum daily, maximum daily) for Herbert Forest (NZTM E1425422 N4987563) weather station between 1981 and 2010

	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Herbert Forest													
Mean	15.2	14.6	13.3	10.8	8.5	6.0	5.4	6.7	8.8	10.5	11.8	13.7	**10.4**
Min	9.4	9.0	7.6	4.7	2.9	0.6	-0.1	0.9	2.9	4.8	6.0	8.3	**4.8**
Max	20.9	20.3	19.1	16.9	14.0	11.5	11.0	12.5	14.7	16.2	17.7	19.0	**16.2**

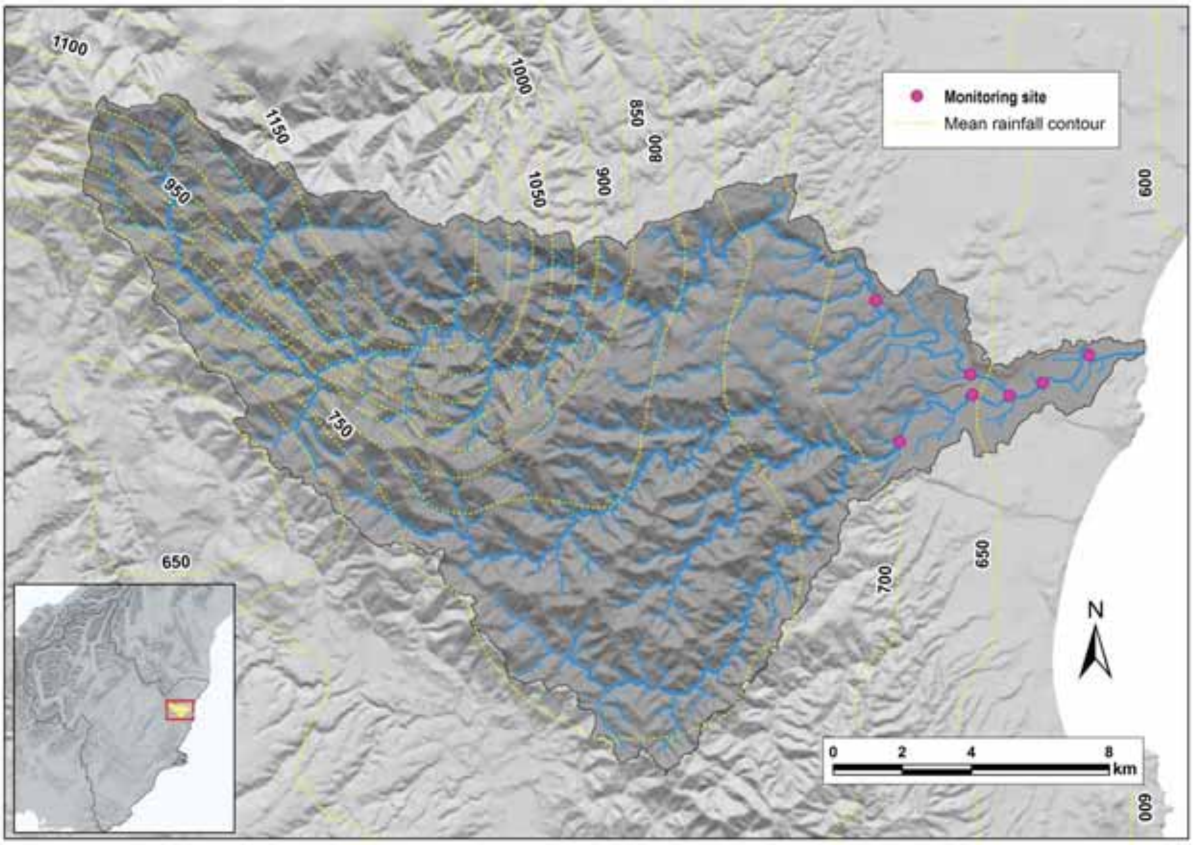

Figure 2.2 The pattern of rainfall within the Waianakarua catchment

2.1.2 Geology

The geology of the upper Waianakarua catchment consists mainly of semischist (Forsyth 2001). Some sandstones and mudstones are present in the lower catchment, just upstream of SH1, although alluvium overlies basement rock in most of the lower catchment (Forsyth 2001). An area of igneous rocks (Deborah volcanics) is located immediately to the north of Waianakarua Road, although most of this drains into the Bow Alley Creek catchment (Forsyth 2001).

2.1.3 Geomorphology

All three branches of the upper Waianakarua River consist of confined, meandering channels cutting into schist bedrock, with a mixed gravel and bedrock bed (ORC, 2008). In the lower catchment, the channel is mostly a mobile single-thread, with some partially braided sections incised into an elevated gravel floodplain (ORC, 2008). Gravel extraction takes place in several locations in the North Branch (Sharpes Bend and upstream of Graves Dam), a 1 km section of the South Branch upstream of the SH1 bridge, and at two locations downstream of the confluence of the North and South branches (ORC, 2008). Historical river management activities have included channel realignment and willow planting (ORC, 2008).

2.1.4 Catchment land cover

Vegetation cover in the upper catchment is mainly tussock and scrub, much of which is extensively grazed (Figure 2.3). Much of the catchments of the Middle and South branches consist of mixed native bush, with some plantation forestry in the hill country immediately to the west of SH1 (Figure 2.3). In comparison, the catchment of the North Branch consists of a greater proportion of plantation forestry, although with substantial areas of native bush and scrub (Figure 2.3). Much of the intensive agriculture in the catchment occurs in the lower catchment between SH1 and the coast, with some areas on the alluvial terraces to the south of the Middle Branch (Figure 2.3).

Most of the land administered by the Department of Conservation in the Waianakarua catchment is present in the Middle (35.6 km^2) and South branches (10.3 km^2), representing about 52% of the total land area in the Middle Branch and 30% of the total land area in the South Branch. In comparison, there is little conservation land present in the North Branch (0.3 km^2, 0.2% of the total land area).

2.2 Hydrology and water use

2.2.1 Hydrology of the Waianakarua River

The mean flow in the Waianakarua River at Brown's Pump is 2,223 l/s, while the median flow is 783 l/s (ORC, unpublished data). The lowest recorded 7-d low flow was 107 l/s, recorded in March 2010.

2.2.2 Minimum flow site and water allocation

Minimum flows for the whole of the catchment are set at Brown's Pump. The minimum flow at this site is 300 l/s. Total current water allocation for the Waianakarua catchment is 189 l/s, meaning that it is currently over-allocated by 39 l/s, based on the default catchment allocation rule.

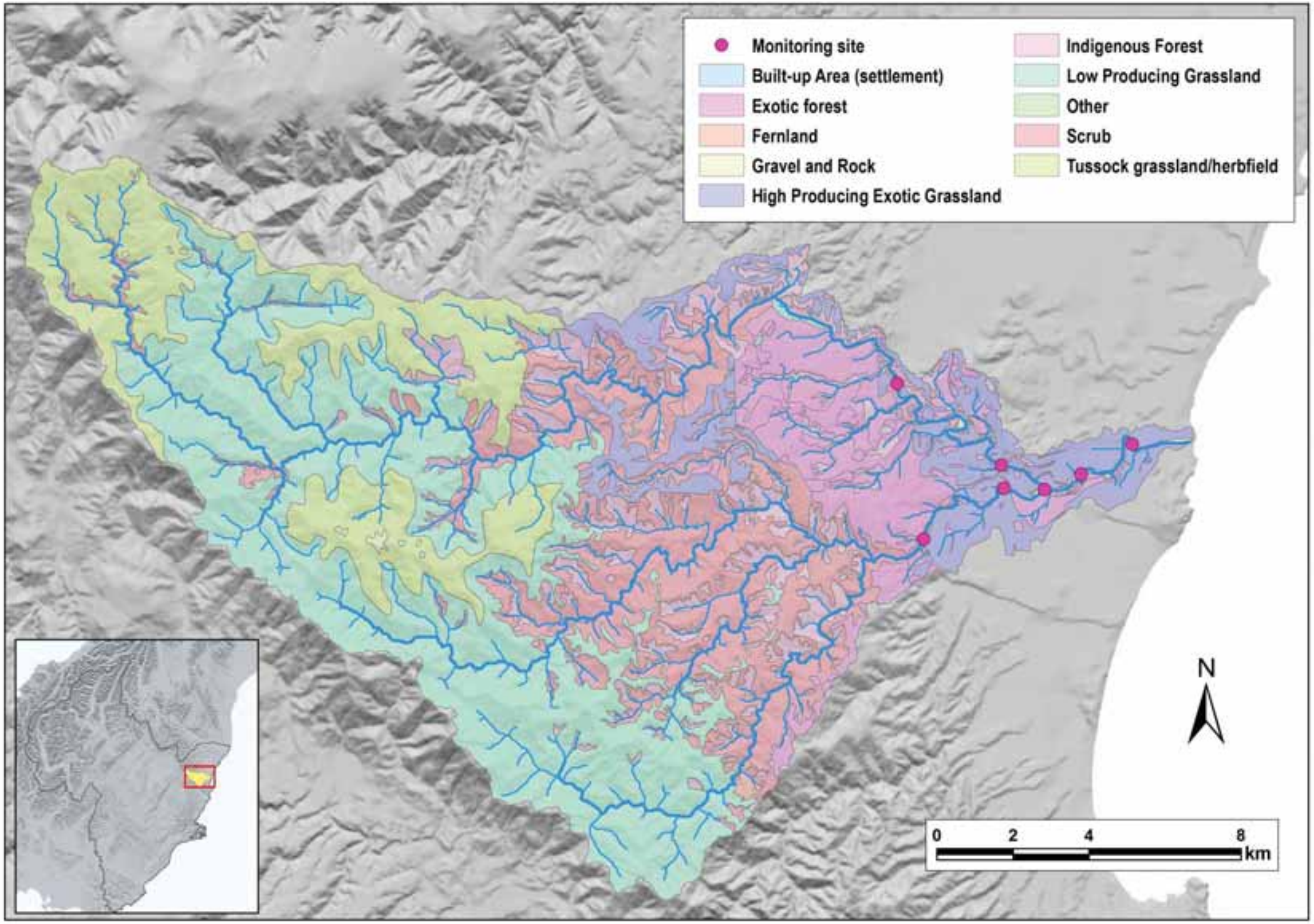

Figure 2.3 Land cover of the Waianakarua catchment, based on the Land Cover Database (Version 3)

3 Regional planning

3.1 Water quality guidelines –plan change 6A

Plan change 6A was notified on 20 March 2013 and sets out numerical water quality standards for all catchments in the Otago region (Schedule 15). It establishes limits for all discharges to lakes, rivers, wetlands and drains into two discharge limit areas (Schedule 16). The Waianakarua catchment is in receiving water group 2. The numerical water quality standards for this group are outlined in Table 3.1.

The receiving water standards outlined in Table 3.1 are applied as 5-year, 80th percentiles when flows are at or below median flow (0.783 m^3/s), with the flows in the Waianakarua catchment being set at the gauging site at Brown's Pump.

Table 3.1 Receiving water numerical standards and timeframe for achieving 'good' water quality in the Waianakarua catchment

	Nitrate-nitrite nitrogen	**Dissolved reactive phosphorus**	**Ammoniacal nitrogen**	***Escherichia coli***	**Turbidity**
Numerical standard	0.075 mg/l	0.01 mg/l	0.1 mg/l	260 cfu/100 ml	5 NTU
Timeframe	31 March 2012	31 March 2012	31 March 2012	31 March 2012	31 March 2012

4 Sampling and analysis methods

4.1 Monitoring sites

ORC's SoE monitoring network includes one site on the Waianakarua River at Brown's Pump, where water quality monitoring has been undertaken since 4 August 1999 (

Table 4.1, Figure 2.1). A further six sites were monitored between 26 July 2012 and 15 April 2013, as part of this study (

Table 4.1, Figure 2.1).

Table 4.1 Location of sites monitored during this study, with the types of sampling undertaken at each site

Monitoring site	Location	Easting	Northing	Distance from ocean (km)	WQ	Invert	Fish
Brown's Pump	Brown's Pump	1430610	4986676	1.6	Y	Y	Y
Mid-main stem	1 km downstream of confluence, 2 km upstream of Browns Pump	1429264	4985892	4.0	Y	Y	N
Confluence	200 m downstream of confluence of North and South Branches	1428305	4985506	5.3	Y	Y	Y
South Branch at SH1	South Branch between SH1 and railway bridge	1427233	4985531	6.5	Y	Y	Y
Upper South Branch	South Branch at end of McKerrow Rd	1425123	4984193	10.2	Y	Y	Y
North Branch at SH1	North Branch between SH1 and railway bridge	1427169	4986122	6.7	Y	Y	Y
Upper North Branch	At ford on Cosy Dell Rd	1424416	4988274	12.8	Y	Y	Y

Water quality samples were collected from each of the seven monitoring sites every fortnight between 26 July 2012 and14 April 2013. These samples were analysed for total nitrogen (TN), nitrate-nitrite nitrogen (NNN), ammoniacal nitrogen (NH_4-N), total phosphorus (TP), dissolved reactive phosphorus (DRP), suspended solids (SS) and *Escherichia coli* (*E. coli*). These analyses were conducted by Hill Laboratories (Hamilton, www.hill-labs.co.nz).

The concentration of total SS was determined by filtration (nominal pore size of 1.2-1.5 µm) and gravimetric determination (following Method 2540D, APHA 21st edition, 2005). The detection limit for this analysis was 3 g/m^3.

NNN was determined by automated cadmium reduction on a flow injection analyser (Method 4500-NO_3^- I, APHA 21st edition, 2005), with a detection limit of 0.002 mg/l. Total NH_4-N was determined by phenol/hypochlorite colorimetry, using a discrete analyser after filtration (Method 4500-NH_3 F (modified from manual analysis), APHA 21st edition, 2005), with a detection limit of 0.010 mg/L. Total Kjedahl nitrogen (TKN) was determined after copper sulphate digestion with copper sulphate catalyst by phenol/hypochlorite colorimetry, using a discrete analyser (Method 4500-N_{org} (modified), 4500-NH_3 F (modified), APHA 21st edition, 2005) with a detection limit of 0.10 mg/L. TN was calculated by summing NNN + TKN, with a detection limit of 0.05 mg/L.

DRP was determined by molybdenum blue colorimetry, using a discrete analyser after filtration (Method 4500-P E (modified from manual analysis, APHA 21st edition, 2005)), with a detection limit of 0.004 mg/L. TP was determined using ascorbic acid colorimetry on a discrete analyser (Method 4500-P B & E (modified), APHA 21st edition, 2005, with modification from National Water and Soil Conservation Organisation 1982, after acid persulphate digestion). This analysis had a detection limit of 0.004 mg/L.

E. coli counts were determined after membrane filtration by count on m-FC agar, which was incubated at 44.5°C for 22 hours (Method 9222, APHA 22nd edition, 2012). The detection limit was 1 cfu/100 mL.

4.1.1 Effluent contamination

AgResearch has developed the following equation, based on the concentrations of phosphorus, *E. coli* and NH_4-N (AgResearch 2011), to identify effluent contamination of surface water:

$$\text{Effluent score} = e^{0.13 \cdot Ln(E.coli+1)+0.14 \cdot Ln(NH_4-N+0.005)+0.57(TP+0.0025)}$$

Values exceeding 1.554 indicate the presence of effluent contamination in surface waters.

4.2 Data presentation

Where sufficient water quality data were available, they were presented as box plots, as these provide information on distribution (Figure 4.1).

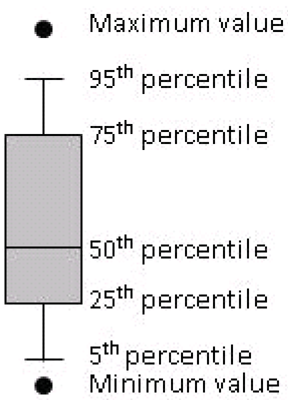

Figure 4.1 The interpretation of the various components of a box plot, as presented in this report

5 Habitat assessment

At each sampling site, instream and riparian habitats were assessed following Protocol P2 of Harding *et al.* (2009). Instream assessments included assessment of the length of meso-habitats (rapid/run/riffle/pool/backwater/other), pool morphology (max. depth, sediment depth and crest depth), channel cross-section profile, substrate composition, macrophyte cover, periphyton cover, cover by woody debris and leaf packs, and percentage of bank cover (Field forms P2b & c). Riparian assessments also included the width and intactness of buffers, vegetation composition, bank stability and livestock access to riparian areas (Field form P2d).

6 Biological assessment

6.1 Periphyton

6.1.1 Field methods

Periphyton community composition was monitored at two sites as part of SoE monitoring. Algal samples were collected by selecting three stones at each site, taken from one-quarter, one-half and three-quarters of the stream width. At each collection point, a stone was randomly selected and removed to the river bank. A 5 cm x 5 cm (0.0025 m^2) area of each stone surface was scrubbed with a small brush into a tray and rinsed with river water. The scrubbings from the three stones were pooled and transferred to a sample container using river water. The sample was transported to the laboratory and preserved in formaldehyde.

