Christchurch City Council
City Environment Group

Christchurch Rivers Water Quality Monitoring

Annual Results Summary

May 2011 – April 2012

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Summary

This report summarises the results of the Christchurch City Council (CCC) rivers water quality monitoring programme for the period between May 2011 and April 2012.

Monthly water samples were collected from 41 sites across the five major catchments of Christchurch City – the Avon, Heathcote, Halswell, Styx, and Otukaikino. The results of this monitoring are compared with the ANZECC (2000) water quality guidelines and the water quality standards in the Canterbury Natural Resources Regional Plan (NRRP) to provide some context. Based on water quality data collected during the 2011-2012 year, the main findings are:

Nitrate-nitrite nitrogen (NNN) and dissolved reactive phosphorus (DRP) concentrations are elevated in all catchments to levels which would be expected to encourage the proliferation of aquatic plants and algae. Whereas NNN concentrations decrease downstream for the Avon and Heathcote catchments, DRP concentrations tend to show an increase. The Heathcote River at Templetons Road has the highest average NNN concentration of all monitoring sites. Monitoring sites on several tributaries, including Riccarton Drain, Haytons Drain and Kaputone Stream had higher DRP concentrations that the mainstem rivers, suggesting that they were contributing to the downstream increases in DRP.

Average ammonia nitrogen concentrations for the 2011-2012 year were at levels that would not be expected to have chronic toxic effects on aquatic life for most sites. The exception was Haytons Drain at Wigram Road, where high ammonia nitrogen concentrations were frequently recorded. There were several other sites that did have potentially harmful concentrations of ammonia nitrogen recorded during individual sampling rounds, including Riccarton Drain, Curletts Drain and Kaputone Stream.

Biochemical oxygen demand (BOD) is typically low in Christchurch's main rivers, but some tributaries, including Riccarton Drain, Haytons Drain, Curletts Drain and Smacks Creek exceed the recommended guidelines, suggesting that there is potential for bacteria to deplete oxygen levels in the water at some of these sites. Under normal flow conditions, water clarity is high and total suspended solids (TSS) concentrations are low in the majority of the city waterways. TSS levels tend to increase downstream in the main rivers and there are some tributaries where TSS loads are high in comparison to the main rivers (including Dudley Creek and Haytons Drain).

E. coli concentrations have exceeded the recommended guideline for contact recreation for all sites in the Avon, Heathcote, Styx and Halswell catchments at some time during the 2011-2012 year. There were several sites across the city where the average concentration of *E. coli* for this year was below the guideline.

Monitoring for heavy metals in each of the catchments has showed that copper and zinc commonly exceed default trigger values, but when hardness modified trigger values (HMTV) are used, the trigger values are exceeded infrequently. Cadmium, lead and mercury rarely exceed trigger values.

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1 Rivers Water Quality Monitoring Programme

1.1 Sample Collection Methods

River water samples are collected as part of Christchurch City Council's baseline surface water quality monitoring programme from sites in the Avon, Heathcote, Styx, Otukaikino and Halswell catchments. There are 41 sampling sites in the current monitoring programme, covering the main catchments of the city (Table 1, Figure 1). Water samples are collected monthly by the CCC laboratory and analysed for the parameters listed in Table 2.

Table 1 River water quality monitoring sites in Christchurch City

Catchment	Site Description	Easting	Northing
Avon	Wairarapa Stream	2478250	5742915
	Waimairi Stream	2478232	5742784
	Avon River at Mona Vale	2478334	5742658
	Avon River at Carlton Mill corner[1]	2479737	5742871
	Riccarton Drain	2479019	5741648
	Addington Drain	2479427	5741438
	Avon River at Manchester St	2480890	5742093
	Dudley Creek	2482575	5743763
	Avon River at Dallington Tce/Gayhurst Rd	2483562	5742822
	Horseshoe Lake discharge	2484344	5744907
	Avon River at Avondale Rd[1]	2484754	5745170
	Avon River at Pages/Seaview Bridge	2487487	5744202
	Avon River at Bridge St	2487694	5742425
Heathcote	Heathcote River at Templetons Rd	2475913	5738508
	Haytons Drain at Wigram Rd[1]	2475219	5739384
	Haytons Drain at Retention Basin	2476019	5739207
	Curletts Road Drain at Motorway[1]	2476404	5739969
	Curletts Road Drain US Heathcote	2476927	5739322
	Heathcote River at Rose St	2478700	5737528
	Cashmere Stream at Worsleys Rd	2479030	5736765
	Heathcote River at Ferniehurst St	2479157	5737222
	Heathcote River at Bowenvale Ave	2481198	5737390
	Heathcote River at Opawa Rd/Clarendon Tce	2483072	5739226
	Heathcote River at MacKenzie Ave[1]	2483521	5739528
	Heathcote River at Catherine St[1]	2484415	5739494
	Heathcote River at Tunnel Rd	2485076	5739154
	Heathcote River at Ferrymead Bridge	2486494	5738760
Styx	Smacks Creek at Gardiners Rd	2476803	5749571
	Styx River at Gardiners Rd	2476789	5748841
	Styx River at Main North Rd	2479066	5748834
	Kaputone at Blakes Rd	2480401	5749645
	Kaputone at Belfast Rd	2482195	5749882
	Styx River at Marshland Rd Bridge	2482359	5749393
	Styx River at Richards Bridge	2483977	5751255
	Styx River at Harbour Rd Bridge	2485000	5756366
Halswell	Halswell Retention Basin inlet[1]	2471698	5738633
	Halswell Retention Basin outlet[1]	2471793	5738525
	Nottingham Stream at Candys Rd	2474530	5734689
	Halswell River at Akaroa Highway	2474444	5733330
Otukaikino	Otukaikino at Groynes inlet	2477878	5750484
City Outfall	City Outfall Drain	2485954	5739637

[1] Sites monitored for a reduced suite of parameters, excluding turbidity, total nitrogen, total phosphorus, metals, and dissolved organic carbon

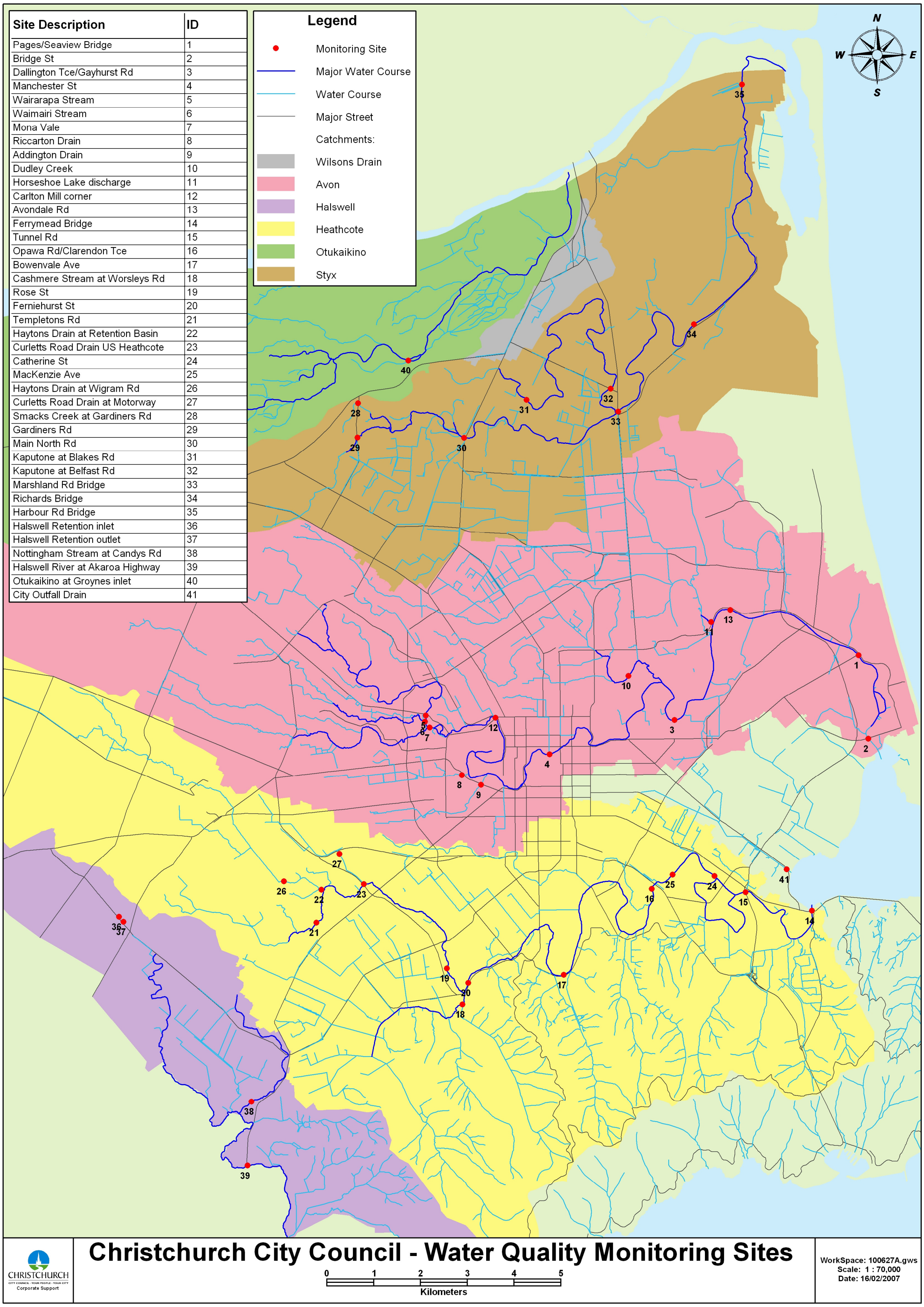

Figure 1 River water quality monitoring sites in Christchurch City

1.2 Parameters and Guideline Values

Table 2 Water quality parameters analysed for Christchurch City river water quality monitoring sites and the standards or guidelines relevant to each parameter.

Parameter
pH
Temperature
Dissolved Oxygen Saturation
Conductivity
Turbidity
Total Suspended Solids
Nitrate Nitrogen
Nitrite Nitrogen
Nitrate-Nitrite Nitrogen
Ammonia Nitrogen
Total Nitrogen
Total Phosphorus
Dissolved Reactive Phosphorus
Faecal Coliforms
E. coli
Enterococci
Cadmium
Copper
Lead
Zinc
Mercury
Biochemical Oxygen Demand
Dissolved Organic Carbon
Total Petroleum Hydrocarbons

1.3 Methods for Data Analysis

1.3.1 Summary Statistics

Water quality parameters for each site were summarised by the mean and standard error of 12 monthly samples collected between May 2011 and April 2012. Mean and standard error for each site was displayed on a bar graph for each catchment.