6.1.2 Laboratory analysis

Each sample was thoroughly mixed, and three aliquots were removed to an inverted microscope settling chamber. They were then allowed to settle for 10 minutes. Samples were analysed according to the ‘relative abundance using an inverted microscope’ method outlined in Biggs and Kilroy (2000). Samples were inspected under 200-400x magnification to identify algal species present using the keys of Biggs and Kilroy (2000), Entwisle *et al*. (1988) and Moore (2000). Algae were given an abundance score ranging from 1 (rare) to 8 (dominant), based on the protocol of Biggs and Kilroy (2000). Internal quality assurance procedures were followed.

6.2 Macroinvertebrates

Aquatic macroinvertebrates are organisms that live on or within the beds of rivers and streams. Examples include insect larvae (e.g. mayflies, stoneflies, caddisflies and beetles), aquatic oligochaetes (worms), snails and crustaceans (e.g. amphipods and crayfish). Macroinvertebrates are useful for assessing the biological health of a river because they are found everywhere, vary in their tolerance to temperature, dissolved oxygen, sediment and chemical pollution and are relatively long lived (taking six months to two years to complete their life-cycle). Therefore, the presence or absence of such taxa can provide significant insight into long-term changes in water quality.

Macroinvertebrate communities were sampled at seven sites in the Waianakarua River in March 2013. At each site, one extensive kick-net sample was collected, following Protocol C2, ‘hard-bottomed, semi-quantitative sampling of stream macroinvertebrate communities’ (Stark *et al.*, 2001), which requires sampling a range of habitats, including riffles, mosses, wooden debris and leaf packs. Samples were preserved in 90% ethanol in the field and returned to a laboratory for processing. Following Protocol P1, ‘semi-quantitative coded abundance’, macroinvertebrate samples were coded into one of five abundance categories: rare (1-4), common (5-19), abundant (20-99), very abundant (100-499) or very, very abundant (500+).

In the laboratory, the samples were passed through a 500 µm sieve to remove fine material. The sieve contents were then placed onto a white tray, and the macroinvertebrates were identified under a dissecting microscope (10-40X), using the identification key of Winterbourn *et al.* (2000).

The indices commonly used to measure stream health are summarised below:

- **Species richness** is the total number of species (or taxa) collected at a sampling site. In general terms, high species richness may be considered 'good'; however, mildly impacted or polluted rivers, with slight nutrient enrichment, can have higher species richness than unimpacted, pristine streams.
- **Ephemeroptera plecoptera and trichoptera (EPT) richness** is the sum of the total number of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) species collected. These insects are often the most sensitive to organic pollution; therefore, low numbers might indicate a polluted environment. Comparing the percentage of EPT species to the total number of species found at a site can give an indication of the importance of these species in the overall community.
- **Macroinvertebrate community index (MCI)** uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream. Taxa are assigned scores of between 1 and 10, depending on their tolerance. A score of 1 represents taxa that are highly tolerant of organic pollution, while 10 represents taxa that are sensitive to organic pollution. The MCI score is obtained by adding the scores of individual taxa and dividing the total by the number of taxa present at the site and multiplying this figure by 20 (a scaling factor). MCI scores can be interpreted based on the water quality classes proposed by Stark *et al.* (2001) (Table 6.1).
- **Semi-quantitative macroinvertebrate community index (SQMCI)** is a variation of the MCI that accounts for the abundance of pollution sensitive and tolerant species. The SQMCI is calculated from coded-abundance data. Individual taxa counts are assigned to one of the following abundance classes: rare (R, 1-4 individuals), common (C, 5-19 individuals), abundant (A, 20-100 individuals), very abundant (VA, 100-500 individuals), very, very abundant (VVA, >500 individuals). SQMCI scores can be interpreted based on the water quality classes proposed by Stark *et al.* (2001) (Table 6.1).

Table 6.1 Criteria for aquatic macroinvertebrate health, according to different macroinvertebrate indices (following Stark *et al*., 2001)

Macroinvertebrate index	Poor	Fair	Good	Excellent
MCI	<80	80-99	100-119	>120
SQMCI	<4.00	4-4.99	5-5.99	>6

6.3 Fish communities

6.3.1 *Field surveys*

Each site was electric-fished, using a pulsed DC Kainga EFM300 backpack electro-shocker. At Brown's Pump, fish were surveyed following the New Zealand Freshwater Fish Sampling Protocols (Joy *et al.* 2013). A 150 m reach was divided into ten 15 m-long sub-reaches, and each section was electric fished in a single pass from downstream to upstream. When each section was fished, all fish caught were measured using a fish board and recorded. When 50 individuals of an individual species had been measured, individuals in subsequent sections were counted and recorded.

Electric-fishing at other sites (main stem at confluence, upper South Branch, South Branch at SH1, upper North Branch and North Branch at SH1) was undertaken by stop-netting off an area of about 100 m^2, and electric-fishing this area in an downstream direction in three passes, with a 15-minute rest period between each pass to allow fish to settle. The backpack operator used a sieve-dip net, while another team member used a pole seine net immediately below the electro-shocker. A third member carried buckets for fish collection. Fish from each pass were measured, counted and then released downstream of the downstream stop-net. At each site, all trout were also weighed (in grams) and then measured from the tip of the snout to the caudal fork (total length, mm).

6.3.2 *Data analysis*

The body condition of trout was assessed by relating body weight to total length of the individual using the formula (following Barnham and Baxter, 1998):

$$K = \frac{10^N W}{L^3}$$

where K is the condition factor; W is the weight of the fish in grams (g); L is the length of the fish in millimetres (mm); and N equals 5. A photographic representation is shown in Figure 6.1.

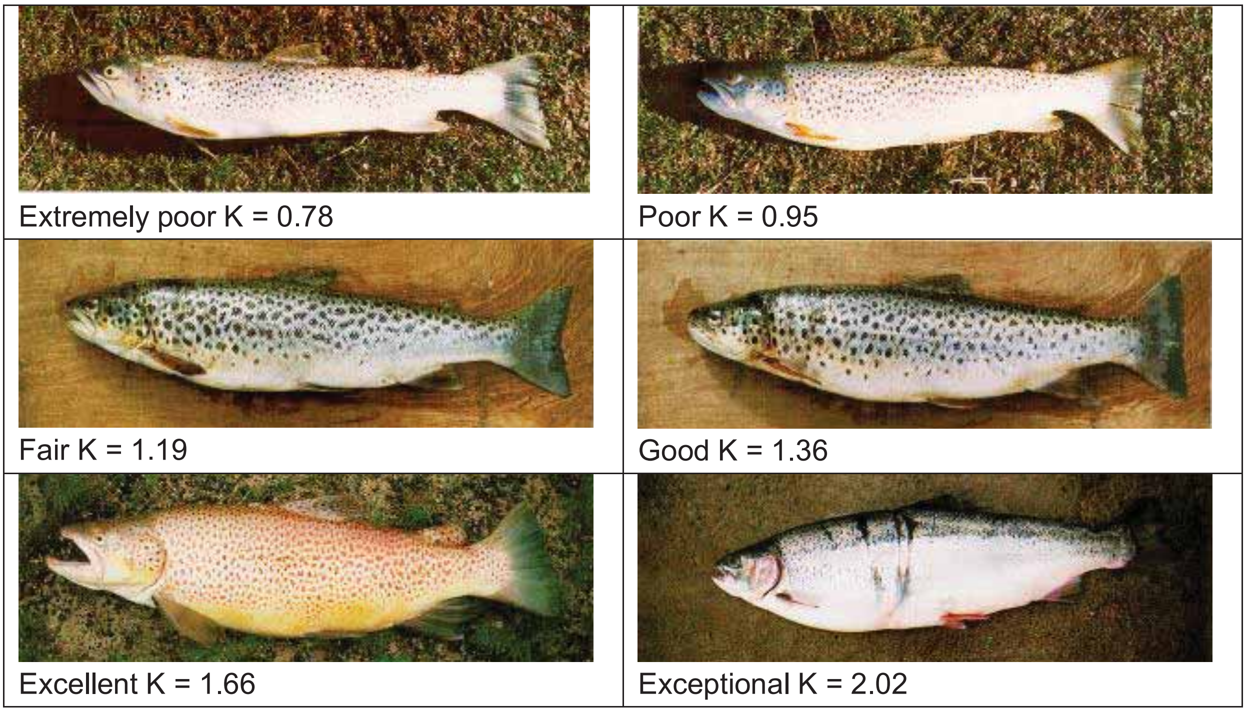

Figure 6.1 Photo representation of trout with different condition factors (Barnham and Baxter, 1998)

6.3.3 Fish density classes

Brown trout and native fish density at sites within the Waianakarua catchment were classed as 'excellent', 'good', 'fair' or 'poor', based on the relative density to density quartiles, calculated using a dataset based on waterways throughout coastal Otago. This regional data set was developed using the New Zealand Freshwater Fish Database (NZFFD) to obtain fish density data for all coastal river sites in the Otago region (based on two or more electric-fishing passes over a known area (m^2)) and data collected by ORC. All sites were ranked on fish density per square metre (total fish density, brown trout density) and then broken into quartiles.

7 Results

7.1 State of the environment monitoring

SoE monitoring has been undertaken at Brown's Pump since August 1999.

7.1.1 Trend analysis

Analysis of trends in water quality at Brown's Pump between August 1999 and April 2013 shows that all parameters have not changed significantly during this period (Table 7.1).

Trends were not assessed for NH_4-N or SS. NH_4-N concentrations were very low: 68% of readings were below the detection limit (0.01 mg/l), and 0.03 mg/l was the highest recorded. Trends in SS concentrations were not considered because the lower detection limit changed during the monitoring period from 1 mg/l to 3 mg/l, and most readings (66%) were below the detection limit, with a maximum recorded concentration of 4 mg/l.

Table 7.1 Trends in water quality parameters at the SoE monitoring site at Brown's Pump between August 1999 and April 2013. The *Z*-statistic indicates the direction of any trend detected, while the *P*-value indicates the probability of that trend occurring by chance. Trends with a *P*-value of less than 0.05 are considered to be statistically significant.

Parameter	*Z*	*P*	Trend
TN	0.08	0.93	None
NNN	0.81	0.42	None
TP	1.45	0.15	None
DRP	1.52	0.13	None
Turbidity	1.1	0.27	None
E. coli	-1.15	0.25	None

7.1.2 Compliance with water plan standards

Plan change 6A sets out water quality standards for receiving waters in the Otago region (Schedule 15; Table 3.1). These standards apply as 5-year, 80^{th} percentiles, when flows are at or below median flow at Brown's Pump (0.783 m^3/s). To assess compliance with the Schedule 15 Standards, SoE monitoring data collected from Brown's Pump were used to calculate 5-year running 80^{th} percentiles, which were compared to the appropriate standard. Only data collected when flows were below median flow were used for these calculations.

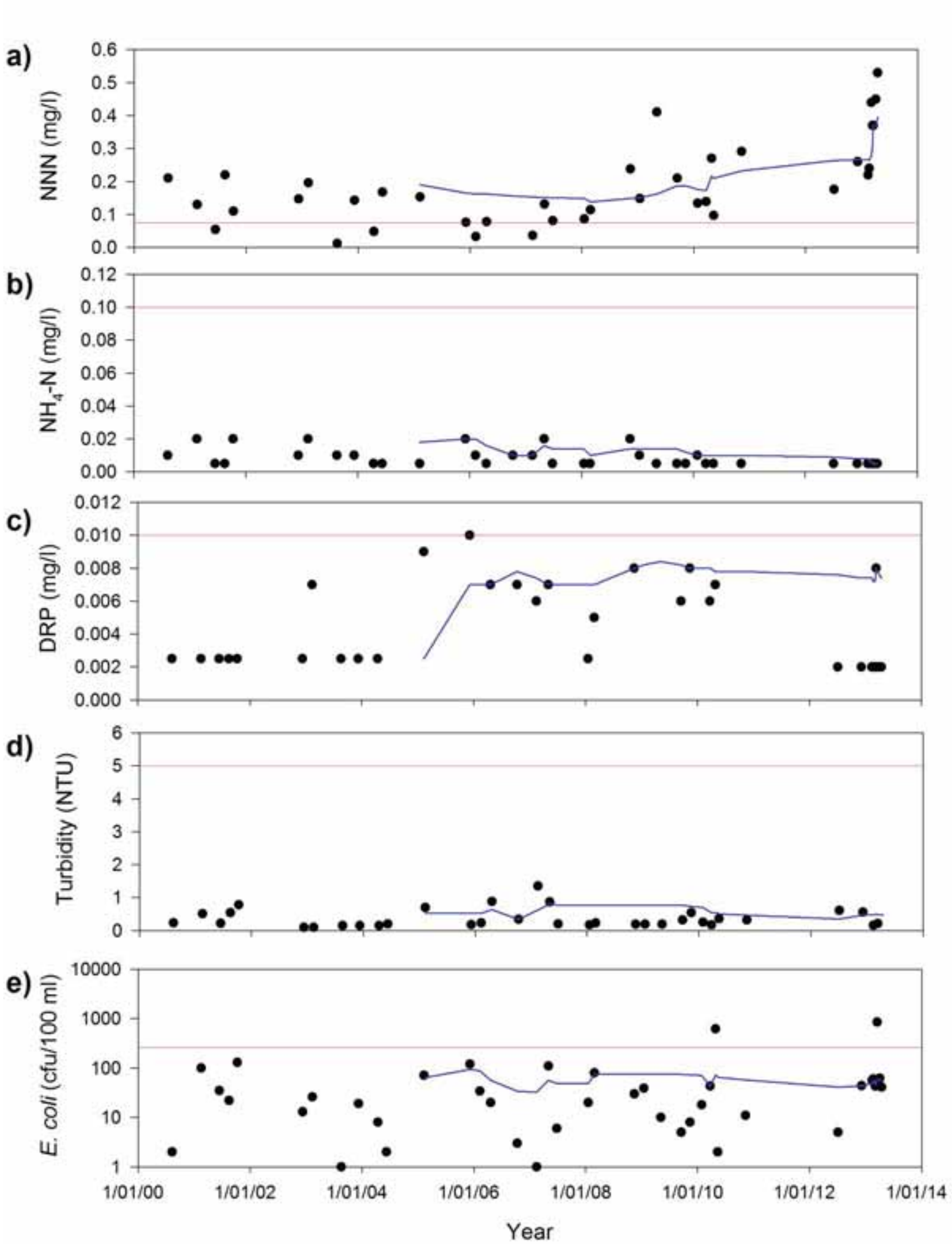

Figure 7.1 Comparisons of a) NNN, b) NH_4-N, c) DRP, d) turbidity and e) *E. coli* readings (on a logarithmic scale) when flows are below median flow with Schedule 15 standards (red lines). Blue lines represent the 5-year moving 80th percentile.

Of the variables considered, only NNN exceeded the Schedule 15 standard (Figure 7.1a-e). NH_4-N (Figure 7.1b), turbidity (Figure 7.1d) and *E. coli* (Figure 7.1e) were well within the Schedule 15 standards, while DRP was approaching the Schedule 15 standard (Figure 7.1c).

7.1.3 Water temperature

Water temperature has been recorded at Brown's Pump in the Waianakarua River on 80 occasions, as part of SoE monitoring, and on 79 occasions, as part of hydrological gaugings. However, these readings were taken during daylight hours, and so are likely to overestimate the mean water temperature and minimum water temperature. The mean water temperature recorded was 12.0°C (n=80), with a minimum of 2.0°C and a maximum of 22.1°C (Figure 7.2).

Mosley (1982) presented and fitted sine curves water temperature data for 254 flow-recorder sites throughout New Zealand, including one site in the Waianakarua, located about 1.2 km upstream of the Brown's Pump SoE monitoring site (NZTM E1430219 N4986037). The mean temperature recorded at this site was 11.3°C (n=79), with a minimum of 1.5°C and a maximum of 20.0°C. The fitted sine curve fitted by Mosley (1982) was:

$$T_i = 11.3 + 6.7 * sine\ (2\pi t_i + 1.27)$$

where T_i is the temperature at time t_i (where $0 < t_i \leq 1$).