For the purpose of calculating summary statistics, where water quality results were reported by the laboratory as 'less than' the lower detection limit, the data were converted to a value equal to half of the reported detection limit.

1.3.2 Trend Analysis

Trend analysis was completed for data collected over a five year period between January 2007 and December 2011, using the Time Trends software developed by NIWA (http://www.niwa.co.nz/our-science/freshwater/tools/analysis). The trend analysis was performed on raw data and flow adjusted data within the Time Trends software. Trend analysis was only performed on parameters that did not have a high proportion of data reported below laboratory detection limits, as these values can compromise the results of trend analysis. This meant that trend analysis was not performed for heavy metals data. The Seasonal Kendall trend test within the Time Trends software was used to test the significance of trends in water quality over time. The non-parametric Seasonal Kendall Sen Slope Estimator was used as a measure of the magnitude and direction of the trend, and this was normalised by dividing by the site median to provide a measure of the slope as a percent change per year (NIWA 2011).

Where water quality results were reported by the laboratory as 'less than' the lower detection limit, the Time Trends software defaulted to a value of 10% below the detection limit, and this was used for the analysis of trends.

2 Annual results and comparison with guidelines

A summary of the water quality data collected for each catchment between May 2011 and April 2012 is provided in Appendix 1.

2.1 Nitrate-Nitrite Nitrogen (NNN)

Elevated concentrations of nitrate-nitrite nitrogen (NNN) can lead to the proliferation of aquatic plants and algae, because nitrate and nitrite are oxidised forms of nitrogen that are readily available to plants. The ANZECC (2000) water quality guidelines provide a trigger value of 0.444 mg/L for lowland rivers to avoid excessive plant growth.

Mean concentrations of NNN decrease downstream in the mainstems of the Avon and Heathcote rivers (Figure 2 & Figure 3). Tributaries in the upper Avon catchment, such as Waimairi Stream and Riccarton Drain also have high concentrations of NNN compared to lower catchment sites. At most sites in the Avon and Heathcote catchments, average NNN concentrations for the monitoring period were greater than the 0.444 mg/L recommended to avoid excessive plant growth.

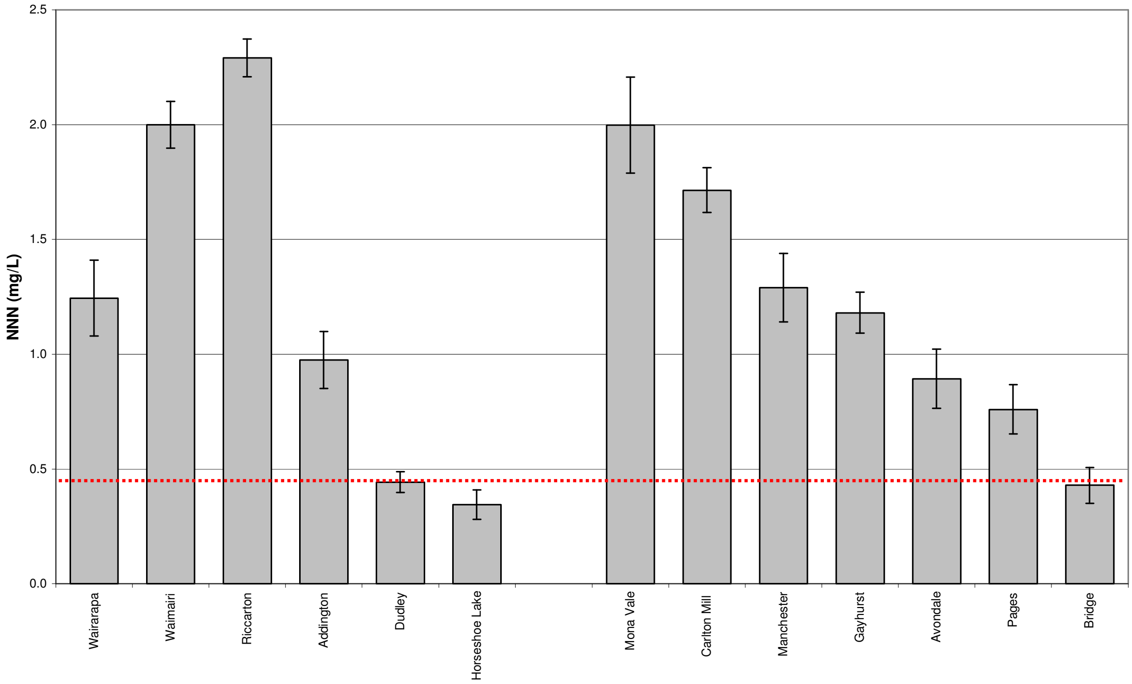

Figure 2 NNN concentrations for sites in the Avon catchment, mean ± SE for monthly samples between May 2011 and April 2012. Tributary sites are displayed on the left side of the graph and mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 0.444 mg/L is shown as a red dotted line.

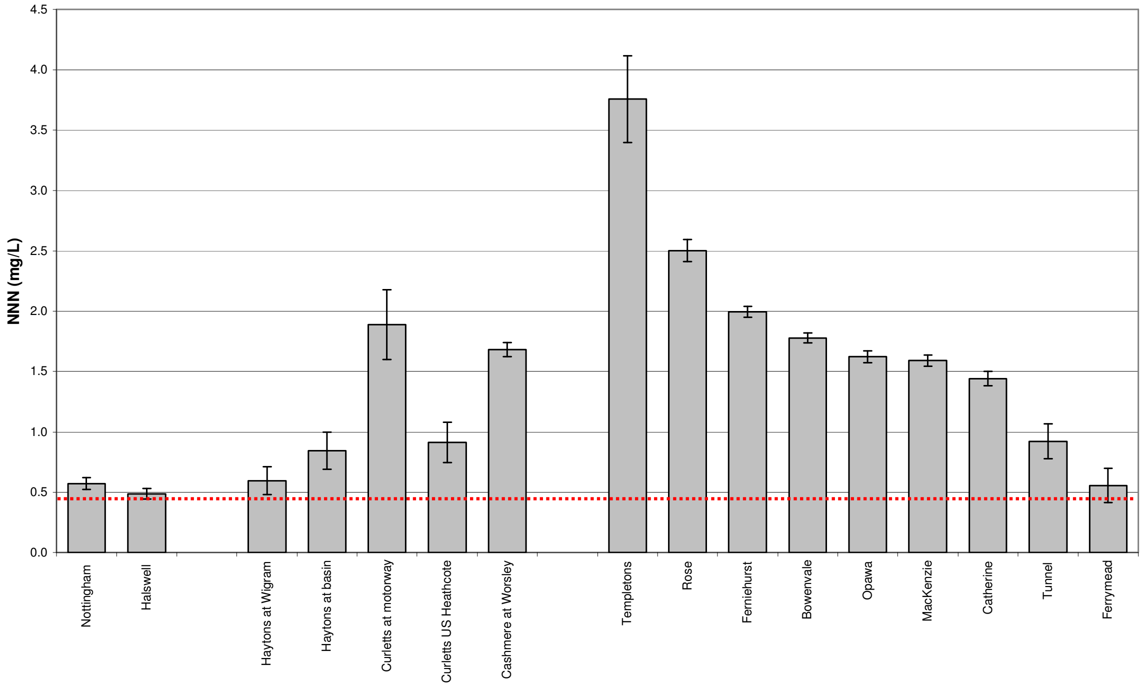

Figure 3 NNN concentrations for sites in the Heathcote and Halswell catchments, mean ± SE for monthly samples between May 2011 and April 2012. Halswell sites are to the left of the graph, followed by Heathcote tributary sites and then Heathcote mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 0.444 mg/L is shown as a red dotted line.

The two sites in the Halswell catchment exceeded guideline values for NNN, but had relatively low NNN compared to sites in the upper Heathcote catchment (Figure 3).

For the Otukaikino River at the Groynes, the average NNN concentration was well below the ANZECC (2000) guideline of 0.444 mg/L. In comparison, most sites in the Styx catchment were above or just below the ANZECC (2000) guideline (Figure 4). There was no obvious pattern of change to NNN concentrations with distance down the Styx River catchment. The Harbour Road monitoring site had the highest recorded NNN concentration within the Styx catchment, but there was high variation between sampling rounds at this site. The Kaputone Stream also recorded high NNN concentrations compared to other sites within the Styx catchment during the 2011-2012 year, especially the Blakes Road monitoring site.

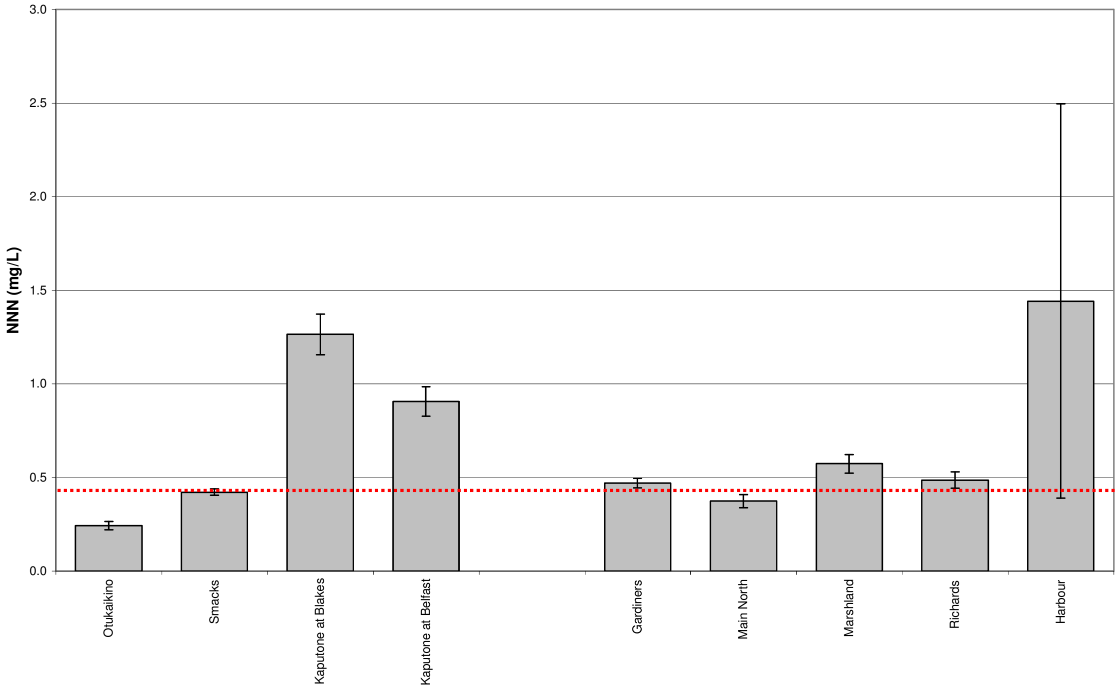

Figure 4 NNN concentrations for sites in the Styx and Otukaikino catchments, mean ± SE for monthly samples between May 2011 and April 2012. Otukaikino and Styx tributary sites are displayed on the left side of the graph and Styx River mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 0.444 mg/L is shown as a red dotted line.