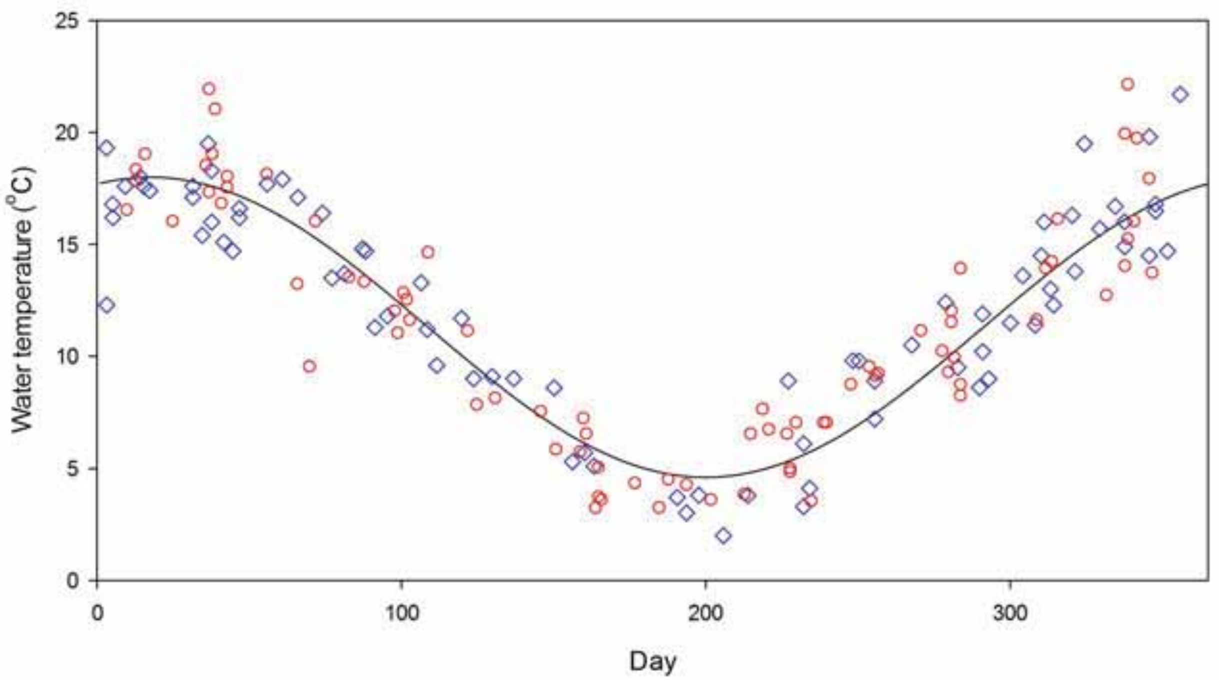

Figure 7.2 Water temperature recorded at the Brown's Pump site in the Waianakarua river during SoE monitoring between July 1999 and March 2013 (red circles) and hydrological gaugings between July 2006 and March 2013 (blue diamonds). The black line is a sine curve fitted to data from the Waianakarua River about 1.2 km upstream of Brown's Pump (NZTM E1430219 N4986037) by Mosley (1982).

7.2 Catchment water quality monitoring results

7.2.1 Nitrogen

TN concentrations were very low at both sites in the North Branch, with median concentrations being very close to the detection limit at all flows (Figure 7.3a). In the South Branch, TN concentrations were substantially higher at the SH1 bridge than at McKerrow Road. Downstream of the confluence, concentrations increased with distance downstream. Results for NNN were very similar. Low concentrations were found at the two sites in the North Branch; higher concentrations were found at the SH1 bridge in the South Branch than at McKerrow Road, and concentrations in the main stem were found to increase with distance downstream (Figure 7.3b). Concentrations of NH_4-N were very low at all sites, with only three readings at or above the detection limit recorded when flows were higher than the median flow (Figure 7.3c).

Plan change 6A sets out water quality standards for receiving waters in the Otago region (Schedule 15; Table 3.1). These standards apply as 5-year, 80th percentiles, when flows are at or below median flow at Brown's Pump (0.783 m^3/s). While limited, data collected when flows were below median flow were compared to the Schedule 15 standards. The 80th percentiles of NNN concentrations at all sites in the South Branch and main stem exceeded the standard, while both sites in the North Branch were within the receiving water quality standards (Figure 7.3b). NH_4-N concentrations at all sites were well within the Schedule 15 standard (Figure 7.3c).

7.2.2 Phosphorus

TP and DRP concentrations were generally very low at all sites sampled, with most measurements taken when flows were below the median below the detection limit (Figure 7.4a and b).

Most DRP readings were well within the Schedule 15 standard (Figure 7.4b), although it should be kept in mind of the 19 sampling occasions, that only four occurred when flows were less than median flow.

7.2.3 SS and turbidity

SS concentrations at all sites on all sampling occasions were at or below the detection limit of 3 mg/l. Turbidity was not monitored between 27 July 2012 and 15 April 2013. However, it was measured as part of SoE monitoring at the Brown's Pump site. The median turbidity recorded was 0.23 NTU, and the 80th percentile was 0.55 NTU (N=34). These values are well within the Schedule 15 value for the Waianakarua River (5 NTU).

7.2.4 Escherichia coli

During low flows (below median), *E. coli* counts were generally low, with the highest median concentrations recorded at the two downstream sites (Figure 7.5). The only reading that exceeded the Schedule 15 value was recorded in a sample from the upper site in the South Branch (1500 cfu/100 ml). The reason for this single anomalous reading is unclear.

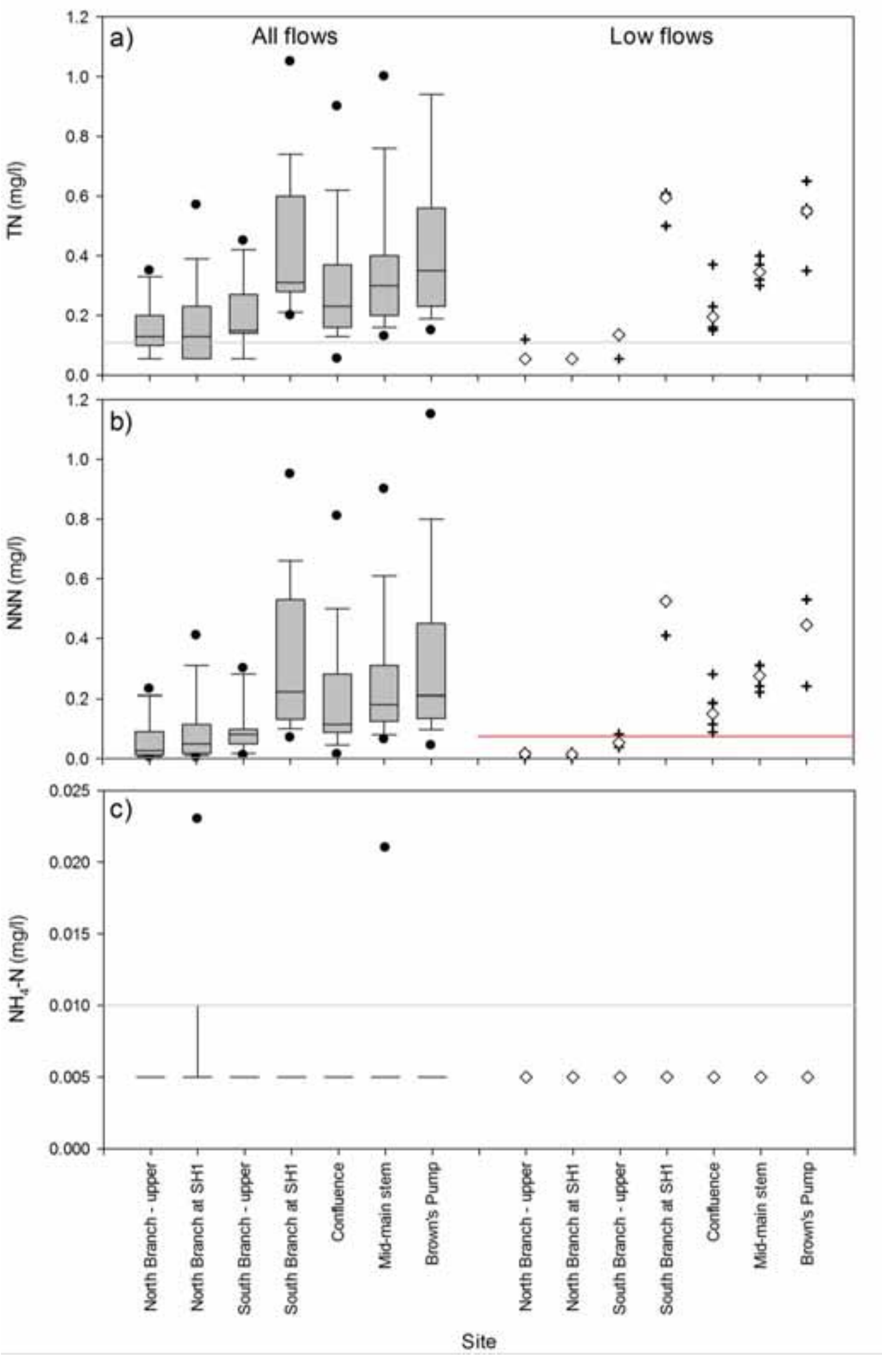

Figure 7.3 a) Total nitrogen, b) nitrate-nitrite nitrogen and c) ammoniacal nitrogen concentrations in the Waianakarua River under all flows (left, box plots) and low flows (right, scatter plots, open diamonds represent median values). The red line represents the Schedule 15 standard from plan change 6A. No Schedule 15 standard is shown for ammoniacal nitrogen because observed concentrations were much lower than the standard. Grey lines represent the detection limit for each variable.

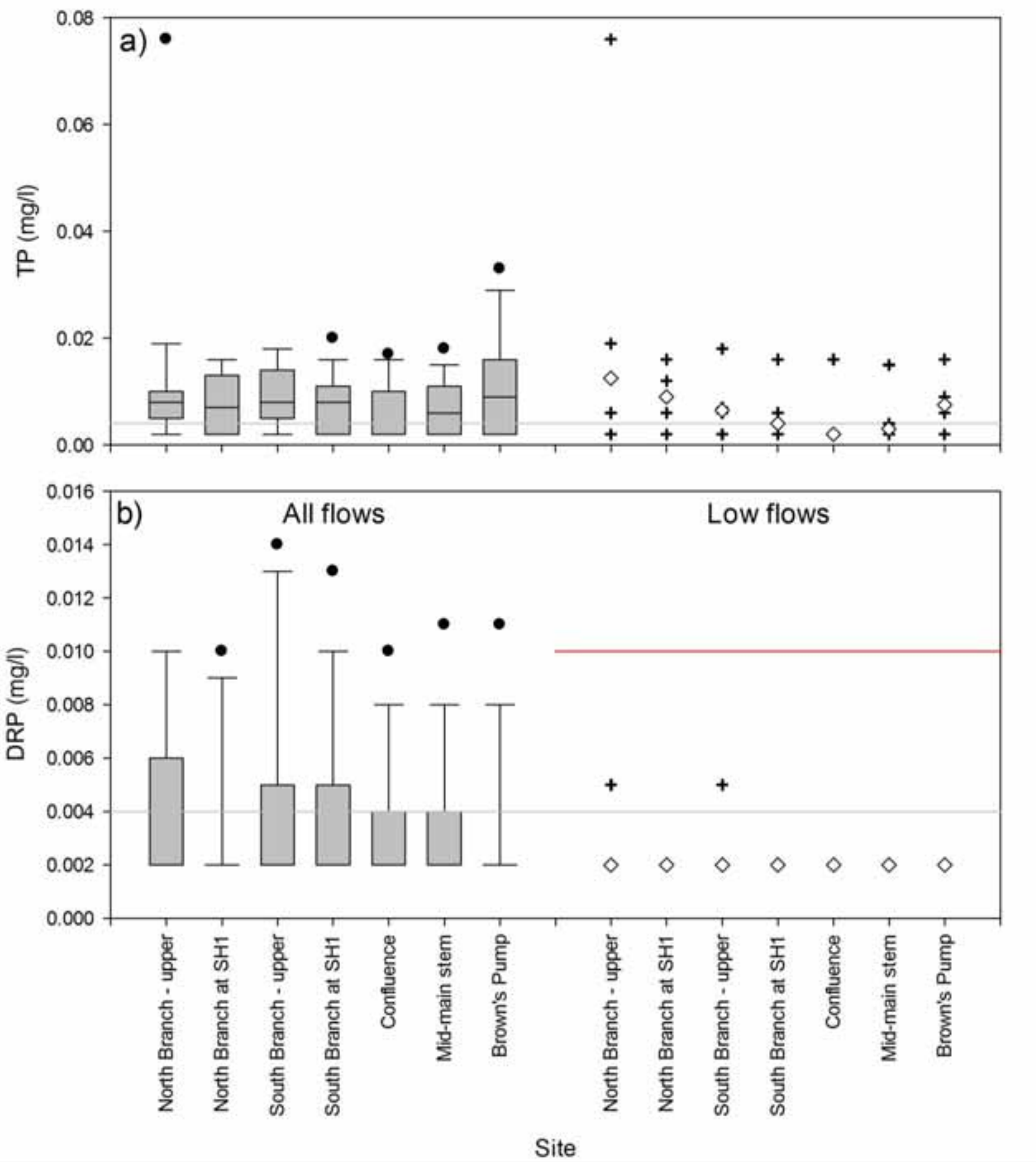

Figure 7.4 a) Total phosphorus and b) dissolved reactive phosphorus concentrations in the Waianakarua River under all flows (left, box plots) and low flows (right, scatter plots, open diamonds represent median values). The red line represents the Schedule 15 standard from plan change 6A. Grey lines represent the detection limit for each variable.

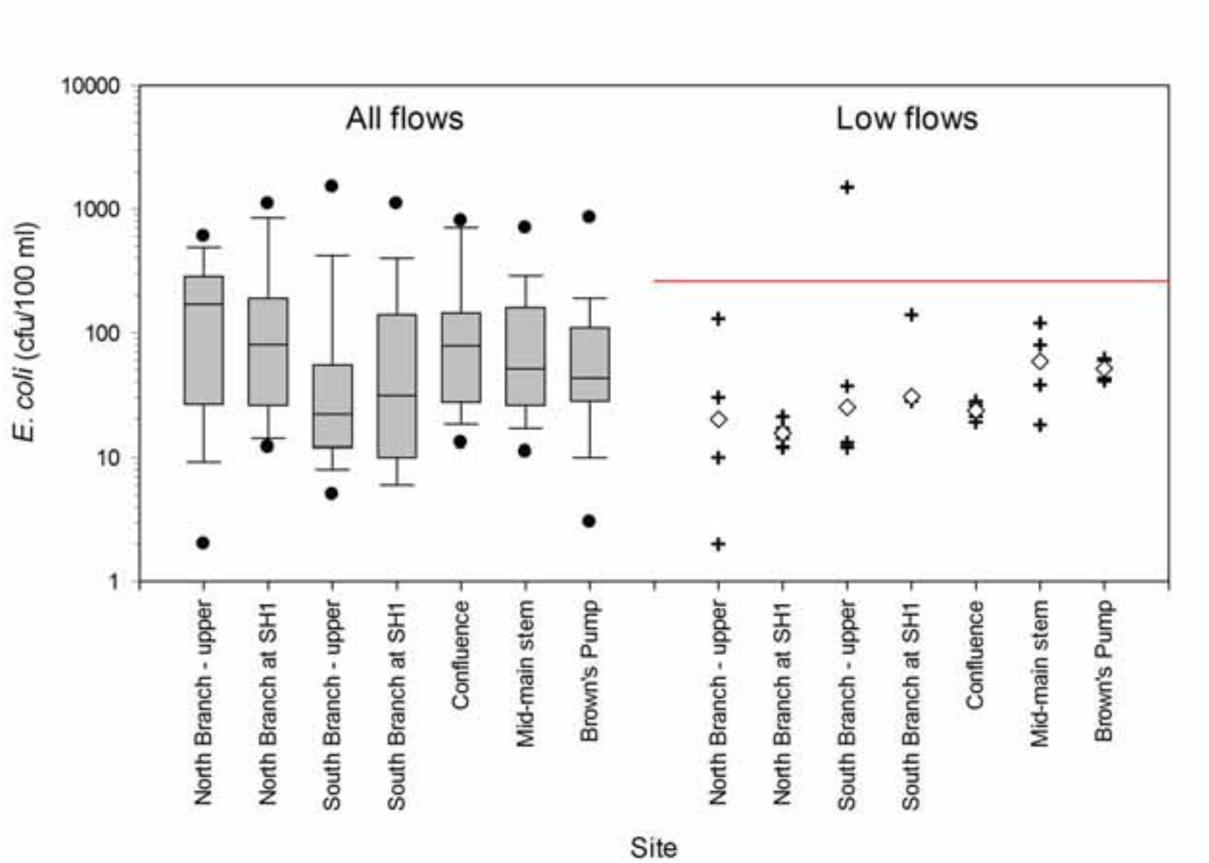

Figure 7.5 *Escherichia coli* concentrations (logarithmic scale) in the Waianakarua River under all flows (left, box plots) and low flows (right, scatter plots, open diamonds represent median values). The red line represents the Schedule 15 standard from plan change 6A. The detection limit for *E. coli* was 1 cfu/100 ml.

7.2.5 Effluent contamination

Using the test developed by AgResearch (2011) to detect the contamination of surface waters by effluent, there was no indication of effluent contamination at any of the sites in the Waianakarua catchment.

8 Habitat assessment

The riverbed at all sites was dominated by gravels (2-63 mm), with cobbles and bedrock also abundant at some sites (Table 8.1). Cobbles were not embedded at most sites, and sediment was uncompacted (Table 8.1). The banks were very stable at all sites in the North and South branches, with bedrock or engineering structures (bridge abutments) at all of these sites. In contrast, bank stability was low at all main stem sites, with the exception of the true-right bank at Brown’s Pump, which is stabilised by dense willows (Appendix 2). Pools were present at most survey sites, with maximum water depth up to 2 m, but no deposits of fine sediments were evident in any of these sites (Table 8.1).

Intact riparian buffers were present at most of the sites surveyed, which were dominated by exotic shrubs (including broom, gorse, briar rose and buddleia) and deciduous trees (willows, alders and poplars). Intact buffers were present on only one bank at two sites: the South Branch at SH1 and the main stem at the confluence, both of which had 1-20% gaps on the true-left bank (Appendix 2). Stock access to the riverbed was restricted at all sites surveyed (Appendix 2).

Steep river banks, surrounding hills and riparian vegetation, shaded the river channel at most sites, with channel aspect being an important factor. The main stem sites at the confluence and mid-main stem were very open, with little or no shading of the channel.

Table 8.1 Instream habitat characteristics of sampling sites in the Waianakarua River

		Upper South Branch	South Branch at SH1	Upper North Branch	North Branch at SH1	Main stem at confluence	Mid-main stem	Brown's Pump
Approx. survey reach length (m)		160	100	110	78	200	140	150
Wetted width (approx.) (m)		7.8	5.2	6.6	8.2	8.2	c.12	11.5
%Concrete/artificial		-	-	-	3	-	-	-
%Bedrock	>4000 mm	20	20	13	-	1	-	17
%Boulder	256-4000 mm	2	3	2	18	-	-	2
%Cobble	64-255 mm	21	8	37	33	22	30	7
%Gravel	2-63 mm	44	70	40	37	75	70	40
%Silt, sand	<2 mm	17	-	12	9	3	10	2
%Embeddedness		-	-	3%	-	-	-	-
Substrate compactness		Loose	Loose	Loose	Loose	Loose	Loose	Loose
%Woody debris & leaf packs		-	0.5	3	-	7.5	-	5
%Obstructions to flow		-	1	7	-	2	0	7
%Bank cover		-	-	17	1	-	-	-
Pools	Max. depth (m)	2	-	1.5	1	-	1.2	1
	Fine sediment depth (m)	0	-	0	0	-	0	0
	Crest depth (m)	0.2	-	0.4	0.3	-	0.13	0.2
	Number of pools in reach	1	0	2	2	0	3	1

9 Aquatic plants

9.1 State of the environment periphyton monitoring

Periphyton was monitored in the North Branch at SH1 in 2004 and at Brown's Pump in each year between 2007 and 2013. In 2004, the periphyton community in the North Branch at SH1 was dominated by the red filamentous red alga *Audouinella* sp., with the stalked diatom *Gomphoneis* and the diatoms *Encyonema* and *Synedra* also common (Table 9.1). Benthic cyanobacteria were the most abundant periphyton taxa at Brown's Pump in 208, 2011 and 2012, while, in 2010, benthic cyanobacteria were co-dominant with the diatom *Cymbella* (Table 10.1). In 2013, the diatoms *Cymbella* and *Encyonema* were abundant, while benthic cyanobacteria were common to abundant (Table 10.1).

Benthic cyanobacteria, such as the genus *Phormidium*, may produce toxins that pose a health risk to humans and animals. Cyanobacteria-produced neurotoxins have been implicated in the deaths of numerous dogs in New Zealand (Hamill 2001; Wood *et al.* 2007). Cyanobacterial mats can be dislodged from the riverbed and wash to the bank. Dogs, attracted by their distinctive musty smell, may eat them. Death occurs rapidly following the ingestion of a lethal dose. Warning signs are erected at public access points on the Waianakarua, including the river mouth; the North Branch, downstream of the SH1 bridge; Reid Road; Graves Dam, at the ford on Cosy Dell Road; and the South Branch, at the end of McKerrow Road.

9.2 Aquatic plant cover – 2013 survey

The cover of aquatic macrophytes (vascular plants) and periphyton was assessed as part of habitat assessments in April 2013. Macrophytes were rare at sites in the main stem, with some monkey musk (*Mimulus guttatus*) evident in the North Branch at SH1. Periphyton cover was dominated by dark brown-black taxa (primarily cyanobacteria) at many sites, while light brown taxa (predominantly diatoms) were the most abundant periphyton taxa at the upper North Branch site (Table 8.1). Short filamentous green algae were the most common type of periphyton found at the mid-main stem site (Table 8.1), while a mix of light brown (diatoms) and short green taxa were abundant at Brown's Pump (Table 8.1).

Table 9.1 Periphyton taxa collected at two sites in the Waianakarua River as part of the state of the environment monitoring programme. Abundance codes are based on Biggs & Kilroy (2000): 1 = rare, 2 = rare-occasional, 3 = occasional, 4 = occasional-common, 5 = common, 6 = common-abundant, 7 = abundant and 8 = dominant.

Site	**North Branch at SH1**	**Brown's Pump**						
Code	**2004**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Green filamentous								
Stigeoclonium sp.				4			2	
Green, non-filamentous								
Ankistrodesmus spp.	1							
Scenedesmus spp.					4			
Red filamentous								
Audouinella sp.	8	3	3					
Diatoms								
Cocconeis placentula (50x30µm)	3							
Cymbella kappii	4				8		3	7
Cymbella cf. *tumida*					4			
Cymbella spp. (small)					5			
Diploneis elliptica	1							
Encyonema spp.	5				4			7
Fragilaria spp.	2							
Frustulia spp.				4		2		
Gomphoneis sp.	6		4	4	4	4	3	
Hantzschia				4		1		
Melosira varians				4				3
Naviculoid diatom			1	4		2		
Navicula cf. *cryptocephala*	3							
Nitzschia spp.	3			3	4		2	3
Pinnularia			2					
Rhoicosphenia spp.					1	2		
cf. *Synedra rumpens*	4							
Synedra ulna	3			3				
Synedra ulna var. *ramesi*	5							
Cyanobacteria								
Oscillatoria/Phormidium	2		6		8	5	4	6
Rivularia			2	3				2
Unknown cyanobacteria							5	
Phytoplankton								
Cosmarium			3	3	2			

Table 9.2 Cover of macrophytes and periphyton at sampling sites in the Waianakarua River in April 2013

		Upper South Branch	South Branch at SH1	Upper North Branch	North Branch at SH1	Main stem at confluence	Mid-main stem	Brown's Pump
%Macrophytes	Monkey musk	-	-	-	1	-	-	-
%Algae	Light brown	-	-	25	-	-	-	47
	Dark brown-black	27	40	-	28	14	17	-
	Short filamentous green	-	-	-	-	-	53	30
	Long filamentous green	-	-	-	1	-	-	-

Otago Regional Council

10 Macroinvertebrates

10.1 Community composition

10.1.1 State of the environment monitoring

The macroinvertebrate community of the Waianakarua River at Brown's Pump was dominated by the larvae of the mayfly *Deleatidium* on most sampling occasions between 2007 and 2013 (Table 11.1). Elmid beetles and chironomid midge larvae (Orthocladiinae) were also among the most abundant taxa at Brown's Pump on many occasions (Table 11.1). Other taxa among the most abundant include the mudsnail, *Potamopyrgus antipodarum*, larvae of the net-spinning caddis fly, *Aoteapsyche*, and larvae of the cased caddis flies, *Olinga* and *Pycnocentrodes* (Table 11.1).

10.1.2 Catchment monitoring 2013

During macroinvertebrate sampling at seven sites in the Waianakarua catchment in 2013, the highest number of different types of macroinvertebrate were collected from the South Branch at McKerrow Road (31 taxa), while the lowest number was collected from the North Branch at SH1 (18 taxa) and Brown's Pump (17 taxa) (Table 11.2). Between 21 and 22 macroinvertebrate taxa were collected at the four remaining sites (Table 11.2). Most of the taxa collected at all sites belonged to the EPT orders (Table 11.2). *Deleatidium* mayfly larvae were the most abundant taxon at most sites (Table 11.2). Orthoclad chironomid larvae were among the most abundant taxa at the lower site in the North Branch and at all sites in the main stem, while the net-spinning caddis fly *Aoteapsyche* was among the most abundant taxa in the South Branch at SH1 and in the main stem at the confluence and middle sites (Table 11.2).

10.2 Macroinvertebrate community indices

10.2.1 State of the environment monitoring

Macroinvertebrate sampling was undertaken on two occasions at the North Branch at SH1 and on seven occasions at Brown's Pump, as part of the SoE monitoring programme. These samples can be used to compute the macroinvertebrate community index and its semi-quantitative variant, which can be used to assess the degree of organic pollution and/or sedimentation at these sites. This can be done by comparing the calculated score for a site to the national water quality classes of Stark & Maxted (2004) (Table 6.1), although interpretation of such results can be affected by inter-site differences. Another, more robust way, of assessing water quality using macroinvertebrate indices is to look for the change in indices over time.

Table 10.1 Macroinvertebrate taxa collected from the Waianakarua River as part of state of the environment monitoring. Only taxa that were abundant at one site or more are shown. A full table is presented in Appendix 3. Relative abundance scores are described in Table 6.1.

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Sample location	**MCI Score**	**North Branch at SH1**		**Waianakurua at Brown's Pump**						
Sample date		**09-Jan-03**	**2004**	**4-Jan-07**	**4-Apr-08**	**8-Apr-09**	**07-Feb-10**	**4-Apr-11**	**9-Jan-12**	**22-Feb-13**
Elmidae	6	VA	VA	VA	VA	VA	VA	C	A	R
DIPTERA										
Chironominae	2	A		R	A	C		C		
Maoridiamesa species	3				A			R	C	R
Orthocladiinae	2	VA	A	R	VA	A	VA	A	A	VA
Tanypodinae	5						A			
EPHEMEROPTERA										
Deleatidium species	8	VA	VA	VA	VA	VA	VA	VA	VVA	VA
MOLLUSCA										
Potamopyrgus antipodarum	4		VVA	C	A		VA	A		
OLIGOCHAETA	1			R		A		R	R	
TRICHOPTERA										
Aoteapsyche species	4	VA	A	A	VA	A	VA	A	A	A
Hydrobiosidae early instar	5			C	A	R				
Hydrobiosis umbripennis-gp	5	C	R	R	A			C	A	
Olinga species	9	VA	VA	A	R	A	VA			A
Psilochorema species	8	A		C	C	R	C		C	R
Pycnocentrodes species	5	A	VVA	A	VA	A	VVA	C	R	C
Taxonomic richness		**11**	**10**	**16**	**17**	**19**	**21**	**22**	**13**	**17**
MCI		**128**	**127**	**109**	**113**	**123**	**104**	**100**	**103**	**111**
SQMCI		**5.75**	**5.19**	**6.68**	**4.91**	**6.09**	**5.25**	**6.00**	**7.42**	**5.27**
EPT taxonomic richness		**5**	**4**	**8**	**8**	**11**	**8**	**11**	**6**	**9**
%EPT richness		**45%**	**40%**	**50%**	**47%**	**58%**	**38%**	**50%**	**46%**	**53%**

Table 10.2 Macroinvertebrate data collected from seven sites in the Waianakarua River in 2013. Relative abundance scores are described in Table 6.1. Only taxa that were abundant at one site or more are shown. A full table is presented in Appendix 4. Relative abundance scores are described in Table 6.1.

		Waianakarua River						
TAXON	**MCI score**	**South Branch at McKerrow Rd**	**South Branch at SH1**	**North Branch at ford**	**North Branch at SH1**	**At confluence**	**Mid-main stem**	**Brown's pump**
		11-Apr-13	**10-Apr-13**	**11-Apr-13**	**11-Apr-13**	**10-Apr-13**	**11-Apr-13**	**22-Feb-13**
DIPTERA								
Austrosimulium species	3	R	A	R	R	C	R	C
Orthocladiinae	2	R	A	A	VA	VVA	VVA	VA
Tanypodinae	5	A		R				
Tanytarsini	3	C	A	R	A	A	A	C
EPHEMEROPTERA								
Austroclima species	9		A		C	A	A	
Deleatidium species	8	VA	VA	VA	VA	VA	VVA	VA
MEGALOPTERA								
Archichauliodes diversus	7	A		C	C	R	C	C
MOLLUSCA								
Potamopyrgus antipodarum	4	VA	A	C		R	R	
TRICHOPTERA								
Aoteapsyche species	4	C	VA	A	C	VA	VA	A
Helicopsyche species	10	A	R	A			R	
Hydrobiosis species	5	C	A	A	C	A	A	C
Olinga species	9	VA	A	A	A	A	A	A
Psilochorema species	8	A	C	C	C	C	C	R
Pycnocentria species	7	C	R	C	A	C		
Pycnocentrodes species	5	VA	A	A	C	A	C	C
Number of taxa		**31**	**21**	**22**	**18**	**21**	**22**	**17**
Number of EPT taxa		**16**	**13**	**14**	**9**	**12**	**11**	**9**
%EPT taxa		**52%**	**62%**	**64%**	**50%**	**57%**	**50%**	**53%**
MCI score		**117**	**122**	**126**	**117**	**122**	**117**	**111**
SQMCI score		**6.56**	**5.63**	**6.80**	**5.42**	**3.66**	**5.07**	**5.27**

MCI scores for the North Branch at SH1 in 2003 and 2004 both exceeded 125, indicating excellent water quality, according to the classes of Stark & Maxted (2004) (Table 6.1). MCI scores for Brown's Pump ranged between 100 and 123 (mean = 109) in samples collected between 2007 and 2013, which would put this site in the 'good' to 'excellent' (Stark & Maxted 2004) (Table 6.1). However, given that the Brown's Pump site is in the very lowest reaches of the catchment, just upstream of tidal influence, these MCI scores probably indicate a lower gradient and higher proportion of fine sediments in the lower river. SQMCI scores for Brown's Pump ranged between 4.91 and 7.42 (mean = 5.94) in samples collected between 2007 and 2013. SQMCI scores in most years indicated 'excellent' water quality (Stark & Maxted 2004). No significant trend was evident for any of the macroinvertebrate metrics between 2007 and 2013 (Mann-Kruskall trend test, $P>0.33$) (Figure 10.1).

10.2.2 Catchment monitoring 2013

During the 2013 survey, MCI scores at all sites were indicative of 'good' to 'excellent' water quality, as were SQMCI scores at most sites (Table 11.2). The exception was the SQMCI score for the confluence site (3.66), which indicates 'poor' water quality. This probably reflects the dominance of chironomid midges and other low-scoring species at this site.

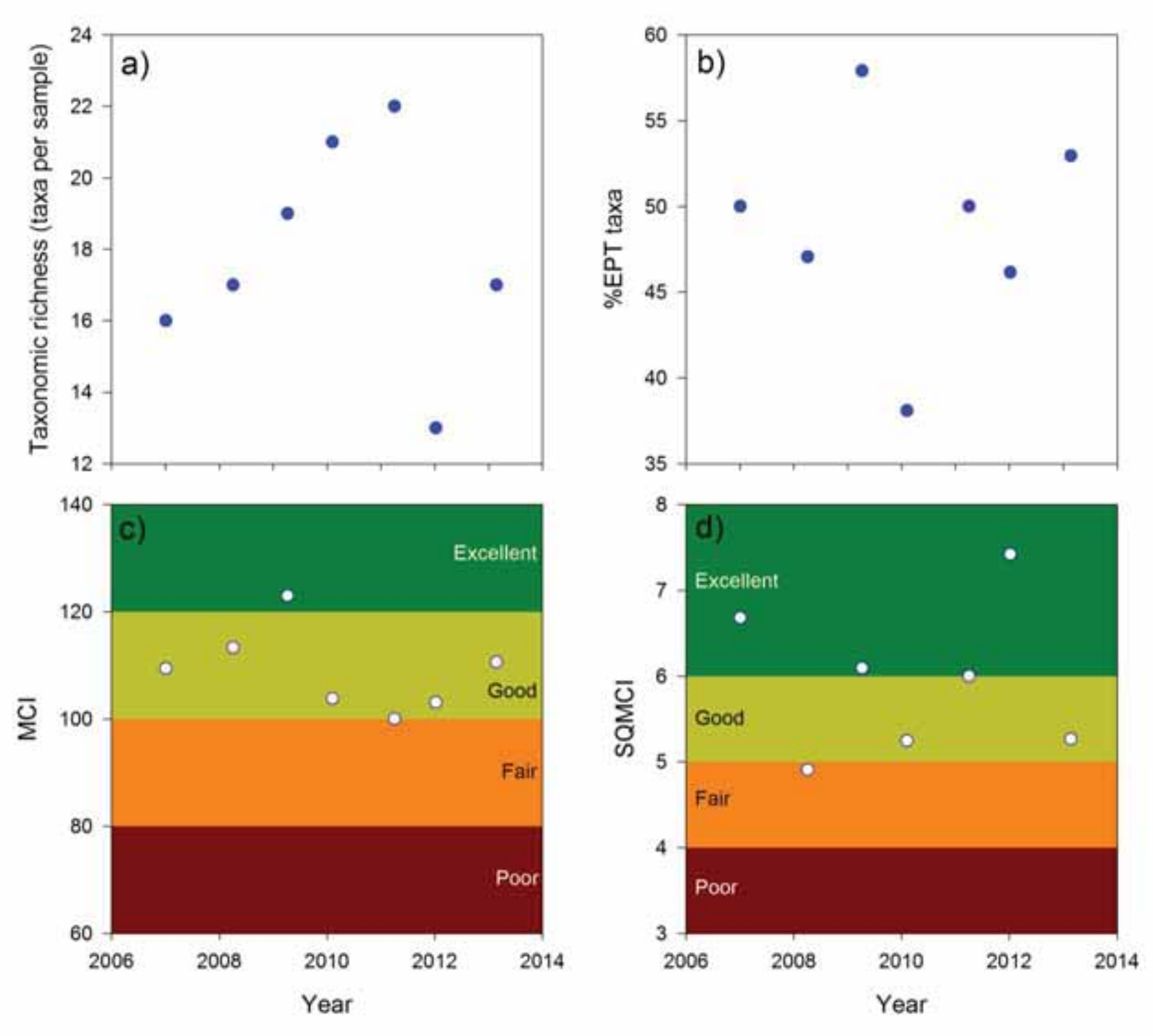

Figure 10.1 Macroinvertebrate metrics at Brown's Pump SoE monitoring site in the Waianakarua River between 2007 and 2013. a) Taxonomic richness, b) % EPT taxa, c) MCI score and d) SQMCI score. MCI and SQMCI water quality classes shown in parts c) and d) are based on those of Stark & Maxted (2007). Lines are lowess curves (tension = 0.8).