2.2 Dissolved Reactive Phosphorus (DRP)

In combination with high nitrogen concentrations, elevated concentrations of dissolved reactive phosphorus (DRP) can lead to the proliferation of aquatic plants and algae. This dissolved form of phosphorus is readily available for plant growth. The ANZECC (2000) water quality guidelines provide a trigger value of 0.01 mg/L for lowland rivers to avoid excessive plant growth. The NRRP water quality standards (NRRP, Table WQL16) provide a higher value of 0.016 mg/L for the spring-fed-plains-urban category of surface waters. At most monitoring sites, average DRP concentrations for the 2011-2012 year were greater than the 0.01 mg/L ANZECC trigger value, with many also exceeding the NRRP standards.

There was an increase in DRP concentration downstream for the Avon River sampling sites (Figure 5). The tributary inflow from Riccarton Drain had considerably higher concentrations of DRP than all other sites in the catchment. For the Heathcote catchment, there was no obvious downstream trend for DRP concentrations, but the two sites on Haytons Drain (Wigram Road and downstream of the retention basin) had substantially higher average DRP than all other sites monitored in the catchment (Figure 6). In the Halswell catchment, the average DRP concentration for the year was higher for Nottingham Stream than for the Halswell River mainstem (Figure 6).

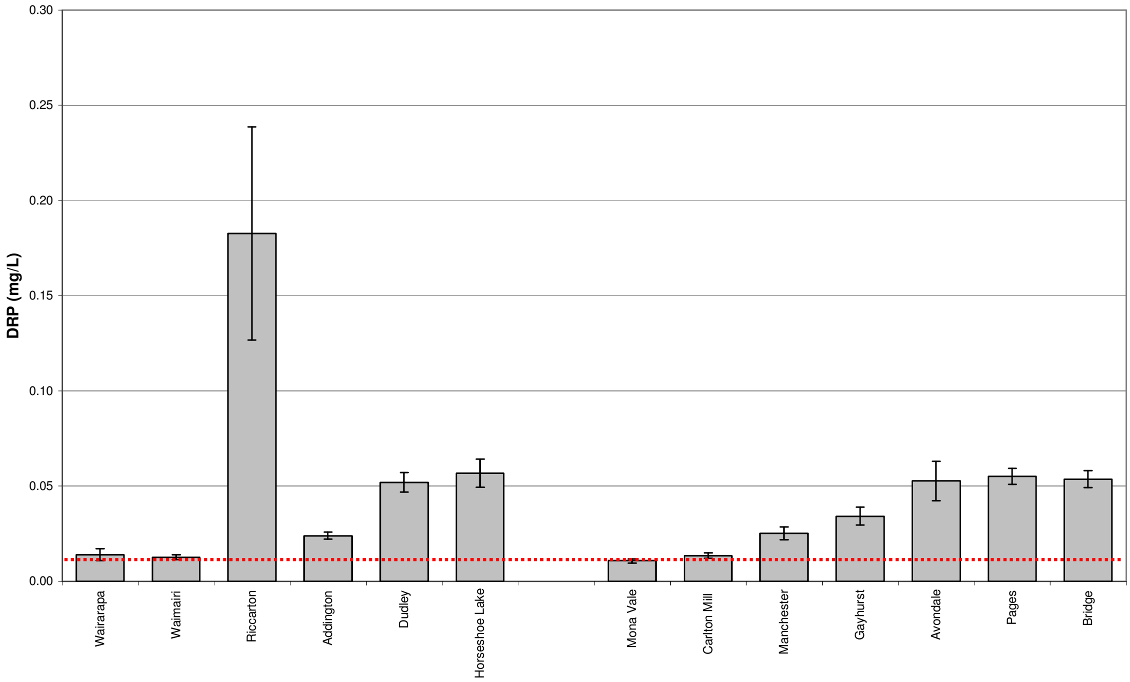

Figure 5 DRP concentrations for sites in the Avon catchment, mean ± SE for monthly samples between May 2011 and April 2012. Tributary sites are displayed on the left side of the graph and mainstem sites to the right, arranged from upstream to downstream (left to right). The ANZECC (2000) guideline value of 0.01 mg/L is shown as a red dotted line.

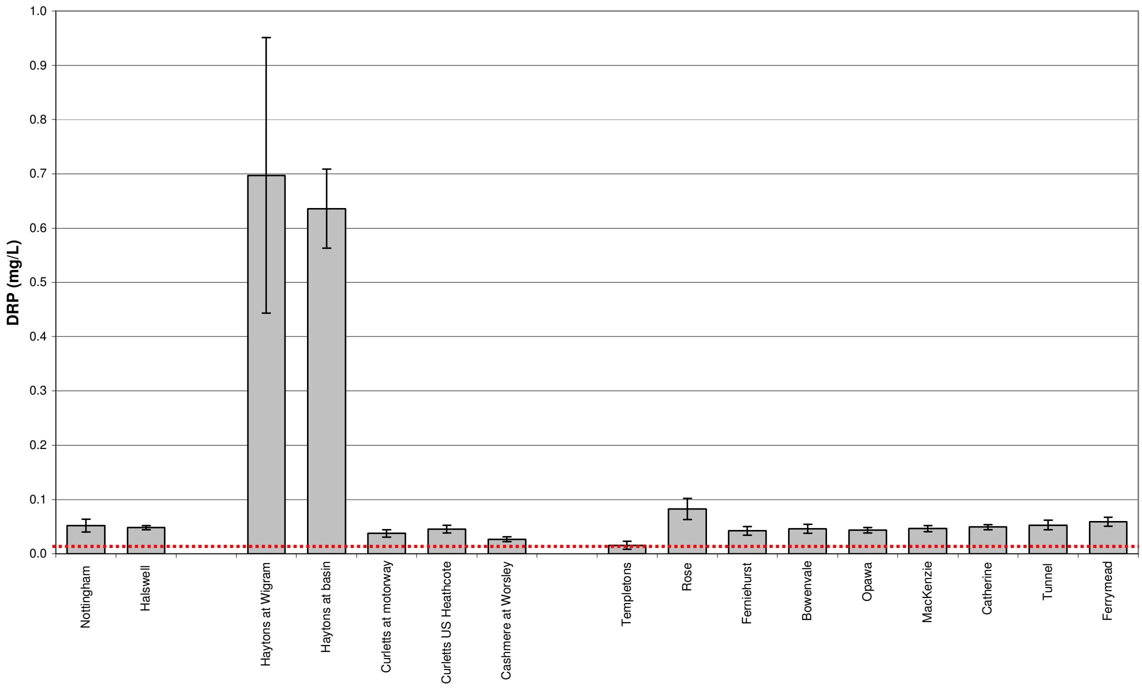

Figure 6 DRP concentrations for sites in the Heathcote and Halswell catchments, mean ± SE for monthly samples between May 2011 and April 2012. Halswell sites are to the left of the graph, followed by Heathcote tributary sites and then Heathcote mainstem sites to the right, arranged from upstream to downstream (left to right). The ANZECC (2000) guideline value of 0.01 mg/L is shown as a red dotted line.

There was a substantial increase in DRP concentrations for the Styx River between the monitoring site at Main North Road and the site at Marshland Road (Figure 7). Tributary inflow from the Kaputone Stream between these two sites had particularly high DRP concentrations compared to all other sites in the catchment. The one site monitored on the Otukaikino River had similar DRP concentrations to the upper Styx River sites.

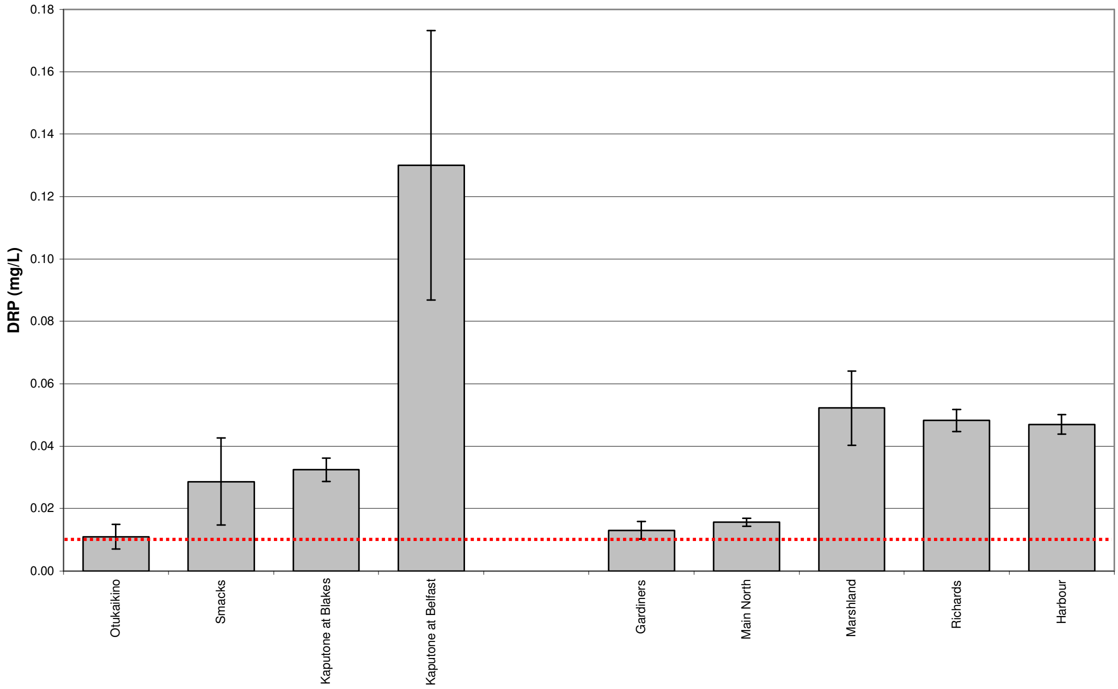

Figure 7 DRP concentrations for sites in the Styx and Otukaikino catchments, mean ± SE for monthly samples between May 2011 and April 2012. Otukaikino and Styx tributary sites are displayed on the left side of the graph and Styx River mainstem sites to the right, arranged from upstream to downstream (left to right). The ANZECC (2000) guideline value of 0.01 mg/L is shown as a red dotted line.

2.3 Ammonia Nitrogen

Ammonia nitrogen is typically a minor component of the nitrogen available for plant growth, but at high levels can have toxic effects on aquatic ecosystems. The toxicity of ammonia varies with pH and the NRRP water quality standards (NRRP, Table WQL17.1) provide maximum total ammonia concentrations for 95% species protection from chronic ammonia toxicity at different values of pH, ranging from 2.57 mg/L at pH 6 to 0.180 mg/L at pH 9. A pH of 7.5 is typical for Christchurch waterways, and therefore, the relevant ammonia standard is 1.61 mg/L. The NRRP standards are based on the ANZECC (2000) guidelines. Ammonia values for acute toxicity will be higher than those discussed above.

At all waterway monitoring sites, except for Haytons at Wigram Road, average ammonia nitrogen concentrations for the 2011-2012 year were below the guideline value of 1.61 mg/L (Figure 8, Figure 9, Figure 10). However, several sites exceeded this trigger value for individual sampling rounds, including Riccarton Drain, Haytons Drain, Curletts Stream, and Kaputone Stream. Average concentrations of ammonia nitrogen increased downstream on the Avon River (Figure 8). There was a less consistent downstream increase for the Heathcote River, and no obvious downstream trends for sites in the Halswell, Styx and Otukaikino catchments. A number of tributaries had high ammonia values in comparison to the main rivers, including Riccarton Drain and Dudley Creek in the Avon catchment, Haytons Drain in the Heathcote catchment, and Kaputone Stream in the Styx catchment.

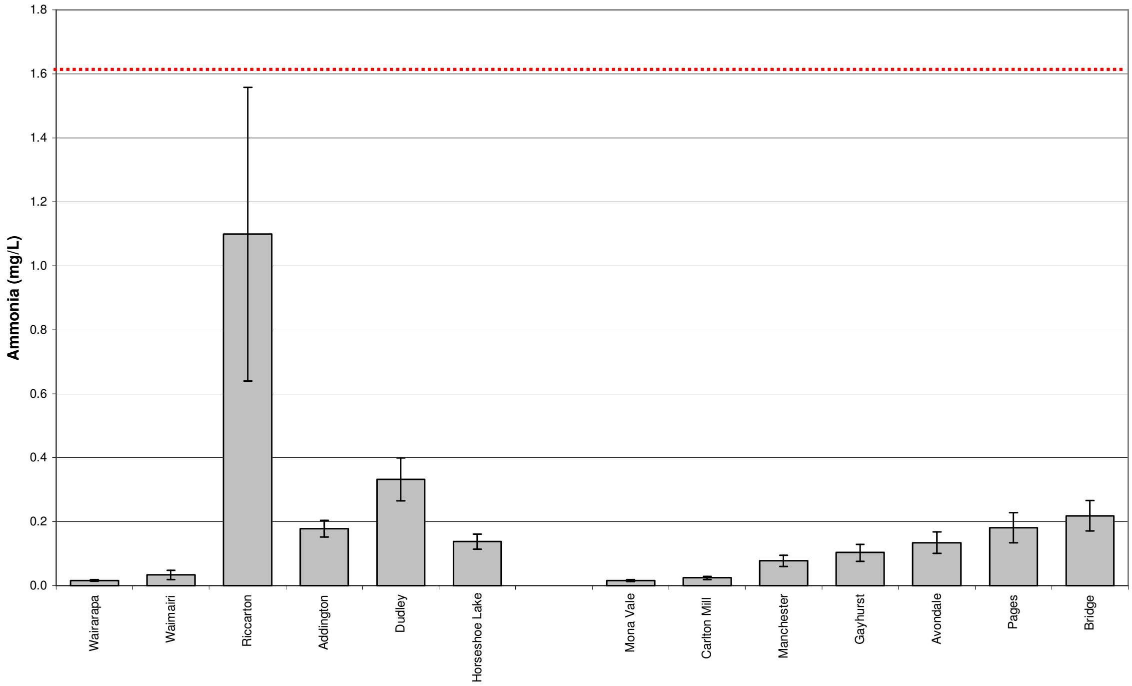

Figure 8 Ammonia Nitrogen concentrations for sites in the Avon catchment, mean ± SE for monthly samples between May 2011 and April 2012. Tributary sites are displayed on the left side of the graph and mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 1.61 mg/L (at pH 7.5) is shown as a red dotted line.

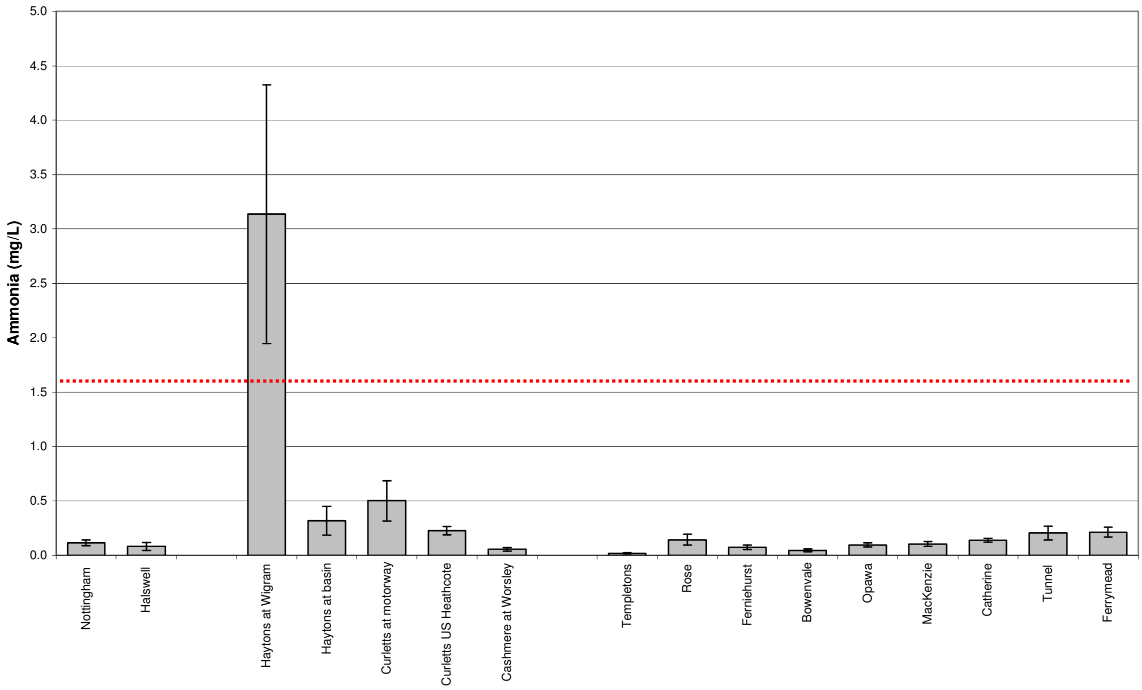

Figure 9 Ammonia Nitrogen concentrations for sites in the Heathcote and Halswell catchments, mean ± SE for monthly samples between May 2011 and April 2012. Halswell sites are to the left of the graph, followed by Heathcote tributary sites and then Heathcote mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 1.61 mg/L (at pH 7.5) is shown as a red dotted line.

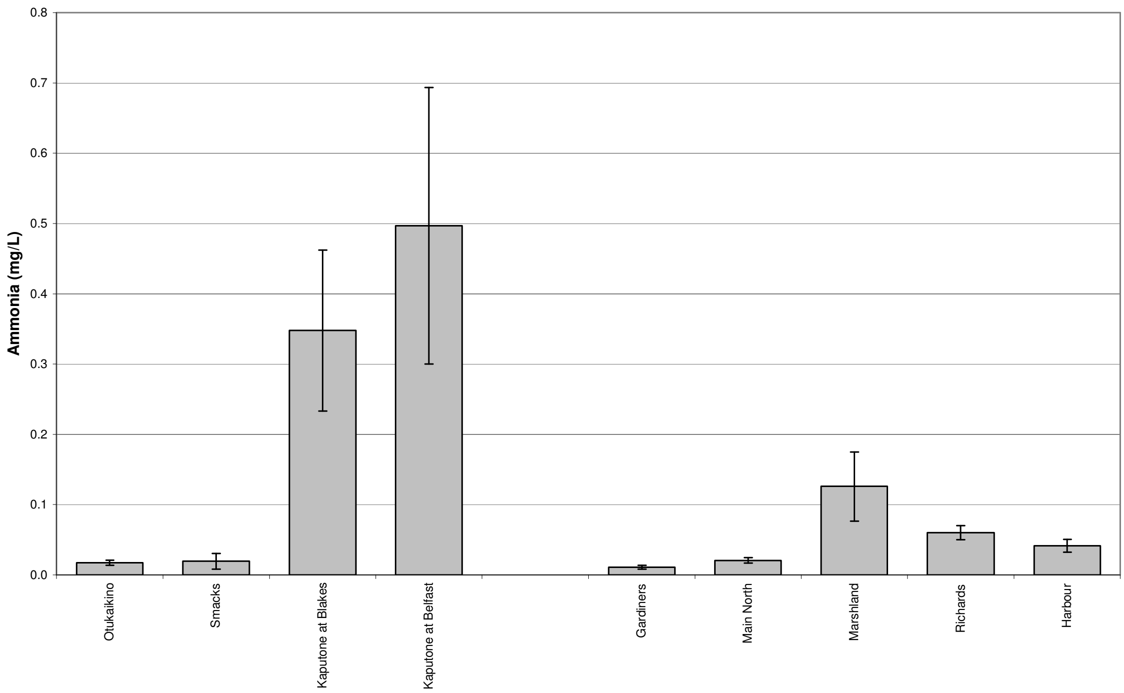

Figure 10 Ammonia nitrogen concentrations for sites in the Styx and Otukaikino catchments, mean ± SE for monthly samples between May 2011 and April 2012. Otukaikino and Styx tributary sites are displayed on the left side of the graph and Styx River mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 1.61 mg/L is not shown on this graph because the scale does not extend that high.