11 Fish sampling

As part of the study, electric-fishing was undertaken at seven sites in the Waianakarua catchment. Fourteen fish species were found, 13 of which were native. Brown's Pump was sampled as part of the annual SoE monitoring (following the New Zealand Freshwater Fish Sampling Protocols, Joy *et al.*, 2013, a different sampling protocol to the other sampling sites (in which 100 m^2 site (approximately) was three-pass electric-fished)). The difference in sampling protocols means that the data collected from Brown's Pump is not comparable with the data from other sites.

11.1 State of the environment monitoring

Thirteen species of freshwater fish were collected from Brown's Pump, 11 of which were collected in 2013. Bluegill bullies have been the most abundant species on most occasions, with common bullies being the most abundant species in 2011 (Table 11.2). Common bullies, lamprey, Canterbury galaxais and torrentfish were also among the most abundant species at this site (Table 11.2).

Shortfin and longfin eels, inanga, upland bullies were collected at Brown's Pump on most sampling occasions (Table 11.2). Koaro were collected from Brown's Pump in 2010, while black flounder and brown trout were collected on three sampling occasions (Table 11.2).

Table 11.1 Density of fish (per 100 m^2) sampled at the Brown's Pump SoE monitoring site between 2009 and 2013, following the New Zealand Freshwater Fish Sampling Protocols (Joy *et al.*, 2013)

Family	Common name	Species	Density (per 100 m^2)				
			5/05/09	14/04/10	22/02/11	18/04/12	7/03/13
Anguillidae	Shortfin eel	*Anguilla australis*	0.3	1.8	1.1	0.7	0.5
	Longfin eel	*Anguilla dieffenbachii*	0.1	-	0.3	0.3	0.1
	Unidentified eel	*Anguilla* indet.	-	0.6	-	-	-
Eleotridae	Common bully	*Gobiomorphus cotidianus*	23.2	45.2	21.8	15.9	16.1
	Upland bully	*Gobiomorphus breviceps*	-	8.7	9.7	6.1	0.6
	Bluegill bully	*Gobiomorphus hubbsi*	29.0	104.7	11.7	27.9	26.5
Galaxiidae	Inanga	*Galaxias maculatus*	3.8	1.7	0.1	1.3	0.1
	Koaro	*Galaxias brevipinnis*	-	0.2	-	-	-
	Canterbury galaxias	*Galaxias vulgaris*	6.8	6.3	3.2	1.0	1.7
	Unidentified galaxid	*Galaxias* indet.	-	-	-	-	-
Geotriidae	Lamprey		23.1	35.3	8.4	5.7	5.4
Pinguipedidae	Torrentfish	*Cheimarrichthys fosteri*	7.8	15.9	1.3	5.0	1.6
Pleuronectidae	Black flounder	*Rhombosolea retiaria*	0.6	-	-	0.4	0.6
Retropinnidae	Common smelt	*Retropinna retropinna*	-	-	-	-	0.4
Salmonidae	Brown trout	*Salmo trutta*	0.5	0.6	-	0.3	-

11.2 2013 Catchment survey

Lower numbers of fish species were collected from most sites in the North and South branches upstream (upper North Branch, upper South Branch and South Branch at SH1) than from the main stem at the confluence (Table 11.2). Nine fish species were collected from the North Branch at SH1 (Table 11.2). Of the species recorded from the Waianakarua River in 2013, seven are currently classified as 'declining'. These were longfin eel, torrentfish, inanga, koaro, lamprey, bluegill bully and redfin bully (Allibone *et al.*, 2010).

Canterbury galaxias were the most abundant species at two sites (upper North Branch, South Branch at SH1) and were present at all sites sampled (Table 11.2). Common bullies were the most abundant species at two sites (North Branch at SH1, upper South Branch) and were present at all sites sampled (Table 11.2). Bluegill bullies were the most abundant fish species in the main stem at the confluence and were collected at both North Branch sites, but they were not collected at either site in the South Branch (Table 11.2). Numerous torrentfish were collected in the main stem at the confluence, with many being collected from under coarse substrate in an area with low water velocities along the true-right bank (Figure 11.1). Similar numbers were caught on successive electric-fishing runs (19 individuals on first pass, 19 on the second pass and 18 on the third pass).

Table 11.2 Density (per 100 m^2) and number of fish species at the five sites sampled as part of the 2013 catchment study. The number of fish species present at Brown's Pump in 2013 is included for comparison (*=present).

Species		North Branch		South Branch		Main stem at confluence	Brown's Pump
		Upper	SH1	Upper	SH1		
Longfin eel		1.1	1.5	-	3.6	6.6	*
Shortfin eel		-	1.5	-	-	0.6	*
Common bully		14.6	45.6	36.8	29.1	58.6	*
Bluegill bully		28.1	19.1	-	-	238.7	*
Torrentfish		10.1	1.5	-	9.1	30.9	*
Redfin bully		-	-	-	-	14.9	-
Upland bully		16.9	26.5	14.2	174.5	51.4	*
Canterbury galaxias		102.2	13.2	16.1	374.5	55.8	*
Inanga		-	4.4	-	-	-	*
Koaro		-	-	16.8	-	-	-
Lamprey	ammocoetes	-	-	0.6	-	-	*
	macrothelmia	-	1.5	0.6	-	-	*
Black Flounder		-	-	-	-	-	*
Common smelt		-	-	-	-	-	*
Brown trout		-	-	3.2	-	-	-
Total density (per 100 m^2)		**173.0**	**114.7**	**88.4**	**590.9**	**457.5**	-
Number of species		**6**	**9**	**6**	**5**	**8**	**11**
Distance to sea (km)		13	7	10	7	5	2

Figure 11.1 The sampling site in the Waianakarua River main stem at the confluence. The red arrow indicates the area where numerous torrentfish were found among cobbles in areas with lower water velocities.

12 Discussion

12.1 Water quality

12.1.1 Long-term trends

Water quality at the SoE monitoring site in the Waianakarua River (at Brown's Pump) has been consistent over the period of monitoring (2001-2013), with no trends detected for any of the water quality variables considered.

12.1.2 Spatial patterns in water quality

12.1.2.1 Nutrients

Nutrient concentrations affect the growth of algae and other periphyton, and high biomasses of periphyton can affect a wide range of instream values, including aesthetics, biodiversity, recreation and water quality (Biggs 2000). Periphyton biomass is determined by the balance between two opposing processes: biomass accrual and biomass loss (Biggs 2000). Biomass accrual is driven by the availability of nutrients, light and water temperature, while biomass loss is driven by disturbance (substrate instability, water velocity and SS) and grazing (mainly by invertebrates). In an unregulated river like the Waianakarua, the processes affecting biomass loss are not able to be manipulated, meaning that nutrient management is the only practical means of managing periphyton biomass to maintain instream values.

TN and NNN were lowest at both sites in the North Branch and in the upper South Branch. TN and NNN concentrations in the South Branch at SH1 were markedly higher than recorded at the upstream site (McKerrow Road, 3.5 km upstream), suggesting that a significant source of nitrogen enters the river between these two sites. Concentrations of TN and NNN increased with distance downstream of the confluence, probably reflecting the intensive farming practices in the lower catchment. There are a limited number of waterways that enter the lower river, suggesting that nitrogen is entering the surface water via leaching to groundwater, which then enters the lower river.

Concentrations of DRP were generally very low, with the concentration of the majority of samples below the detection limit at all sites sampled. Nitrogen to phosphorus (N:P) ratios suggest that periphyton in the South Branch at SH1 and all main stem sites are phosphorus-limited. However, ratios in the North Branch and upper South Branch varied markedly, indicating that no one nutrient was consistently limiting algal growth and/or that they may be co-limiting.

12.1.2.2 Water temperature

Water temperature is a fundamental factor affecting all aspects of stream systems and an essential factor to consider in the management of waterways. Water temperature (especially high water temperatures) directly affects fish populations, by affecting their survival, growth, spawning, egg development and migration, but it can also affect fish populations indirectly, through effects on physicochemical conditions and food supplies (Olsen *et al*., 2012).

Of the fish species collected from the Waianakarua River (Section 11), brown trout (*Salmo trutta*) and common smelt (*Retropinna retropinna*) are probably the most sensitive to high water temperatures. The thermal requirements of brown trout are well understood (Elliott, 1994). Significant mortality of brown trout is expected to occur in relatively short time periods at temperatures above 25°C. Brown trout cease feeding when water temperatures exceed 19°C, so prolonged periods of water temperatures in excess of 19°C will retard growth. The growth optimum for brown trout feeding on invertebrates is 14°C, but it becomes 17°C for trout fed on a fish diet (Elliott & Hurley, 1998, 1999, 2000). Todd *et al.* (2008) calculated acute and chronic thermal criteria for a range of cold-water and warm-water fish species, and, for brown trout, they recommended an acute thermal threshold of 24.6°C and a chronic thermal threshold of 19.6°C. The acute thermal threshold is calculated as the highest two-hour average water temperature measured within any 24-hour period, while the chronic thermal threshold is expressed as the maximum weekly average temperature (Todd *et al.*, 2008).

Of the native fish collected from the Waianakarua River, common smelt are likely to have the lowest tolerance to high water temperatures, although they are likely to be more tolerant than brown trout, as they have acute and chronic thermal thresholds of 26°C. However, note that the chronic criterion is based on a maximum weekly average temperature, while the acute criterion is based on the highest 2-h average (Olsen *et al.*, 2012).

Water temperature was recorded in the South Branch (17 July, 2012 - 28 March, 2013) and North Branch (17 July, 2012 - 3 January, 2013 and 2 - 27 March, 2013) during this study. The maximum temperature recorded in the South Branch over the monitoring period was 22.5°C, with the highest 2-h average temperature being 22.5 and the highest 7-day average temperature being 19.4°C. The maximum temperature recorded in the North Branch over the monitoring period was 23.6°C, with the highest 2-h average temperature being 23.4°C, and the highest 7-day average temperature being 18.2°C. These recordings did not exceed either the acute or chronic thermal thresholds for brown trout (based on Todd *et al.* (2008)), although the maximum 7-day average in the South Branch (19.4°C) was approaching the chronic threshold suggested by Todd *et al.* (2008). These data collected from the Waianakarua River suggest that it provides a highly suitable thermal environment for brown trout and for all native fish species collected.

12.1.2.3 Faecal contamination

Water contaminated with faecal matter poses a range of possible health risks to recreational users, including serious gastrointestinal and respiratory illnesses. Counts of the bacterium *E. coli* are commonly used as an indicator of faecal contamination and a measure of the probability of the presence of other disease-causing agents, such as the protozoa *Giardia* and *Cryptosporidium*, the bacterium *Campylobacter* and various other bacteria and viruses.

Counts of *E. coli* in the Waianakarua catchment were generally low, with the highest median counts found at the two downstream sites (mid-main stem and Brown's Pump). However, a single elevated count was found in the upper South Branch (1500 cfu/100 ml on 18 March), the reasons for which are not clear. There was no indication of effluent contamination at any of the sites in the Waianakarua catchment.

12.1.2.4 Substrate and riparian cover

As well as water quality, the quantity and quality of habitat are important factors that can affect many instream values, among which composition of the streambed is particularly important because it provides the attachment substrate for periphyton and the habitat for macroinvertebrates and fish. The substrate at all sites in the catchment was dominated by gravels, cobbles and bedrock, with no sign of significant fine sediment deposition. Similarly, there was no significant sediment compaction or embeddedness at any of the sites.

The sites in both branches had stable banks and were shaded by the surrounding landscape and riparian vegetation. In contrast, the main stem sites had less stable banks and were more open, with shading mainly being provided by riparian vegetation. The openness of these sites is a natural attribute, compared to the more heavily shaded sites; however, it probably exacerbates the effects of the higher nutrient levels on the growth of periphyton by increasing light and water temperatures.

Light, nutrients and water temperature are the most important factors affecting periphyton accrual (Biggs 2000). The results of these habitat assessments, along with increasing NNN concentrations with distance downstream in the main stem, suggest that the lower Waianakarua River is at greatest risk of nuisance growths of periphyton developing.

12.1.3 Compliance with plan change 6A standards

Plan change 6A outlines the water quality standards for receiving waters (Schedule 15, Table 3.1) and discharge limits (Schedule 16). Receiving water standards are applied as 5-year, 80th percentiles, when flows are at or below median flow (0.783 m3/s), with the flows in the Waianakarua catchment being set at the gauging site at Brown's Pump.

Most of the sites sampled in the catchment were sampled between July 2012 and April 2013, with four samples being collected when flows were below the median flow. Consequently, 80th percentiles were calculated on the basis of limited data and should be treated with caution. This is not a concern for the SoE monitoring site at Brown's Pump.

Between 2001 and 2013, NNN concentrations at four of the sites surveyed, and at Brown's Pump (assessed as a running 5-year 80th percentile), exceeded the Schedule 15 standard (Table 13.1). In contrast, between 2012 and 2013, the 80th percentiles of NH_4-N and DRP did not exceed the Schedule 15 standards at any of the sites (Table 13.1). The 80th percentiles of *E. coli* counts at the upper site in the South Branch exceeded the Schedule 15 value, although this was caused by a single anomalous high reading (Table 13.1). The 80th percentile of turbidity at Brown's Pump was very low and well below the Schedule 15 value (Table 13.1).

Table 12.1 Comparison of 80th percentiles of water quality parameters with receiving water quality standards in plan change 6A (Schedule 15, Table 3.1). Values that exceed the Schedule 15 standard are highlighted red. The 80th percentiles were calculated based on samples collected when flows were below median flow.

Site	Period	NNN 0.075 mg/l	NH_4-N 0.1 mg/l	DRP 0.01 mg/l	*E. coli* 260 cfu/100 ml	Turbidity 5 NTU
North Branch - upper	2012-2013	0.021	0.005	0.003	70	-
North Branch at SH1	2012-2013	0.019	0.005	0.002	19	-
South Branch - upper	2012-2013	0.066	0.005	0.003	622	-
South Branch at SH1	2012-2013	0.530	0.005	0.002	75	-
Main stem at confluence	2012-2013	0.224	0.005	0.002	27	-
Mid-main stem	2012-2013	0.310	0.005	0.002	96	-
Mainstem at Brown's Pump	2012-2013	0.482	0.005	0.002	61	-
	2001-2013	0.238	0.010	0.007	59	0.55

12.2 Biological monitoring

12.2.1 Periphyton

The periphyton community forms the slimy coating on the surface of stones and other substrates in freshwaters. This community can include green (Chlorophyta), yellow-green (Xanthophyta), golden brown (Chrysophyta) and red (Rhodophyta) algae, blue-greens (Cyanobacteria), diatoms (Bacillariophyta), bacteria and fungi. Periphyton is an integral part of stream food webs. It captures energy from the sun and converts it, via photosynthesis, to energy sources available to macroinvertebrates, which feed on it. These, in turn, are fed on by other invertebrates and fish. However, periphyton can form nuisance blooms that can detrimentally affect other instream values, such as aesthetics, biodiversity, recreation (swimming and angling), water takes (irrigation, stock/drinking water and industrial) and water quality.