2.4 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is an indicator of the amount of biodegradable organic material in the water and a measure of the amount of oxygen required by bacteria to break down this organic material. High values of BOD indicate the potential for bacteria to deplete oxygen levels in the water. A guideline value for BOD is 2 mg/L (MfE 1992).

Average values of BOD were less than this guideline for all mainstem sites in the Avon, Heathcote, Halswell, Styx, and Otukaikino rivers for 2011-2012 (Figure 11, Figure 12, Figure 13), with many of the sites frequently recording values lower than the laboratory detection level of 1 mg/L. Several tributary sites did exceed the guideline, including Riccarton Drain, Haytons Drain, Curletts Drain and Smacks Creek.

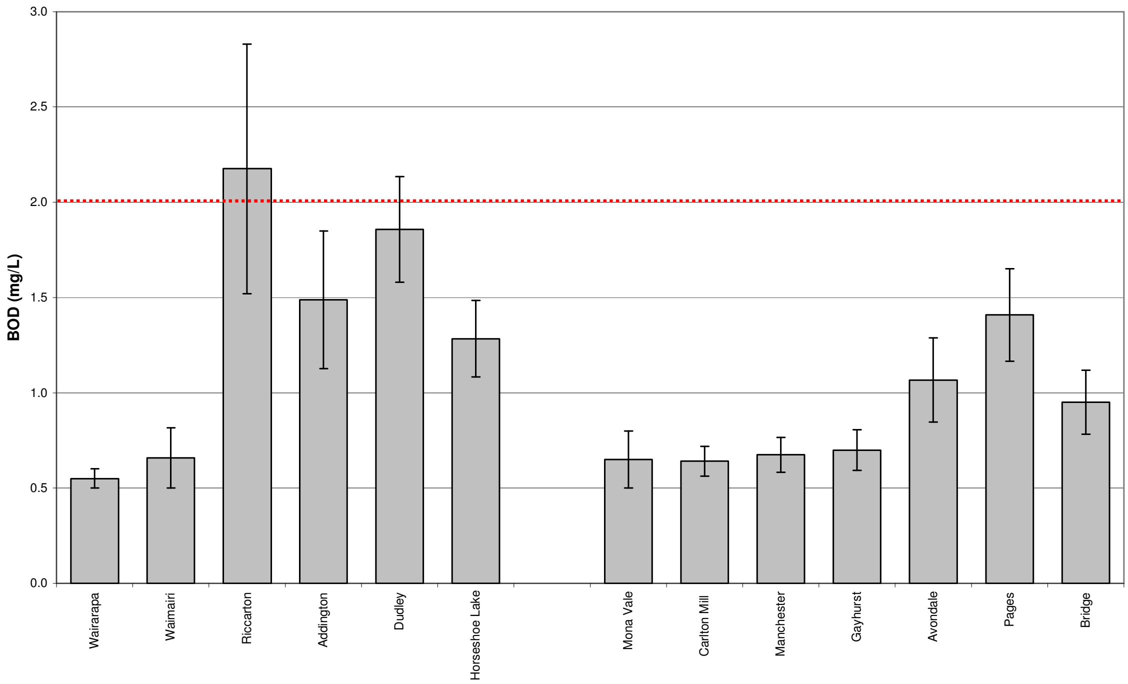

Figure 11 BOD concentrations for sites in the Avon catchment, mean ± SE for monthly samples between May 2011 and April 2012. Tributary sites are displayed on the left side of the graph and mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 2 mg/L is shown as a red dotted line.

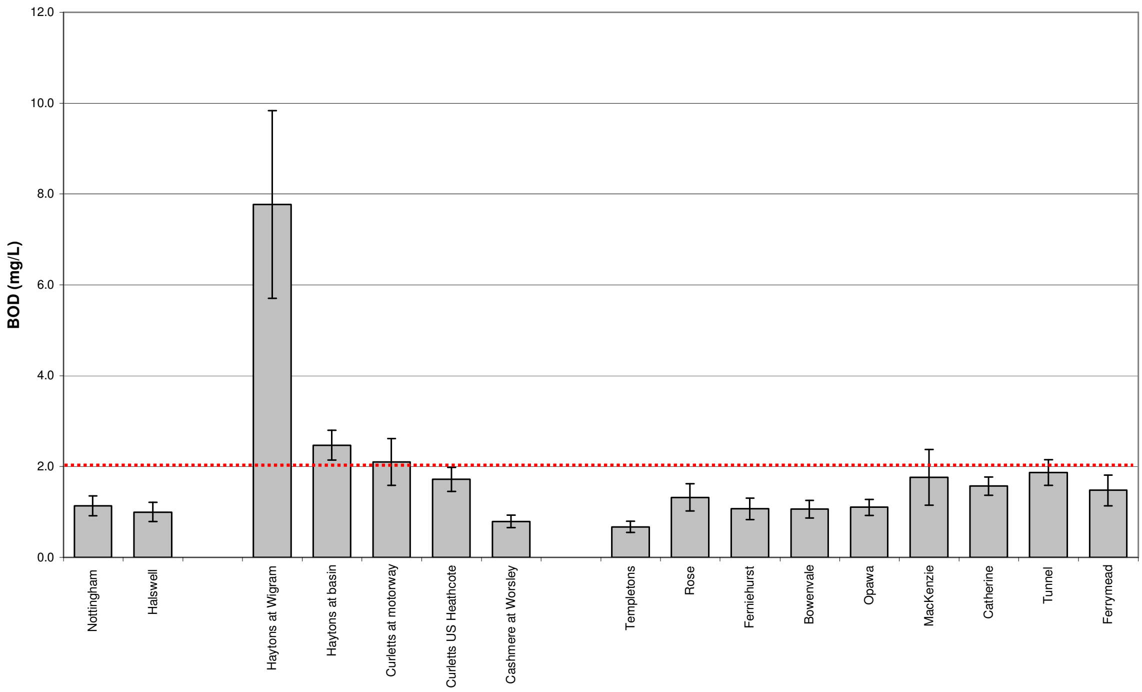

Figure 12 BOD concentrations for sites in the Heathcote and Halswell catchments, mean ± SE for monthly samples between May 2011 and April 2012. Halswell sites are to the left of the graph, followed by Heathcote tributary sites and then Heathcote mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 2 mg/L is shown as a red dotted line.

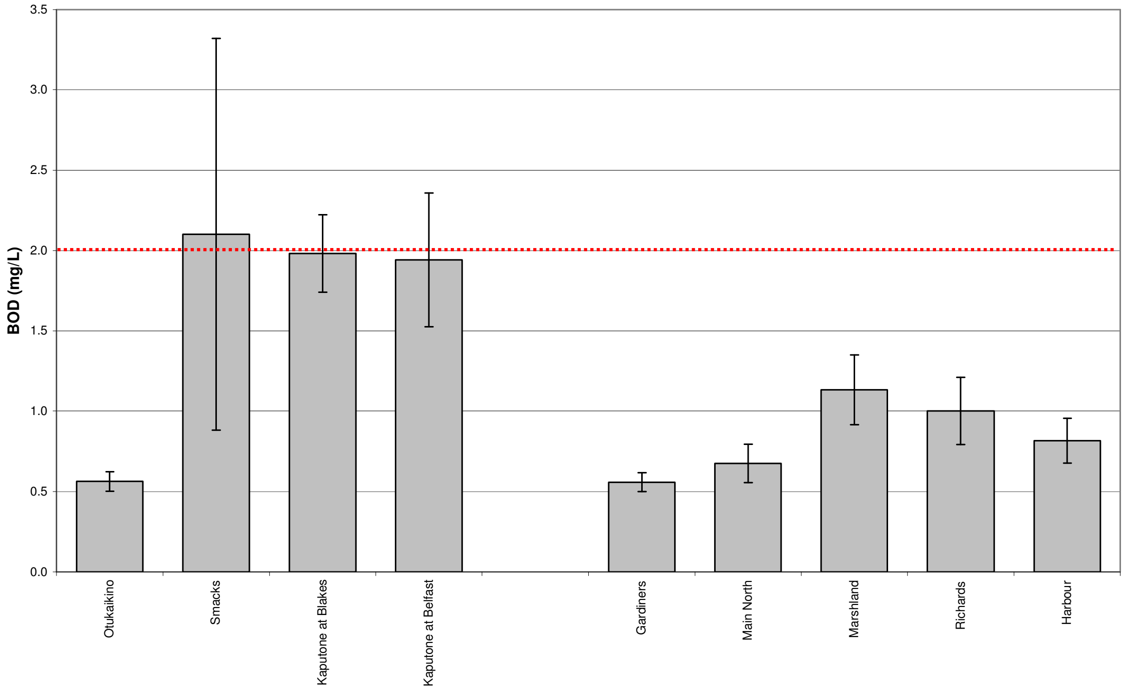

Figure 13 BOD concentrations for sites in the Styx and Otukaikino catchments, mean ± SE for monthly samples between May 2011 and April 2012. Otukaikino and Styx tributary sites are displayed on the left side of the graph and Styx River mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 2 mg/L is shown as a red dotted line.

2.5 Total Suspended Solids (TSS)

Elevated levels of suspended sediment in the water column decrease the clarity of the water and can influence the behaviour of invertebrates and fish, as well as the growth of aquatic plants. A guideline of 25 mg/L (Ryan 1991) provides for the protection of aesthetic values and the aquatic ecosystem.

Average values of total suspended solids (TSS) increased downstream on the Avon and Heathcote rivers (Figure 14 & Figure 15), with a less consistent downstream increase for the Styx River (Figure 16), and insufficient sites in the Halswell catchment to consider downstream trends (Figure 15). None of the sites in the Avon catchment exceeded the guideline, whereas average values for all of the lower Heathcote sites downstream of Catherine Street did exceed the guideline. Haytons Drain at Wigram Road had the highest TSS value of all of the sites, with an average TSS of greater than 70 mg/L.

Values of TSS for all sites monitored within the Styx and Otukaikino catchments were well below the 25 mg/L guideline, with averages of less than 5 mg/L for all sites for the 2011-2012 year (Figure 16). Samples from sites in these catchments were regularly recorded as being below the laboratory detection limits for TSS. Monitoring sites on Nottingham Stream and the Halswell River also frequently recorded TSS values below the present laboratory detection level of 3 mg/L during the 2011-2012 year.