Cyanobacteria, a group of photosynthetic bacteria, were the dominant (or co-dominant) periphyton taxa at Brown's Pump on most sampling occasions. In rivers and streams, they usually grow attached to the bed (referred to as 'benthic'), and, under the right conditions (high levels of light, warm temperatures and stable flows), they can form thick mats, which can affect water quality. They may also form toxins that pose a risk to human and animal health, including hepatotoxins that affect the liver, neurotoxins that affect the nervous system and dermatotoxins that irritate the skin.

The main benthic cyanobacterium in New Zealand rivers is *Phormidium* (Order: Oscillatoriales), which has been associated with dog deaths throughout New Zealand. Dogs are poisoned either by eating dislodged mats of *Phormidium* or by eating dry mats washed out of the wetted channel during high flows. Phormidium is known to produce the potent neurotoxins anatoxin-a and homoanatoxin-a and microcystin hepatotoxins. However, the factors controlling toxin production are not well understood, and the presence of *Phormidium* mats alone does not mean that toxins will be present. Warning signs have been erected at the main public access points over the spring-autumn period to educate the public to the presence of benthic cyanobacteria and the risks that they present to people and animals. This is an appropriate response to the issue and should continue.

12.2.2 Macroinvertebrates

Macroinvertebrates are a diverse group and include insects, crustaceans, worms, molluscs and mites. They are an important part of stream food webs, linking primary producers (periphyton and terrestrial leaf litter) to higher trophic levels (fish, birds). Because of the length of the aquatic part of their life-cycles, macroinvertebrates also provide a good indication of the medium- to long-term water quality of a waterway. For this reason, they are used in biomonitoring around the world. In New Zealand, the MCI (Stark, 1985), and its derivatives (SQMCI, QMCI: Stark, 1998), are used as a measure of organic enrichment and sedimentation in gravel-bed streams, and 'soft-bottomed' versions of each have been developed (Stark & Maxted, 2007).

The macroinvertebrate community at the Brown's Pump site (2007-2013) indicated that water quality was generally 'good' to 'excellent', while, in 2013, sampling at other sites in the Waianakarua River also indicated 'good' to 'excellent' water quality. MCI scores in the main stem sites declined from the confluence to Brown's Pump, which is consistent with the decline in water quality (increasing TN, NNN and *E. coli*) observed in the main stem.

12.2.3 Fish

The Waianakarua River supports a diverse fish community, with 14 species collected, including seven species that have been classified as ‘at risk’ and ‘declining’ under the New Zealand Freshwater Fish Threat Classification. These are longfin eel, torrentfish, inanga, koaro, lamprey, bluegill bully and redfin bully. Of these species, bluegill bullies were the most abundant species at Brown’s Pump on most occasions, while torrentfish were also abundant. These results show that the Waianakarua catchment provides significant habitat for native freshwater fish.

13 Summary

1. The SoE water quality monitoring site in the Waianakarua River at Brown's Pump has been consistent between 2001 and 2013, with no trends detected for any of the water quality variables considered.

2. Water temperature data collected in the Waianakarua River suggest that the river provides a highly suitable thermal environment for brown trout and all native fish species collected.

3. TN and NNN at both sites in the North Branch were very low. TN and NNN concentrations observed in the upper South Branch were slightly higher, probably because of low nitrogen uptake by algae, and the reach upstream being more heavily shaded than the North Branch sites. TN and NNN concentrations in the South Branch at SH1 were markedly higher than recorded at the upstream site (McKerrow Road, 3.5 km upstream), suggesting that a significant source of nitrogen enters the river between these two sites.

4. Concentrations of TN and NNN increased with distance downstream of the confluence, probably reflecting the intensive farming practices in the lower catchment. Few tributaries enter the lower river, suggesting that nitrogen is entering surface water via leaching to groundwater, which then enters the lower river.

5. Concentrations of DRP tended to be below the detection limit at all sites sampled. Nitrogen to phosphorus (N:P) ratios suggest that periphyton in the South Branch at SH1 and all main stem sites are phosphorus-limited. However, ratios in the North Branch and upper South Branch varied markedly, indicating that no one nutrient was consistently limiting algal growth and/or that they may be co-limiting.

6. Counts of E. coli in the Waianakarua catchment were generally low, with the highest median counts found at the two downstream sites (mid-main stem and Brown's Pump). There was no indication of effluent contamination at any of the sites in the catchment.

7. Water quality in the catchment in 2012/13 was compared to the receiving water quality standards in plan change 6A.

    a. All sites in the catchment complied with the receiving water quality standards for NH4-N (0.1 mg/l) and DRP (0.01 mg/l).

    b. Turbidity readings at Brown's Pump, taken between 2001 and 2013, complied with the standard (5 NTU).

    c. The receiving water quality standard for NNN (0.075 mg/l) was breached in the South Branch at SH1 and all main stem sites, including Brown's Pump.

    d. The only site to exceed the receiving water quality standard for E. coli (260 cfu/100 ml) was the upper South Branch. This was because of one exceptional value, which is probably anomalous.

8. Benthic cyanobacteria were the dominant (or co-dominant) periphyton taxa at Brown's Pump on most sampling occasions. Benthic cyanobacteria have been associated with dog deaths. Warning signs should continue to be erected at the main public access points during the spring-autumn period to educate the public to their presence and the risks they present to people and animals.

9. The macroinvertebrate community at the Brown's Pump site (2007-2013) indicated that water quality was generally 'good' to 'excellent', while sampling at other sites in the Waianakarua River in 2013 also indicated 'good' to 'excellent' water quality. MCI scores in the main stem sites declined from the confluence to Brown's Pump, which is consistent with the decline in water quality (increasing TN, NNN and *E. coli*) observed in the main stem.

10. The Waianakarua River supports a diverse fish community, with 14 species collected, including seven species that have been classified as 'at risk' and 'declining' under the New Zealand Freshwater Fish Threat Classification. These are longfin eel, torrentfish, inanga, koaro, lamprey, bluegill bully and redfin bully.

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Appendix 1 Raw water quality data for sites in the Waianakarua catchment

Site name	Date	*E. coli*	TN	NNN	NH4-N	DRP	TP	TKN	SS
		cfu/100 m	mg/l	mg/l-N	mg/l-N	mg/l-P	mg/l	mg/l	mg/l
Waianakarua at upper North Branch	26/07/2012	32.00	>0.11	0.02	>0.01	>0.004	>0.004	>1	>3
Waianakarua at upper North Branch	7/08/2012	15.00	0.33	0.21	>0.01	0.01	0.01	0.12	>3
Waianakarua at upper North Branch	23/08/2012	16.00	0.35	0.23	0.01	0.01	0.01	0.12	>3
Waianakarua at upper North Branch	3/09/2012		0.20	0.14	>0.01	0.01	0.01	>1	>3
Waianakarua at upper North Branch	18/09/2012	250.00	0.13	0.06	>0.01	0.01	0.01	>1	>3
Waianakarua at upper North Branch	3/10/2012	70.00	0.11	0.03	>0.01	0.00	0.01	>1	>3
Waianakarua at upper North Branch	16/10/2012	70.00	0.17	0.06	>0.01	>0.004	0.01	0.11	>3
Waianakarua at upper North Branch	30/10/2012	230.00	0.12	0.01	>0.01	0.00	0.01	0.11	>3
Waianakarua at upper North Branch	13/11/2012	270.00	0.19	0.06	>0.01	>0.004	0.01	0.13	>3
Waianakarua at upper North Branch	27/11/2012	220.00	0.32	0.02	>0.01	>0.004	>0.004	0.29	>3
Waianakarua at upper North Branch	12/12/2012	460.00	0.10	0.01	>0.01	>0.004	0.01	>1	>3
Waianakarua at upper North Branch	10/01/2013	480.00	0.17	0.09	>0.01	0.01	0.01	>1	>3
Waianakarua at upper North Branch	21/01/2013	210.00	0.13	0.04	0.02	>0.004	>0.004	>1	>3
Waianakarua at upper North Branch	7/02/2013	330.00	0.11	0.01	>0.01	>0.004	0.01	>1	>3
Waianakarua at upper North Branch	19/02/2013	130.00	>0.11	0.02	>0.01	>0.004	0.02	>1	>3
Waianakarua at upper North Branch	5/03/2013	30.00	>0.11	0.01	>0.01	0.01	0.08	>1	>3
Waianakarua at upper North Branch	18/03/2013	600.00	0.20	0.12	>0.01	0.01	0.02	>1	>3
Waianakarua at upper North Branch	3/04/2013	10.00	>0.11	0.02	>0.01	>0.004	0.01	>1	>3
Waianakarua at upper North Branch	15/04/2013	2.00	0.12	0.01	>0.01	>0.004	>0.004	0.11	>3
Waianakarua North Branch at SH1	26/07/2012	43.00	0.14	0.04	>0.01	>0.004	>0.004	0.11	>3
Waianakarua North Branch at SH1	7/08/2012	38.00	0.38	0.28	>0.01	0.01	0.01	>1	>3
Waianakarua North Branch at SH1	23/08/2012	30.00	0.57	0.41	>0.01	0.01	0.02	0.17	>3
Waianakarua North Branch at SH1	3/09/2012	26.00	0.39	0.31	>0.01	0.01	0.01	>1	>3
Waianakarua North Branch at SH1	18/09/2012	80.00	0.22	0.13	>0.01	>0.004	0.01	>1	>3
Waianakarua North Branch at SH1	3/10/2012	140.00	0.12	0.04	>0.01	>0.004	0.01	>1	>3
Waianakarua North Branch at SH1	16/10/2012	140.00	0.25	0.06	>0.01	>0.004	0.01	0.18	>3
Waianakarua North Branch at SH1	30/10/2012	190.00	0.10	0.01	>0.01	>0.004	0.01	>1	>3
Waianakarua North Branch at SH1	13/11/2012	270.00	0.23	0.08	>0.01	>0.004	0.01	0.14	>3
Waianakarua North Branch at SH1	27/11/2012	170.00	0.11	0.06	>0.01	>0.004	>0.004	>1	>3
Waianakarua North Branch at SH1	12/12/2012	100.00	0.11	0.03	>0.01	>0.004	0.01	>1	>3
Waianakarua North Branch at SH1	10/01/2013	410.00	0.19	0.11	>0.01	>0.004	>0.004	>1	>3
Waianakarua North Branch at SH1	21/01/2013	850.00	0.15	0.05	>0.01	>0.004	>0.004	0.10	>3
Waianakarua North Branch at SH1	7/02/2013	47.00	>0.11	0.01	>0.01	>0.004	0.00	>1	>3
Waianakarua North Branch at SH1	19/02/2013	21.00	>0.11	0.01	>0.01	>0.004	0.02	>1	>3
Waianakarua North Branch at SH1	5/03/2013	14.00	>0.11	0.02	>0.01	>0.004	0.01	>1	>3
Waianakarua North Branch at SH1	18/03/2013	1100.00	0.13	0.08	>0.01	>0.004	0.01	>1	>3
Waianakarua North Branch at SH1	3/04/2013	17.00	>0.11	0.02	>0.01	>0.004	0.01	>1	>3
Waianakarua North Branch at SH1	15/04/2013	12.00	>0.11	0.00	>0.01	>0.004	>0.004	>1	>3
Waianakarua at upper South Branch	26/07/2012	5.00	0.14	0.10	>0.01	>0.004	>0.004	>1	>3
Waianakarua at upper South Branch	7/08/2012	8.00	0.42	0.30	>0.01	0.01	0.01	0.12	>3
Waianakarua at upper South Branch	23/08/2012	11.00	0.45	0.28	>0.01	0.01	0.02	0.18	>3
Waianakarua at upper South Branch	3/09/2012	10.00	0.32	0.25	>0.01	0.01	0.01	>1	>3
Waianakarua at upper South Branch	18/09/2012	26.00	0.17	0.09	>0.01	0.01	0.01	>1	>3
Waianakarua at upper South Branch	3/10/2012	150.00	0.20	0.10	>0.01	0.01	0.01	0.10	>3
Waianakarua at upper South Branch	16/10/2012	50.00	0.32	0.08	>0.01	>0.004	0.01	0.24	>3
Waianakarua at upper South Branch	30/10/2012	12.00	>0.11	0.01	>0.01	>0.004	0.01	>1	>3
Waianakarua at upper South Branch	13/11/2012	37.00	0.23	0.08	>0.01	>0.004	0.01	0.15	>3
Waianakarua at upper South Branch	27/11/2012	22.00	0.13	0.02	>0.01	>0.004	>0.004	0.12	>3
Waianakarua at upper South Branch	12/12/2012	16.00	0.15	0.05	>0.01	>0.004	0.01	0.10	>3
Waianakarua at upper South Branch	10/01/2013	65.00	0.19	0.09	>0.01	0.01	0.01	0.10	>3
Waianakarua at upper South Branch	21/01/2013	55.00	0.15	0.05	>0.01	>0.004	>0.004	0.10	>3
Waianakarua at upper South Branch	7/02/2013	22.00	0.15	0.04	>0.01	>0.004	0.01	0.11	>3
Waianakarua at upper South Branch	19/02/2013	13.00	0.13	0.05	>0.01	>0.004	0.02	>1	>3
Waianakarua at upper South Branch	5/03/2013	37.00	0.14	0.06	>0.01	0.01	0.01	>1	>3
Waianakarua at upper South Branch	18/03/2013	420.00	0.27	0.16	>0.01	>0.004	0.01	0.11	>3
Waianakarua at upper South Branch	3/04/2013	1500.00	0.14	0.08	>0.01	>0.004	0.01	>1	>3
Waianakarua at upper South Branch	15/04/2013	12.00	>0.11	0.04	>0.01	>0.004	>0.004	>1	>3