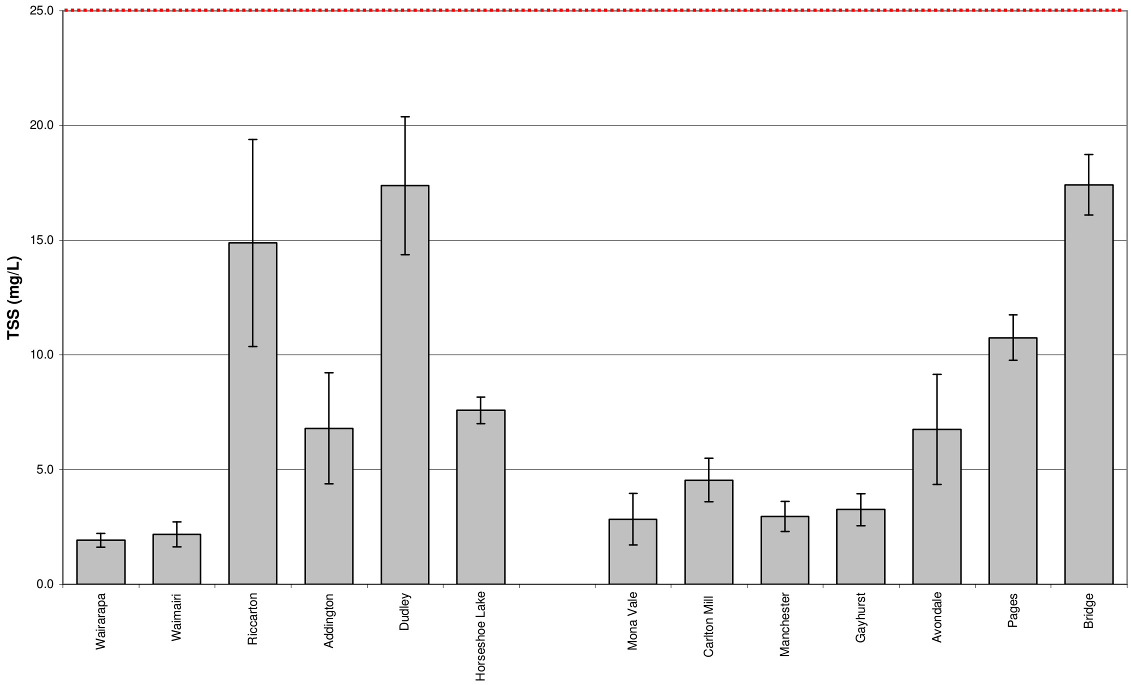

Figure 14 Total suspended solids concentrations for sites in the Avon catchment, mean ± SE for monthly samples between May 2011 and April 2012. Tributary sites are displayed on the left side of the graph and mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 25 mg/L is shown as a red dotted line.

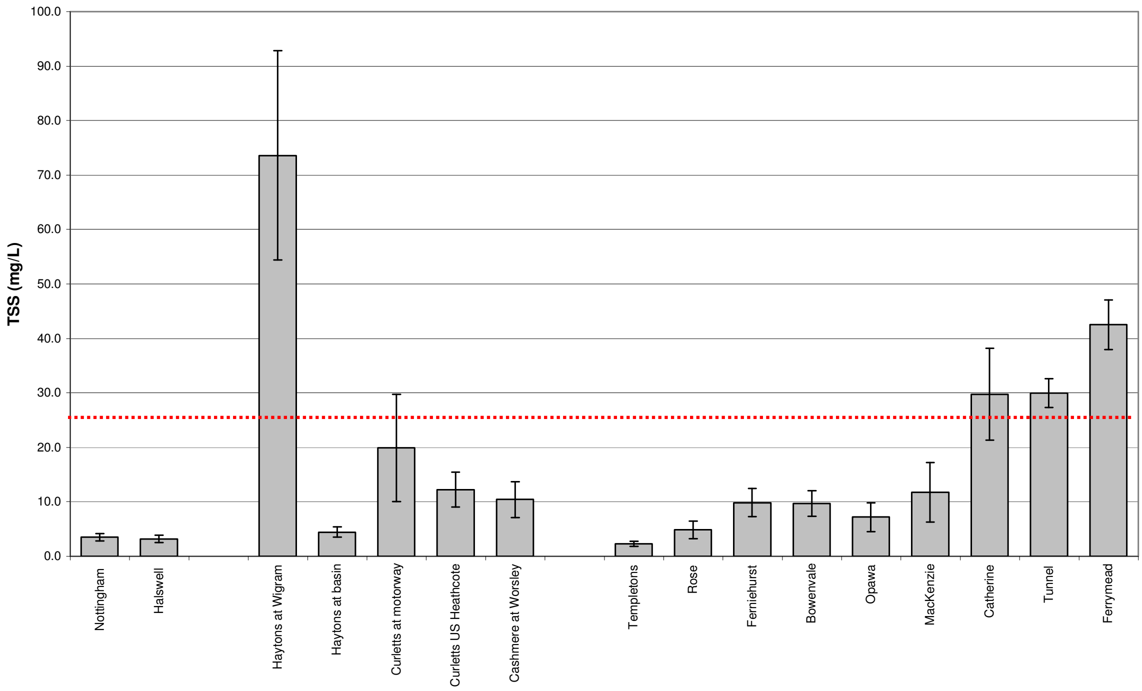

Figure 15 Total suspended solids concentrations for sites in the Heathcote and Halswell catchments, mean ± SE for monthly samples between May 2011 and April 2012. Halswell sites are to the left of the graph, followed by Heathcote tributary sites and then Heathcote mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 25 mg/L is shown as a red dotted line.

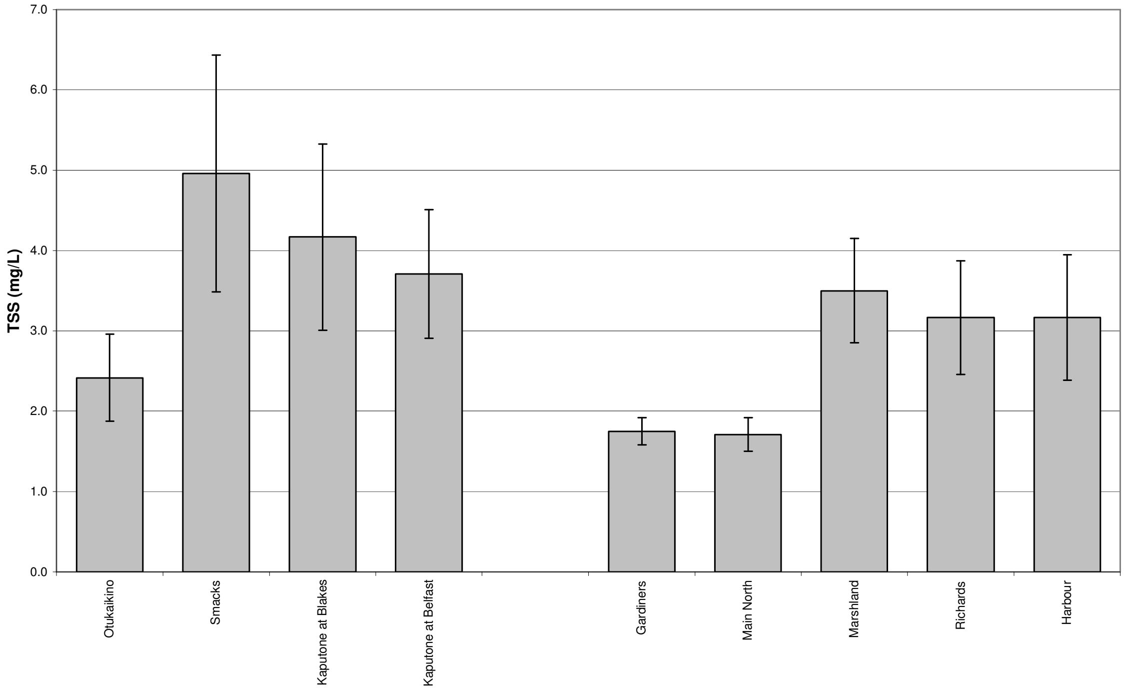

Figure 16 Total suspended solids concentrations for sites in the Styx and Otukaikino catchments, mean ± SE for monthly samples between May 2011 and April 2012. Otukaikino and Styx tributary sites are displayed on the left side of the graph and Styx River mainstem sites to the right, arranged from upstream to downstream (left to right). The guideline value of 25 mg/L is not shown on this graph as the scale does not extend to that value.

2.6 E. coli

Elevated levels of *E. coli* may make the water unsuitable for contact recreation. Guidelines suggest that *E. coli* concentrations of single samples should not exceed 550 *E. coli* /100 mL to be safe for contact recreation (MfE 2003). This is also the value indicated by the NRRP water quality standards (NRRP, Table WQL16) for the water quality classes represented in Christchurch (spring-fed-plains-urban, spring-fed-plains, Banks Peninsula).

In the Avon catchment, Waimairi Stream, Addington Drain, Mona Vale and Carlton Mill corner had average *E. coli* concentrations less than 550 *E. coli* /100 mL (Figure 17), but all of these sites had *E. coli* readings greater than this guideline on more than one occasion through the year. Average *E. coli* concentrations were greater than 550 *E. coli* /100 mL for most sites in the Heathcote catchment for the 2011-2012 year, with the exception of Haytons Drain downstream of the retention basin, Cashmere Stream at Worsleys and the Heathcote River at Templetons Road (Figure 18). Values for both sites in the Halswell catchment also exceeded the guideline (Figure 18).

Average *E. coli* concentrations exceeded guideline values for the Kaputone Stream and for several sites in the mid-lower reaches of the Styx River mainstem (Main North Road, Marshland Road, Richards Bridge) (Figure 19).

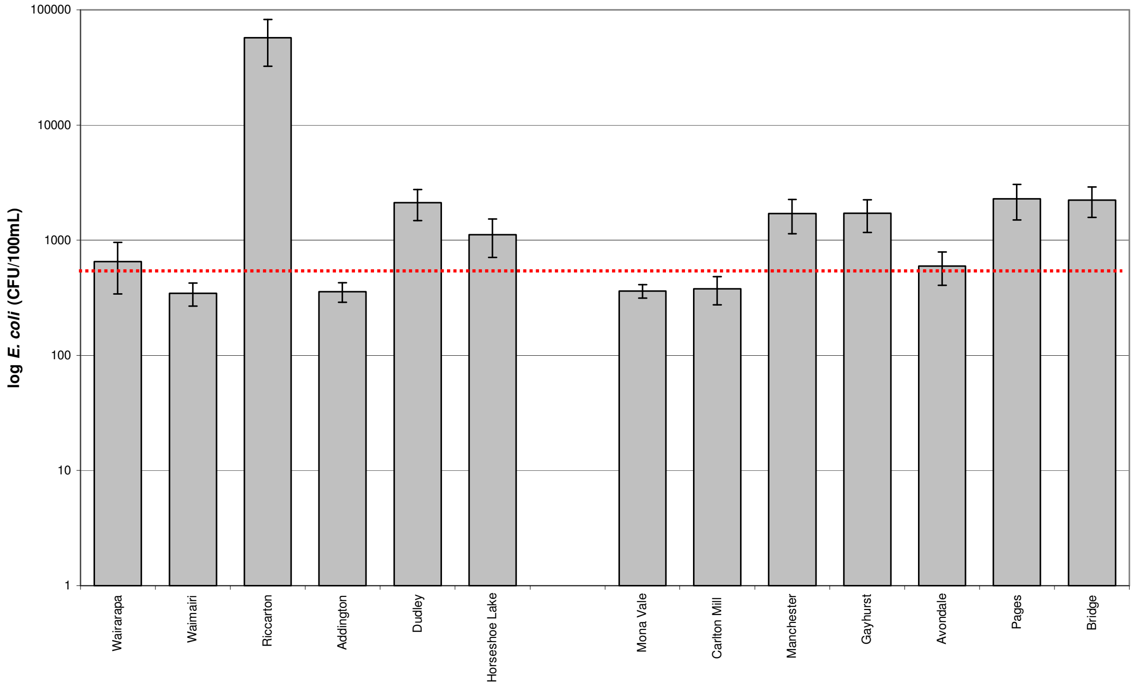

Figure 17 *E. coli* concentrations for sites in the Avon catchment, mean ± SE for monthly samples between May 2011 and April 2012. Tributary sites are displayed on the left side of the graph and mainstem sites to the right, arranged from upstream to downstream (left to right). A guideline value of 550 *E. coli* per 100 mL is shown as a red dotted line. Note that values are shown on a log scale.

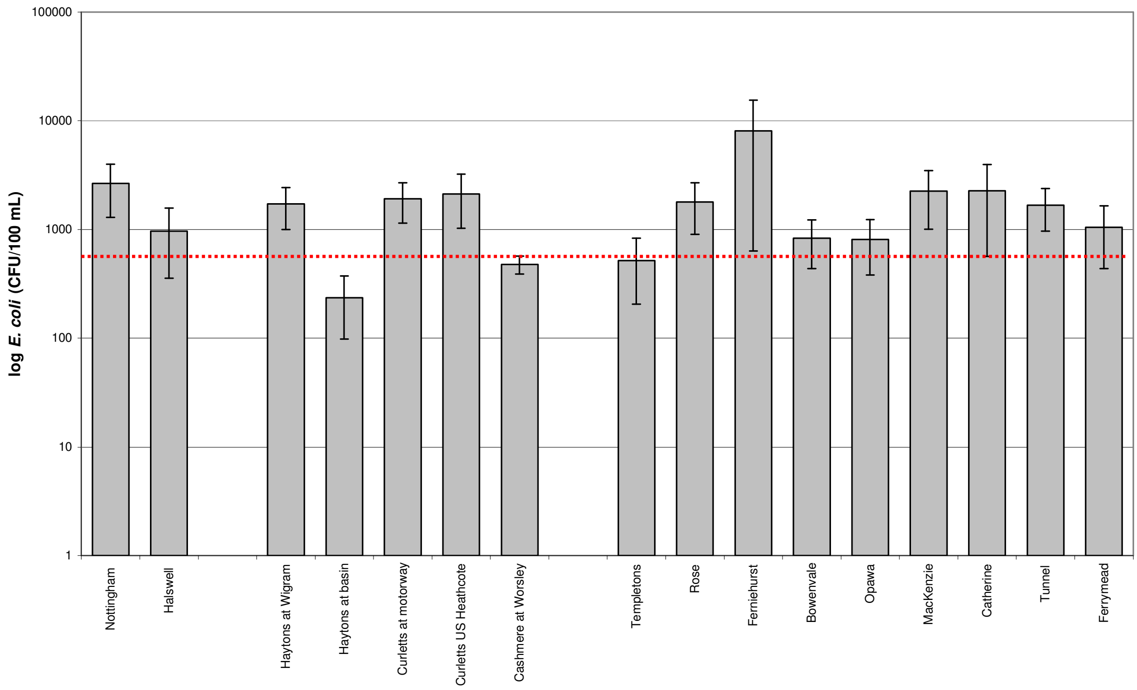

Figure 18 *E. coli* concentrations for sites in the Heathcote and Halswell catchments, mean ± SE for monthly samples between May 2011 and April 2012. Halswell sites are to the left of the graph, followed by Heathcote tributary sites and then Heathcote mainstem sites to the right, arranged from upstream to downstream (left to right). A guideline value of 550 *E. coli* per 100 mL is shown as a red dotted line. Note that values are shown on a log scale.

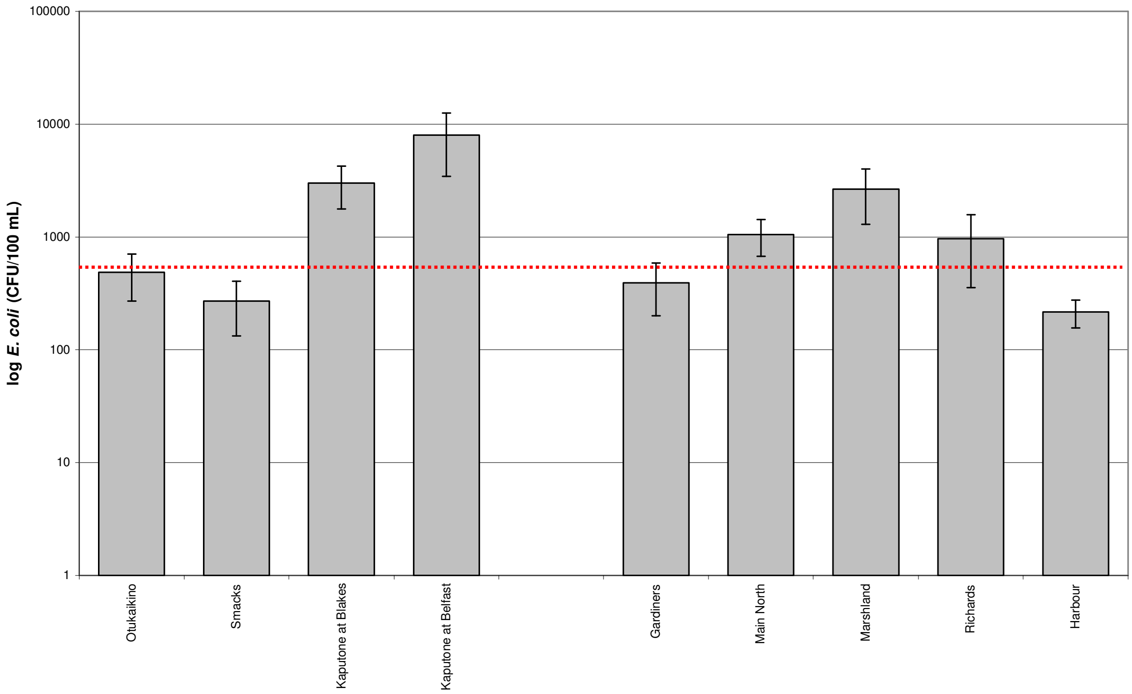

Figure 19 *E. coli* concentrations for sites in the Styx and Otukaikino catchments, mean ± SE for monthly samples between May 2011 and April 2012. Otukaikino and Styx tributary sites are displayed on the left side of the graph and Styx River mainstem sites to the right, arranged from upstream to downstream (left to right). A guideline value of 550 *E. coli* per 100 mL is shown as a red dotted line. Note that values are shown on a log scale.

2.7 Heavy Metals

Water samples from a subset of the water quality monitoring sites in each catchment are analysed each month for total concentrations of cadmium, copper, lead, mercury and zinc. This includes eleven sites in the Avon, ten in the Heathcote, eight in the Styx and two from the Halswell catchment. The ANZECC (2000) water quality guidelines set trigger values for each of these heavy metals to provide a specified level of protection for aquatic life. The NRRP toxicant water quality standards (NRRP, Table WQL17) use the same trigger values as ANZECC (2000) and specify levels of species protection for each water quality management unit. The water quality management units represented within Christchurch City are spring-fed-plains-urban (90% species protection), spring-fed-plains (95% species protection) and Banks Peninsula (99% species protection). All monitoring sites within the Avon catchment are spring-fed-plains-urban. With the exception of Cashmere Stream which is in the Banks Peninsula water quality management unit, all sites in the Heathcote catchment are also spring-fed-plains-urban. The Styx and Halswell catchment sites are in the spring-fed-plains management unit. ANZECC (2000) provides default trigger values for metals at each level of species protection and also provides a method for determining hardness modified trigger values (HMTV) that are relevant to local conditions. Hardness modified trigger values calculated for Christchurch rivers are provided in Appendix 5.

Heavy metals were analysed as total metals for all monitoring sites until December 2011 and these values are used for the current summary. Since this time, dissolved metals have been recorded in the place of total metals. Measures of total metals tend to overestimate the bioavailable fraction of the metal (ANZECC 2000). The dissolved fraction is bioavailable and has the greatest potential to cause toxic effects to instream life, making it a relevant measure to compare with trigger values.

2.7.1 Total Copper

Default trigger values for copper range from 1.0 to 1.8 µg/L, depending on the level of species protection provided at each location (90-99% species protection) (ANZECC 2000). Hardness modified trigger values for copper range from 2.12 µg/L in the Styx River (soft water), to 5.43 µg/L in the Heathcote River (moderate to hard water).

Average copper concentrations for all sites in the Avon River mainstem were below the default copper trigger value for the year, whereas several tributary sites exceeded the default trigger value

(Riccarton, Addington, Dudley and Horseshoe Lake) and Dudley Creek also exceeded the HMTV (Figure 20).