Site name	Date	*E. coli*	TN	NNN	NH4-N	DRP	TP	TKN	SS
		cfu/100 m	mg/l	mg/l-N	mg/l-N	mg/l-P	mg/l	mg/l	mg/l
Waianakarua South Branch at SH1	26/07/2012	44.00	0.28	0.23	>0.01	>0.004	>0.004	>1	>3
Waianakarua South Branch at SH1	7/08/2012	16.00	0.52	0.35	>0.01	0.01	0.01	0.17	>3
Waianakarua South Branch at SH1	23/08/2012	10.00	0.71	0.53	>0.01	0.01	0.02	0.18	>3
Waianakarua South Branch at SH1	3/09/2012	8.00	1.05	0.95	>0.01	0.01	0.01	>1	>3
Waianakarua South Branch at SH1	18/09/2012	>1	0.74	0.66	>0.01	0.01	0.01	>1	>3
Waianakarua South Branch at SH1	3/10/2012	190.00	0.33	0.20	>0.01	0.01	0.01	0.13	>3
Waianakarua South Branch at SH1	16/10/2012	16.00	0.29	0.10	>0.01	>0.004	0.01	0.19	>3
Waianakarua South Branch at SH1	30/10/2012	6.00	0.20	0.07	>0.01	>0.004	>0.004	0.13	>3
Waianakarua South Branch at SH1	13/11/2012	140.00	0.28	0.10	>0.01	>0.004	0.01	0.18	>3
Waianakarua South Branch at SH1	27/11/2012	9.00	0.22	0.13	>0.01	>0.004	>0.004	>1	>3
Waianakarua South Branch at SH1	12/12/2012	39.00	0.27	0.22	>0.01	>0.004	0.01	>1	>3
Waianakarua South Branch at SH1	10/01/2013	60.00	0.28	0.18	>0.01	>0.004	>0.004	>1	>3
Waianakarua South Branch at SH1	21/01/2013	400.00	0.21	0.12	>0.01	>0.004	0.01	>1	3.00
Waianakarua South Branch at SH1	7/02/2013	60.00	0.31	0.21	>0.01	>0.004	0.01	0.10	>3
Waianakarua South Branch at SH1	19/02/2013	28.00	0.50	0.41	>0.01	>0.004	0.02	>1	>3
Waianakarua South Branch at SH1	5/03/2013	140.00	0.60	0.53	>0.01	>0.004	>0.004	>1	>3
Waianakarua South Branch at SH1	18/03/2013	1100.00	0.30	0.22	>0.01	>0.004	0.01	>1	>3
Waianakarua South Branch at SH1	3/04/2013	31.00	0.61	0.53	>0.01	>0.004	0.01	>1	>3
Waianakarua South Branch at SH1	15/04/2013	30.00	0.59	0.52	>0.01	>0.004	>0.004	>1	>3
Waianakarua at confluence	26/07/2012		0.19	0.14	>0.01	>0.004	>0.004	>1	>3
Waianakarua at confluence	7/08/2012	51.00	0.38	0.28	>0.01	0.01	0.01	0.10	>3
Waianakarua at confluence	23/08/2012	50.00	0.61	0.43	>0.01	0.01	0.02	0.18	>3
Waianakarua at confluence	3/09/2012	13.00	0.90	0.81	>0.01	0.01	0.01	>1	>3
Waianakarua at confluence	18/09/2012	80.00	0.62	0.50	>0.01	0.00	0.00	0.12	>3
Waianakarua at confluence	3/10/2012	120.00	0.24	0.12	>0.01	>0.004	0.01	0.13	>3
Waianakarua at confluence	16/10/2012	130.00	0.22	0.08	>0.01	>0.004	0.01	0.14	>3
Waianakarua at confluence	30/10/2012	33.00	0.13	0.05	>0.01	>0.004	>0.004	>1	>3
Waianakarua at confluence	13/11/2012	190.00	0.28	0.09	>0.01	>0.004	0.01	0.19	>3
Waianakarua at confluence	27/11/2012	100.00	0.36	0.11	>0.01	>0.004	>0.004	0.25	>3
Waianakarua at confluence	12/12/2012	80.00	0.20	0.12	>0.01	>0.004	0.00	>1	>3
Waianakarua at confluence	10/01/2013	800.00	0.24	0.16	>0.01	0.01	0.01	>1	>3
Waianakarua at confluence	21/01/2013	300.00	0.17	0.05	>0.01	>0.004	>0.004	0.13	>3
Waianakarua at confluence	7/02/2013	77.00	>0.11	0.01	>0.01	>0.004	>0.004	>1	>3
Waianakarua at confluence	19/02/2013	28.00	0.16	0.09	>0.01	>0.004	0.02	>1	>3
Waianakarua at confluence	5/03/2013	21.00	0.23	0.19	>0.01	>0.004	>0.004	>1	>3
Waianakarua at confluence	18/03/2013	700.00	0.14	0.09	>0.01	>0.004	0.01	>1	>3
Waianakarua at confluence	3/04/2013	19.00	0.37	0.28	>0.01	>0.004	>0.004	>1	>3
Waianakarua at confluence	15/04/2013	26.00	0.15	0.12	>0.01	>0.004	>0.004	>1	>3
Waianakarua at mid-main stem	26/07/2012	24.00	0.20	0.13	>0.01	>0.004	>0.004	>1	>3
Waianakarua at mid-main stem	7/08/2012	26.00	0.53	0.32	0.02	0.01	0.01	0.21	>3
Waianakarua at mid-main stem	23/08/2012	17.00	0.76	0.59	>0.01	0.01	0.02	0.17	>3
Waianakarua at mid-main stem	3/09/2012	11.00	1.00	0.90	>0.01	0.01	0.01	>1	>3
Waianakarua at mid-main stem	18/09/2012	40.00	0.70	0.61	>0.01	0.00	0.00	>1	>3
Waianakarua at mid-main stem	3/10/2012	150.00	0.24	0.13	>0.01	>0.004	0.01	0.11	>3
Waianakarua at mid-main stem	16/10/2012	38.00	0.17	0.08	>0.01	>0.004	0.01	>1	>3
Waianakarua at mid-main stem	30/10/2012	39.00	0.16	0.06	>0.01	>0.004	>0.004	>1	>3
Waianakarua at mid-main stem	13/11/2012	170.00	0.25	0.09	>0.01	>0.004	0.01	0.16	>3
Waianakarua at mid-main stem	27/11/2012	70.00	0.22	0.13	>0.01	>0.004	0.00	>1	>3
Waianakarua at mid-main stem	12/12/2012	160.00	0.21	0.14	>0.01	>0.004	>0.004	>1	>3
Waianakarua at mid-main stem	10/01/2013	290.00	0.30	0.18	>0.01	0.00	0.01	0.11	>3
Waianakarua at mid-main stem	21/01/2013	190.00	0.13	0.08	>0.01	>0.004	0.01	>1	>3
Waianakarua at mid-main stem	7/02/2013	51.00	0.20	0.13	>0.01	>0.004	>0.004	>1	>3
Waianakarua at mid-main stem	19/02/2013	38.00	0.30	0.22	>0.01	>0.004	0.02	>1	>3
Waianakarua at mid-main stem	5/03/2013	18.00	0.37	0.31	>0.01	>0.004	>0.004	>1	>3
Waianakarua at mid-main stem	18/03/2013	700.00	0.39	0.31	>0.01	>0.004	0.01	>1	>3
Waianakarua at mid-main stem	3/04/2013	80.00	0.40	0.31	>0.01	>0.004	0.00	>1	>3
Waianakarua at mid-main stem	15/04/2013	120.00	0.32	0.24	>0.01	>0.004	>0.004	>1	>3

Site name	Time	*E. coli*	TN	NNN	NH4-N	DRP	TP	DO	Turbidity	Water temperature	pH	TKN	SS	Conductivity	DO saturation	Black disc horizontal	TDP	BOD (5 d)
		cfu/100 ml	mg/l	mg/l-N	mg/l-N	mg/l-P	mg/l	mg/l	NTU	degrees C		mg/l	mg/l	mS/cm	(%)	(m)	mg/l	mg/l-O
Waianakarua at Brown's	4/08/1999	16.00	0.32	0.21	0.01	0.0005	<0.005	11.50	1.20	6.50	7.50		<1	0.06		4.20	<0.003	<1
Waianakarua at Brown's	12/04/2000	22.00	0.21	0.07	<0.005	0.00	0.01	11.00	0.30	12.50	7.80		1.00	0.07		4.30	0.01	<1
Waianakarua at Brown's	14/06/2000	50.00	0.34	0.20	0.01	0.00	0.03	13.70	1.00	5.00	7.50		<1	0.15		1.00	0.02	<1
Waianakarua at Brown's	9/08/2000	2.00	0.27	0.21	0.01	<0.005	0.01	11.90	0.23	6.70	7.40		<1	0.08		5.50	0.01	1.50
Waianakarua at Brown's	12/10/2000	160.00	0.52	0.38	0.01	<0.005	<0.005	12.50	0.42	8.20	7.60		<1	0.06			<0.005	2.00
Waianakarua at Brown's	6/12/2000	44.00	0.19	0.08	0.02	0.01	0.01	8.60	0.55	22.10	7.60		<1	0.07		4.00	0.01	<1
Waianakarua at Brown's	14/02/2001	100.00	0.23	0.13	0.02	<0.005	<0.005		0.51	18.00	7.60		<1	0.09		4.00	0.01	<1
Waianakarua at Brown's	13/06/2001	35.00	0.08	0.05	<0.01	<0.005	<0.005	15.50	0.22	3.20	7.50		<1	0.05		5.50	<0.005	<1
Waianakarua at Brown's	15/08/2001	22.00	0.28	0.22	<0.01	<0.005	<0.005	13.00	0.54	6.50	7.20		<1	0.07		4.70	<0.005	<1
Waianakarua at Brown's	9/10/2001	130.00	0.21	0.11	0.02	<0.005	0.02		0.78	11.50	7.40		1.00			2.29	0.01	<1
Waianakarua at Brown's	13/12/2001	190.00	0.18	0.06	0.01	<0.01	<0.005	11.10	0.60	17.90	7.40		<1	0.06		3.54	<0.005	<1
Waianakarua at Brown's	12/02/2002	32.00	0.40	0.26	0.02	<0.01	0.02	9.60	0.32	16.80	7.40		<1	0.10		3.12	<0.005	<1
Waianakarua at Brown's	9/04/2002	<4	0.27	0.15	<0.01	<0.01	<0.005	11.80	0.34	11.00	7.00		<1	0.10		5.74	<0.005	<1
Waianakarua at Brown's	10/06/2002	8.00	0.48	0.33	<0.01	<0.005	<0.005	11.50	0.38	6.50	7.20		<1	0.11		5.63	<0.005	<1
Waianakarua at Brown's	27/08/2002	2.00	0.45	0.35	<0.01	<0.005	<0.005	12.40	0.35	7.00	7.51		<1	0.11		5.45		
Waianakarua at Brown's	9/10/2002	11.00	0.97	0.02	0.02	<0.005	<0.005	11.40	0.15	12.00	7.51		<1	0.05		5.42		
Waianakarua at Brown's	9/12/2002	13.00	0.22	0.15	0.01	<0.005	<0.005	8.90	0.10	19.70	7.58		<1	0.07	93.10	5.33		
Waianakarua at Brown's	10/02/2003	26.00	0.30	0.20	0.02	0.01	0.01	9.00	0.10	21.00	7.55		<1	0.15		5.36		
Waianakarua at Brown's	8/04/2003	91.00	0.16	0.05	0.01	<0.005	<0.005	10.90	0.40	12.00	7.52		<1	0.08		5.70		
Waianakarua at Brown's	9/06/2003	27.00	0.33	0.15	0.03	<0.005	<0.005	12.00	0.45	7.20	7.73		<1	0.10		2.86		
Waianakarua at Brown's	18/08/2003	1.00	0.08	0.01	0.01	<0.005	<0.005	12.90	0.15	7.00	7.90		<1	0.07		6.85		
Waianakarua at Brown's	6/10/2003	2.00	0.17	0.06	0.01	<0.005	<0.005	12.60	0.30	10.20	7.82		<1	0.06	112.00	6.59		
Waianakarua at Brown's	8/12/2003	19.00	0.27	0.14	0.01	<0.005	<0.005	9.10	0.15	16.00	7.65		<1	0.09	90.50	6.83		
Waianakarua at Brown's	9/02/2004	43.00	0.27	0.19	0.02	<0.005	0.01	9.70	0.15	19.00	7.64		<1	0.09		6.12		
Waianakarua at Brown's	13/04/2004	8.00	0.08	0.05	<0.01	<0.005	<0.005	12.90	0.15	11.60			1.00	0.07	119.00	8.86		
Waianakarua at Brown's	8/06/2004	2.00	0.25	0.17	<0.01			13.20	0.20	5.70	7.68		<1	0.12		9.87		
Waianakarua at Brown's	16/08/2004	5.00	0.42	0.37	0.01	0.01	0.01	13.10	0.70	4.80	7.19		<1	0.10		6.20		
Waianakarua at Brown's	12/10/2004	4.00	0.22	0.14	<0.01	0.01	0.01	11.00	0.10	13.90			<1	0.06	108.00	6.72		
Waianakarua at Brown's	14/12/2004	19.00	0.13	<0.005	<0.01			10.60	0.25	13.70	7.37		<1	0.09		6.37		
Waianakarua at Brown's	8/02/2005	71.00	0.29	0.15	<0.01	0.01	0.01	9.70	0.70	21.90			1.00	0.09	110.00	3.61		
Waianakarua at Brown's	11/04/2005	5.00	0.14	0.04	0.01	<0.005	<0.005	11.30	0.10	12.80			<1	0.06	105.00			
Waianakarua at Brown's	14/06/2005	3.00	0.12	0.05	0.01	<0.005	0.01	13.60	0.20	3.69			<1	0.05	104.00			
Waianakarua at Brown's	16/08/2005	54.00	0.40	0.11	<0.01	0.01	0.02	11.60	0.16	4.96			<3	0.07	90.40			
Waianakarua at Brown's	12/10/2005	20.00	0.21	0.06	<0.01	0.01	0.01	9.50	1.90	8.70	7.40		<3	0.07				
Waianakarua at Brown's	5/12/2005	120.00	0.25	0.08	0.02	0.01	0.01	8.40	0.18	19.90			<3	0.07	91.10			
Waianakarua at Brown's	8/02/2006	34.00	0.11	0.03	0.01			10.00	0.23	17.30	8.60		<3	0.08	104.00			
Waianakarua at Brown's	19/04/2006	20.00	0.08	0.08	<0.01	0.01	<0.005	9.00	0.88	14.60			<3	0.07	88.20			
Waianakarua at Brown's	15/06/2006	14.00	0.19	0.12	0.01	0.01	0.01	11.50	0.27	3.56			<3	0.04	86.50			
Waianakarua at Brown's	23/08/2006	29.00	0.12	0.04	<0.01	<0.005	<0.005	13.80	0.77	3.50	7.30		<3	0.06	104.00			
Waianakarua at Brown's	10/10/2006	3.00			0.01	0.01	0.01	9.80	0.34	9.90	7.70		<3	0.06	84.10			

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Site name	Time	*E. coli*	TN	NNN	NH4-N	DRP	TP	DO	Turbidity	Water temperature	pH	TKN	SS	Conductivity	DO saturation	Black disc horizontal	TDP	BOD (5 d)
		cfu/100 ml	mg/l	mg/l-N	mg/l-N	mg/l-P	mg/l	mg/l	NTU	degrees C		mg/l	mg/l	mS/cm	(%)	(m)	mg/l	mg/l-O
Waianakarua at Brown's	5/12/2006	12.00	0.14	0.05	0.01	0.01	0.01	10.30	0.33	14.00	7.50		<3	0.06	99.40			
Waianakarua at Brown's	14/02/2007	<2	0.08	0.04	0.01	0.01	0.01	10.10	1.35	17.50	7.80		<3	0.09	106.00			
Waianakarua at Brown's	2/05/2007	110.00	0.22	0.13	0.02	0.01	0.01	10.60	0.87	11.10	7.10		4.00	0.10	95.50			
Waianakarua at Brown's	26/06/2007	6.00	0.19	0.08	<0.01			13.00	0.20	4.30	7.90		<3	0.10	99.90			
Waianakarua at Brown's	12/09/2007	4.00	0.37	0.29	<0.01			9.80	0.22	9.50	7.80		<3		85.70			
Waianakarua at Brown's	6/11/2007	4.00	0.33	0.15	<0.01				0.23		7.50		<3					
Waianakarua at Brown's	17/01/2008	20.00	0.17	0.09	<0.01	<0.005	0.01	4.70	0.17	19.00	7.60		<3	0.09	50.30			
Waianakarua at Brown's	27/02/2008	80.00	0.22	0.11	<0.01	0.01	0.01	10.40	0.23	18.10			<3	0.08	109.00			
Waianakarua at Brown's	7/05/2008	20.00	0.19	0.12	<0.01	<0.005	0.01		0.18		6.90		<3					
Waianakarua at Brown's	7/07/2008	18.00	0.10	0.02	<0.01	0.01	0.01	15.10	0.12	4.46			<3	0.05	117.00			
Waianakarua at Brown's	28/08/2008	15.00	0.19	0.15	<0.01	0.01	0.02	10.70	1.23	7.00			<3	0.04	90.10			
Waianakarua at Brown's	13/11/2008	30.00	0.38	0.24	0.02	0.01	0.01	10.10	0.19	16.10	7.40		<3	0.10	102.00			
Waianakarua at Brown's	14/01/2009	39.00	0.23	0.15	0.01			8.80	0.19	17.80	7.10		<3	0.10	93.00			
Waianakarua at Brown's	11/03/2009	67.00	0.67	0.50	<0.01	0.01	0.02	10.90	2.42	9.50	6.90		<3	0.09	96.00			
Waianakarua at Brown's	5/05/2009	10.00	0.47	0.41	<0.01			11.30	0.19	7.80	7.50		<3	0.11	96.00			
Waianakarua at Brown's	13/07/2009	15.00			<0.01	0.01	0.01	12.00	1.16	4.23	7.50		<3	0.06	92.20			
Waianakarua at Brown's	15/09/2009	5.00	0.27	0.21	<0.01	0.01	0.01	12.30	0.32	9.20	7.70		<3	0.09	107.00			
Waianakarua at Brown's	11/11/2009	8.00			<0.01	0.01	0.01	8.10	0.54	14.20	7.60		<3	0.07	78.70			
Waianakarua at Brown's	26/01/2010	18.00	0.19	0.13	0.01			9.80	0.25	16.00	7.60		<3	0.10	99.60			
Waianakarua at Brown's	23/03/2010	43.00	0.21	0.14	<0.01	0.01	0.01	9.40	0.17	13.50	7.50		<3	0.11	90.40			
Waianakarua at Brown's	27/04/2010	620.00		0.27		0.01												
Waianakarua at Brown's	11/05/2010	2.00	0.17	0.10	<0.01			8.20	0.36	8.10	7.40		<3	0.11	69.30			
Waianakarua at Brown's	21/07/2010	<1	0.65	0.54	<0.01			14.40	0.25	3.56	7.60		<3	0.06	108.00			
Waianakarua at Brown's	14/09/2010	6.00	0.37	0.22	<0.01	0.01	0.01	12.00	0.84	9.10	7.60		<3	0.08	104.00			
Waianakarua at Brown's	9/11/2010	11.00	0.37	0.29	<0.01			9.80	0.32	13.90	7.50		<3	0.10	94.80			
Waianakarua at Brown's	11/01/2011	30.00	0.15	0.05	<0.01	0.01	0.01	10.00	0.38	16.50	7.80		<3	0.08	103.00			
Waianakarua at Brown's	7/03/2011	4.00	0.14	0.03	<0.01	0.01	0.01	10.60	0.35	13.20	7.70		<3	0.08	100.00			
Waianakarua at Brown's	25/05/2011	9.00	0.40	0.29	<0.01	0.01	0.01	12.50	1.00	7.50	7.50		<3	0.08	105.00			
Waianakarua at Brown's	2/08/2011	15.00	0.19	0.12	<0.01	<0.004	<0.004	16.10	0.22	3.80	7.60	<1	<3	0.09	122.00			
Waianakarua at Brown's	29/09/2011	6.00	0.17	0.07	<0.01	<0.004	<0.004		0.64	11.10	7.60	<1	<3	0.08				
Waianakarua at Brown's	29/11/2011	70.00	0.21	0.09	<0.01	<0.004	0.01	11.40	0.36	12.70	7.60	0.13	<3	0.02	108.00			
Waianakarua at Brown's	7/02/2012	12.00	0.21	0.09	<0.01	<0.004	0.01	10.10	0.17	18.50	7.90	0.11	<3	0.08	108.00			
Waianakarua at Brown's	28/03/2012	50.00	0.30	0.16	<0.01	<0.004	0.00	13.00	0.37	13.30	7.70	0.13	<3	0.07	125.00			
Waianakarua at Brown's	30/05/2012	20.00	0.29	0.25	<0.01	<0.004	0.01	14.00	0.32	5.81	7.60	<1	<3	0.04	112.00			
Waianakarua at Brown's	4/07/2012	5.00	0.33	0.18	<0.01	<0.004	<0.004	14.90	0.61	3.20	7.60	0.15	<3	0.09	111.00			
Waianakarua at Brown's	26/07/2012	3.00	0.22	0.15	<0.01	<0.004	<0.004					<1	<3					
Waianakarua at Brown's	7/08/2012	28.00	0.50	0.33	<0.01	0.01	0.01	13.00	1.95	7.60	7.40	0.17	<3	0.06	109.00			
Waianakarua at Brown's	23/08/2012	28.00	0.87	0.70	<0.01	0.01	0.02					0.18	3.00					
Waianakarua at Brown's	3/09/2012	10.00	1.27	1.15	<0.01	0.01	0.03					0.12	<3					
Waianakarua at Brown's	6/09/2012	27.00	1.20	1.08	<0.01	0.01	0.01	10.80	0.35	8.71	7.50	0.12	<3	0.10	92.30			

Site name	Time	*E. coli*	TN	NNN	NH4-N	DRP	TP	DO	Turbidity	Water temperature	pH	TKN	SS	Conductivity	DO saturation	Black disc horizontal	TDP	BOD (5 d)
		cfu/100 ml	mg/l	mg/l-N	mg/l-N	mg/l-P	mg/l	mg/l	NTU	degrees C		mg/l	mg/l	mS/cm	(%)	(m)	mg/l	mg/l-O
Waianakarua at Brown's	18/09/2012	26.00	0.94	0.80	<0.01	<0.004	0.00					0.14	<3					
Waianakarua at Brown's	3/10/2012	110.00	0.30	0.17	<0.01	<0.004	0.01					0.12	<3					
Waianakarua at Brown's	8/10/2012	27.00	0.26	0.18	<0.01	<0.004	<0.004	11.80	0.43	9.26	7.60	<1	<3	0.08	103.00			
Waianakarua at Brown's	16/10/2012	38.00	0.19	0.10	<0.01	<0.004	0.01					<1	<3					
Waianakarua at Brown's	30/10/2012	12.00	0.15	0.04	<0.01	<0.004	<0.004					0.11	<3					
Waianakarua at Brown's	6/11/2012	17.00	0.17	0.07	<0.01	<0.004	<0.004	11.40	0.32	11.60	7.50	0.10	<3	0.08	105.00			
Waianakarua at Brown's	13/11/2012	190.00	0.31	0.11	<0.01	<0.004	0.01					0.20	<3					
Waianakarua at Brown's	27/11/2012	120.00	0.35	0.17	<0.01	<0.004	<0.004					0.18	<3					
Waianakarua at Brown's	6/12/2012	44.00	0.29	0.26	<0.01	<0.004	0.01	9.40	0.56	15.20	7.60	<1	<3	0.07	93.80			
Waianakarua at Brown's	12/12/2012	42.00	0.23	0.18	<0.01	<0.004	0.02					<1	<3					
Waianakarua at Brown's	10/01/2013	110.00	0.32	0.21	<0.01	<0.004	0.03					0.11	<3					
Waianakarua at Brown's	14/01/2013	150.00	0.28	0.17	<0.01	<0.004	<0.004	9.40	0.39	18.30	7.50	0.11	<3	0.08	99.20			
Waianakarua at Brown's	21/01/2013	160.00	0.23	0.10	<0.01	<0.004	0.01					0.13	<3					
Waianakarua at Brown's	7/02/2013	51.00	0.27	0.13	<0.01	<0.004	<0.004					0.13	<3					
Waianakarua at Brown's	12/02/2013	56.00	0.32	0.22	<0.01	<0.004	<0.004	9.90	0.16	16.80	7.70	0.10	<3	0.09	102.00			
Waianakarua at Brown's	19/02/2013	60.00	0.35	0.24	<0.01	<0.004	0.02					0.11	<3					
Waianakarua at Brown's	5/03/2013	43.00	0.54	0.44	<0.01	<0.004	0.01					<1	<3					
Waianakarua at Brown's	13/03/2013	56.00	0.47	0.37	<0.01	0.01	0.00	10.20	0.21	16.00	7.70	<1	<3	0.11	104.00			
Waianakarua at Brown's	18/03/2013	850.00	0.44	0.37	<0.01	<0.004	0.01					<1	<3					
Waianakarua at Brown's	3/04/2013	62.00	0.56	0.45	<0.01	<0.004	0.01					0.11	<3					
Waianakarua at Brown's	15/04/2013	41.00	0.65	0.53	<0.01	<0.004	<0.004					0.12	<3					

Appendix 2 Instream habitat assessment data

		South Branch at McKerrow Rd			South Branch at SH1			North Branch at ford			North Branch at SH1			Mainstem at confluence			Mid main stem			Brown's Pump		
	Size	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool
Approx. survey reach length (m)		160			100			110			78			200			140			150		
Wetted width (approx.) (m)		7.8			5.2			6.6			8.2			8.2			c.12			11.5		
% of total habitat		4.5	31.5	64	11	89		36	51	13	22	59	19	43	57		3	54	43	27	56	17
%Concrete/artificial		0	0	0	0	0		0	0	0	0	0	10	0	0		0	0	0	0	0	0
%Bedrock	>4000 mm	0	0	60	0	40		10	10	20	0	0	0	0	1		0	0	0	0	0	50
%Boulder	25604000 mm	0	5	2	5	0		0	0	5	50	4	0	0	0		0	0	0	0	0	5
%Cobble	640255 mm	0	60	2	15	0		45	50	15	50	25	25	30	14		50	10		10	0	10
%Gravel	2063 mm	100	25	6	80	60		45	25	50	0	70	40	70	80		50	80	80	90	0	30
%Silt, sand	<2 mm	0	10	40	0	0		0	25	10	0	1	25	0	5		0	10	20	0	0	5
%Embeddedness		0	0	0	0	0		0	0	10	0	0	0	0	0		0	0	0	0	0	0
Substrate compactness		1	1	1	1	1		1	1	1	1	1	1	1	1		1	1	1	1	1	1
%Macrophytes	Monkey musk	0	0	0	0	0		0	0	0	0	2	0	0	0		0	0	0	0	0	0
%Moss		0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0	0	0
%Algae	Light brown	0	0	0	0	0		75	0	0				0	0		0	0	0	90	0	50
	Dark brown0black	80	0	0	80	0		0	0	0	70	15	0	27	1		50	0	0	0	0	0
	Short filamentous green	0	0	0	0	0		0	0	0				0	0		0	80	80	0	90	0
	Long filamentous green	0	<5	0	0	0		0	0	0	1	1	1	0	0		0	0	0	0	0	0
%Woody debris & leaf packs		0	1	0	1	0		2	5	1	0	0	0	10	5		0	0	0	0	10	5
%Obstructions to flow		0	0	0	2	0		5	5	10	0	0	0	2	2		1	0	0	5	5	10
%Bank cover		0	0	0	0	0		50	0	0	2	0	0	0	0		0	0	0	0	0	0
Pool 1	Max. depth (m)			2						1.2			0.7						1			1
	Fine sediment depth (m)			0						0			0						0			0
	Crest depth (m)			0.2						0.5			0.3						0.2			0.2
Pool 2	Max. depth (m)									1.5			1						0.6			
	Fine sediment depth (m)									0			0						0			
	Crest depth (m)									0.3			0.3						0.05			
Pool 3	Max. depth (m)																		1.2			
	Fine sediment depth (m)																		0			
	Crest depth (m)																		0.15			
Riparian vegetation	True right bank	Broom, alder, willow, kanuka			Broom, blackberry, willow, gorse, monkey musk, grass,			Tutu, broom, gorse, briar rose, willow, poplar, kanuka			Grass, lupins, monkey musk (~25%)			Lupins, broom, grass			Willows, alders on island in mid0stream			Willow thicket		
	True left bank	Broom, kanuka, grass, rosehip			Very steep bank/cliff. Grass, gorse, broom, pine plantation on			Bare gravel immediately adjacent to stream. Veg.			Bare gravel (80%), lupins, Buddleia			Bare gravel						Willow, tall grass, broom, lupins		

		South Branch at McKerrow Rd		South Branch at SH1		North Branch at ford		North Branch at SH1		Mainstem at confluence		Mid-main stem		Brown's Pump	
Attributes		TL	TR	TL	TR	TL	TR	TL	TR	TL	TR	TL	TR	TL	TR
Shading of water		25-50%		25-50%		10-25%		10-25%		Little or no shading		Little or no shading		10-25%	
Buffer width		>30 m	5-15 m	>30 m	5-15 m	>30 m	>30 m	>30 m	>30 m	>30 m	>30 m	>30 m	>30 m	>30 m	>30 m
Buffer intactness		Completely intact	Completely intact	Completely intact	1-20% gaps	Completely intact	Completely intact	Completely intact	Completely intact	1-20% gaps	Completely intact	Completely intact	Completely intact	Completely intact	Completely intact
Veg composition	Buffer	Broom, kanuka, grass, briar rose	Broom, alder, willow, kanuka	Very steep bank/cliff. Grass, gorse, broom, pine plantation on top of cliff.	Broom, blackberry, willow, gorse, monkey musk, grass, watercress	Bare gravel adjacent to stream. Veg. above floodplain same as TR bank.	Tutu, broom, gorse, briar rose, willow, poplar, kanuka	Grass, lupins, monkey musk (~25%)	Bare gravel (80%), lupins, *Buddleia*	Lupins, broom, grass	Bare gravel	Bare gravel. Willows, alders on island in mid-stream	Bare gravel. Willows, alders on island in mid-stream	Willow thicket	Willow, tall grass, broom, lupins
	Adjacent land (to 30 m)	As for buffer	As for buffer	Pine plantation on top of cliff	Short grazed grass	Same as TR buffer	As for buffer	As for buffer	As for buffer	As for buffer	As for buffer	As for buffer	As for buffer	Short grazed grass	Short grazed grass
Bank stability		Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Low	Low	Very low	Very low	Low	Very High

Appendix 3 State of the environment macroinvertebrate monitoring data

Sample location	MCI	Waianakarua River (North Branch) at SH1		Waianakurua at Brown's Pump						
Sample date	Score	09-Jan-03	2004	4-Jan-07	4-Apr-08	8-Apr-09	07-Feb-10	4-Apr-11	9-Jan-12	22-Feb-13
ACARI	5						C			
COLEOPTERA										
Berosus species	5					R				
Elmidae	6	VA	VA	VA	VA	VA	VA	C	A	R
CRUSTACEA										
Ostracoda	3						R			
Paracalliope fluviatilis	5			R						
DIPTERA										
Aphrophila species	5	R	R	C	C		R		C	
Austrosimulium species	3							C		C
Chironominae	2	A		R	A	C		C		
Empididae	3						R			
Eriopterini	9	C	R		C	C	R	C	C	C
Hexatomini	5									R
Maoridiamesa species	3				A			R	C	R
Molophilus species	5					R				
Muscidae	3				R		R	R	R	
Orthocladiinae	2	VA	A	R	VA	A	VA	A	A	VA
Tabanidae	3						C	R		
Tanypodinae	5						A			
Tanytarsini	3						C			C
EPHEMEROPTERA										
Deleatidium species	8	VA	VA	VA	VA	VA	VA	VA	VVA	VA
Nesameletus species	9					R				
MEGALOPTERA										
Archichauliodes diversus	7	C	R	C	C	R	R	C		C
MOLLUSCA										
Potamopyrgus antipodarum	4		VVA	C	A		VA	A		
OLIGOCHAETA	1			R		A		R	R	
PLECOPTERA										
Austroperla cyrene	9							R		
Megaleptoperla grandis	9	C								
Stenoperla prasina	10	C	R	C	R	R	R	C		R
Zelandobius species	5									R
Zelandoperla species	10					R		R		
TRICHOPTERA										
Aoteapsyche species	4	VA	A	A	VA	A	VA	A	A	A
Beraeoptera roria	8		C							
Costachorema xanthopterum	7	R								
Hudsonema amabile	6					R				
Hydrobiosidae early instar	5			C	A	R				
Hydrobiosis clavigera group	5	R				R	C			C
Hydrobiosis umbripennis group	5	C	R	R	A			C	A	
Olinga species	9	VA	VA	A	R	A	VA			A
Oxyethira albiceps	2						C	C		R
Paroxyethira species	2							R		
Plectrocnemia maclachlani	8								R	
Psilochorema species	8	A		C	C	R	C		C	R
Pycnocentria species	7		C	R	C	C		R		
Pycnocentrodes species	5	A	VVA	A	VA	A	VVA	C	R	C
Triplectides species	5							C		
Taxonomic richness		11	10	16	17	19	21	22	13	17
MCI		128	127	109	113	123	104	100	103	111
SQMCI		5.75	5.19	6.68	4.91	6.09	5.25	6.00	7.42	5.27
EPT taxonomic richness		5	4	8	8	11	8	11	6	9
%EPT richness		45%	40%	50%	47%	58%	38%	50%	46%	53%

Appendix 4 Macroinvertebrate data from sampling in the Waianakarua catchment in 2013

TAXON	MCI score	Waianakarua River						
		South Branch at McKerrow Rd 11-Apr-13	South Branch at SH1 10-Apr-13	North Branch at ford 11-Apr-13	North Branch at SH1 11-Apr-13	At confluence 10-Apr-13	Mid-main stem 11-Apr-13	Brown's pump 22-Feb-13
COLEOPTERA								
Elmidae	6	C	R	R	C	C	C	R
Scirtidae	8	C			R			
CRUSTACEA								
Ostracoda	3	R						
DIPTERA								
Aphrophila species	5		R	C				
Austrosimulium species	3	R	A	R	R	C	R	C
Chironomus species	1	R						
Empididae	3						R	
Eriopterini	9	R	R		R	C	C	C
Hexatomini	5						R	R
Maoridiamesa species	3		C			C		R
Muscidae	3					R	R	
Orthocladiinae	2	R	A	A	VA	VVA	VVA	VA
Paradixa species	4	R						
Stictocladius species	2	R						
Tanypodinae	5	A		R				
Tanytarsini	3	C	A	R	A	A	A	C
EPHEMEROPTERA								
Ameletopsis perscitus	10	R						
Austroclima species	9		A		C	A	A	
Coloburiscus humeralis	9		C	R				
Deleatidium species	8	VA	VA	VA	VA	VA	VVA	VA
Ichthybotus species	8	R						
Nesameletus species	9	C		C				
HEMIPTERA								
Sigara species	5	R						
MEGALOPTERA								
Archichauliodes diversus	7	A		C	C	R	C	C
MOLLUSCA								
Physa / Physella species	3						R	
Potamopyrgus antipodaru	4	VA	A	C		R	R	
NEMATODA	3				R			
OLIGOCHAETA	1	C			R			
PLECOPTERA								
Stenoperla species	10	C				R	R	R
Zelandobius species	5	R						R
Zelandoperla species	10			R		R		
TRICHOPTERA								
Aoteapsyche species	4	C	VA	A	C	VA	VA	A
Beraeoptera roria	8			C	R			
Costachorema species	7		R			C	C	
Helicopsyche species	10	A	R	A			R	
Hudsonema amabile	6	R	R	R				
Hydrobiosis species	5	C	A	A	C	A	A	C
Neurochorema species	6	R	R	R		R	R	
Olinga species	9	VA	A	A	A	A	A	A
Oxyethira albiceps	2							R
Polyplectropus species	8	R						
Psilochorema species	8	A	C	C	C	C	C	R
Pycnocentria species	7	C	R	C	A	C		
Pycnocentrodes species	5	VA	A	A	C	A	C	C
Number of taxa		31	21	22	18	21	22	17
Number of EPT taxa		16	13	14	9	12	11	9
%EPT taxa		52%	62%	64%	50%	57%	50%	53%
MCI score		117	122	126	117	122	117	111
SQMCI score		6.56	5.63	6.80	5.42	3.66	5.07	5.27

Otago Regional Council