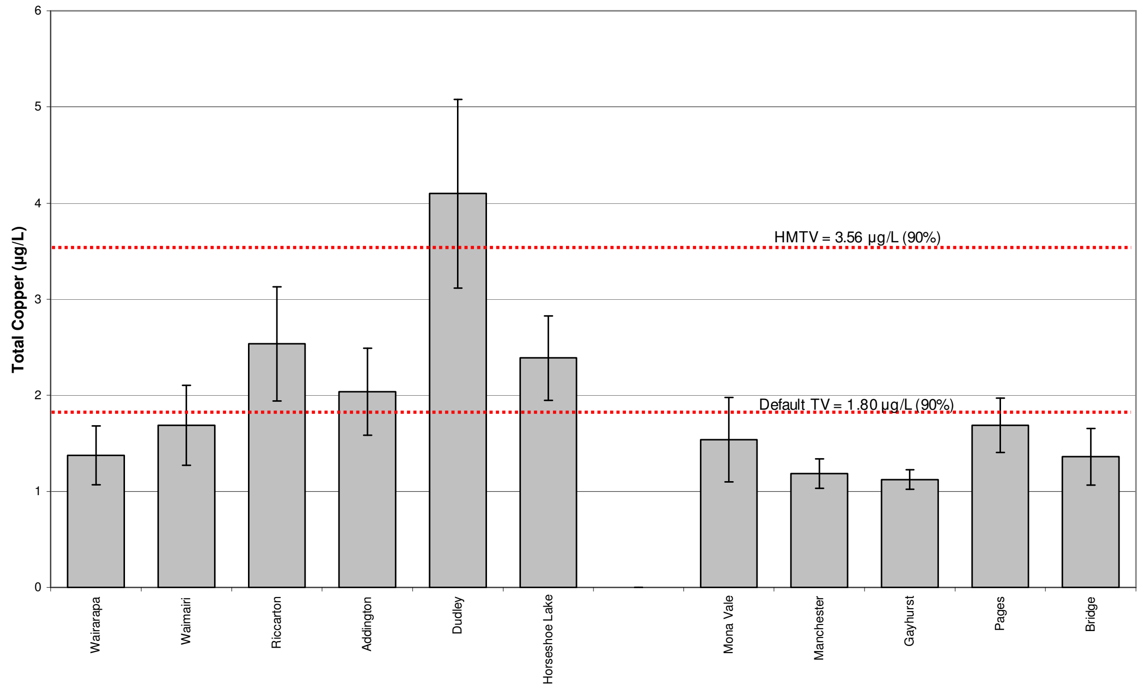

Figure 20 Total copper concentrations for sites in the Avon catchment, mean ± SE for monthly samples between May 2011 and December 2011. Tributary sites are displayed on the left side of the graph and mainstem sites to the right, arranged from upstream to downstream (left to right). ANZECC (2000) default and hardness modified trigger values (HMTV) are displayed as red dotted lines on the graph.

Average copper concentrations for most sites in the Heathcote and Halswell catchments exceeded default trigger values (Figure 21). However, all sites except Curletts Drain were below the HMTV's for their relevant water hardness and water quality management unit.

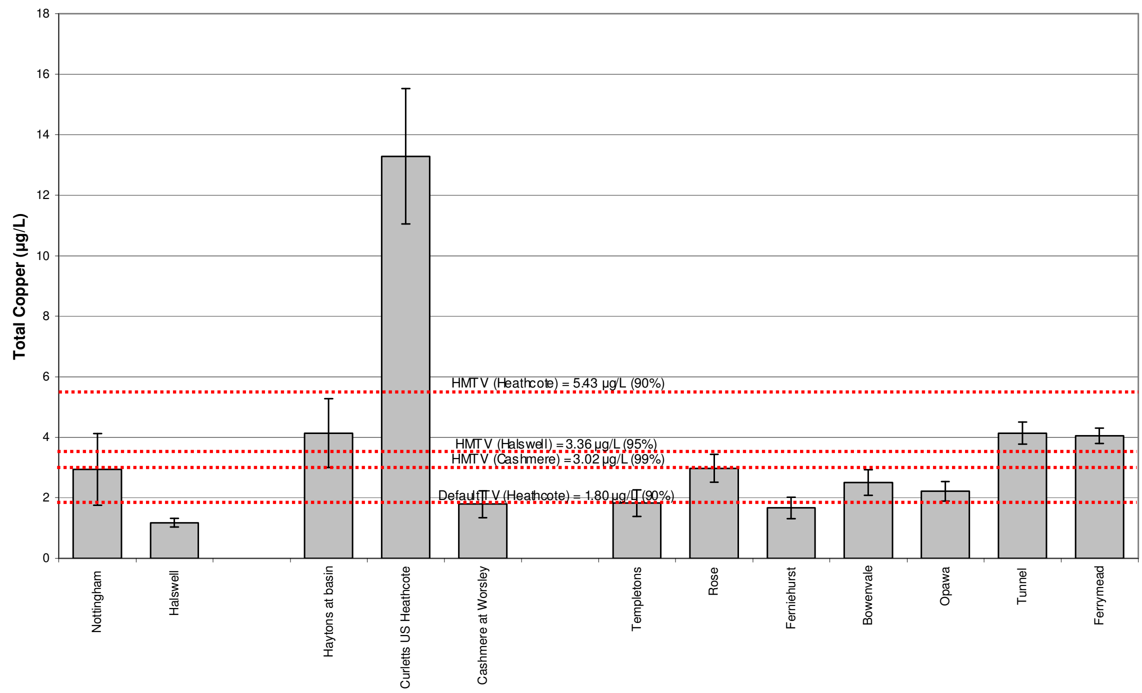

Figure 21 Total copper concentrations for sites in the Heathcote and Halswell catchments, mean ± SE for monthly samples between May 2011 and December 2011. Halswell sites are to the left of the graph, followed by Heathcote tributary sites and then Heathcote mainstem sites to the right, arranged from upstream to downstream (left to right). ANZECC (2000) default and hardness modified trigger values are displayed as red dotted lines on the graph. Note that Cashmere Stream is included in the Banks Peninsula water quality management unit (NRRP) (99% species protection) and Halswell catchment sites are within the spring-fed-plains water quality management unit (95% species protection).

The Styx River is within the spring-fed-plains water quality management unit as defined by the NRRP and therefore a 95% level of species protection is relevant for heavy metals. Average copper concentrations for the Otukaikino River at the Groynes, Kaputone Stream at Belfast Road and the Styx River at Marshland Road were greater than the default trigger value for 95% species protection (Figure 22). Only the Styx River at Marshland Road exceeded the HMTV on average, although most sites did exceed this value for at least one sampling round.

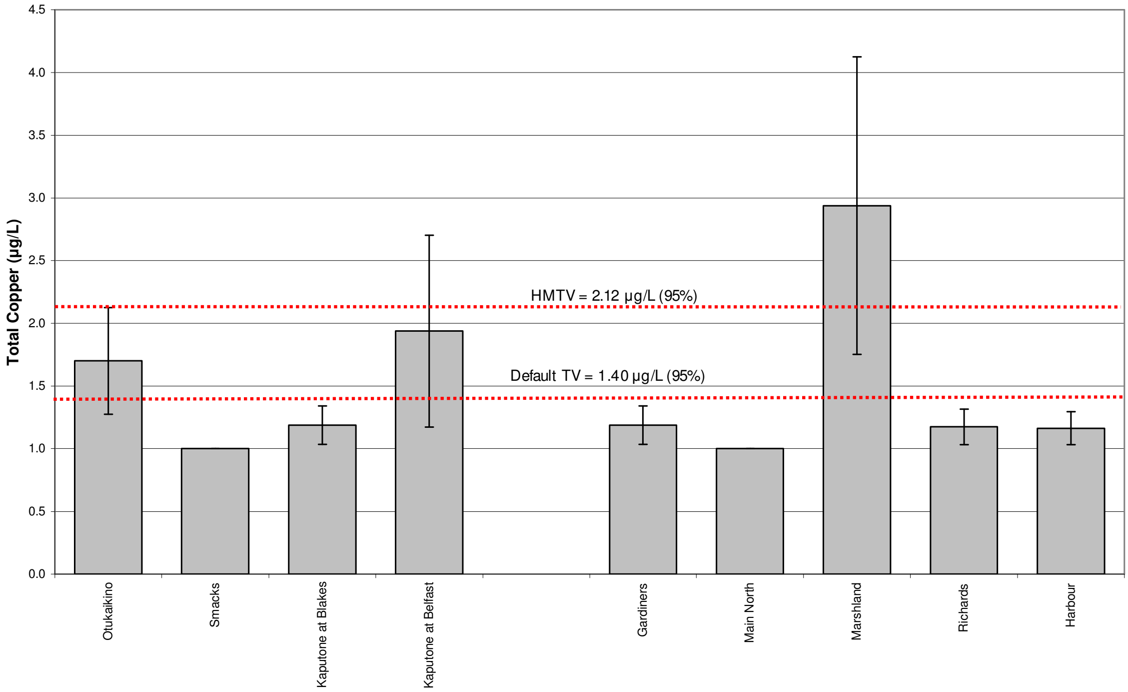

Figure 22 Total copper concentrations for sites in the Styx and Otukaikino catchments, mean ± SE for monthly samples between May 2011 and December 2011. Otukaikino and Styx tributary sites are displayed on the left side of the graph and Styx River mainstem sites to the right, arranged from upstream to downstream (left to right). ANZECC (2000) default and hardness modified trigger values (HMTV) for 95% species protection are displayed as red dotted lines on the graph.

2.7.2 Total Lead

Default trigger values for lead range from 1.0 to 5.6 µg/L, depending on the level of species protection provided at each location (90-99% species protection) (ANZECC 2000). These default trigger values are based on the toxicity of dissolved lead, which would be expected to be lower than the total lead concentrations that have been measured in this sampling programme. Hardness modified trigger values for lead range from 5.21 µg/L for Cashmere Stream (Banks Peninsula water quality management unit, 99% species protection), to 29.16 µg/L in the Heathcote River (spring-fed-plains-urban water quality management unit, moderate to hard water).

With the exception of Dudley Creek, average lead concentrations at all sites within the Avon catchment were well below the default trigger value (Figure 23). Dudley Creek had an average concentration of 7.8 µg/L, which was greater than the default trigger value, but well below the HMTV of 15.54 µg/L.

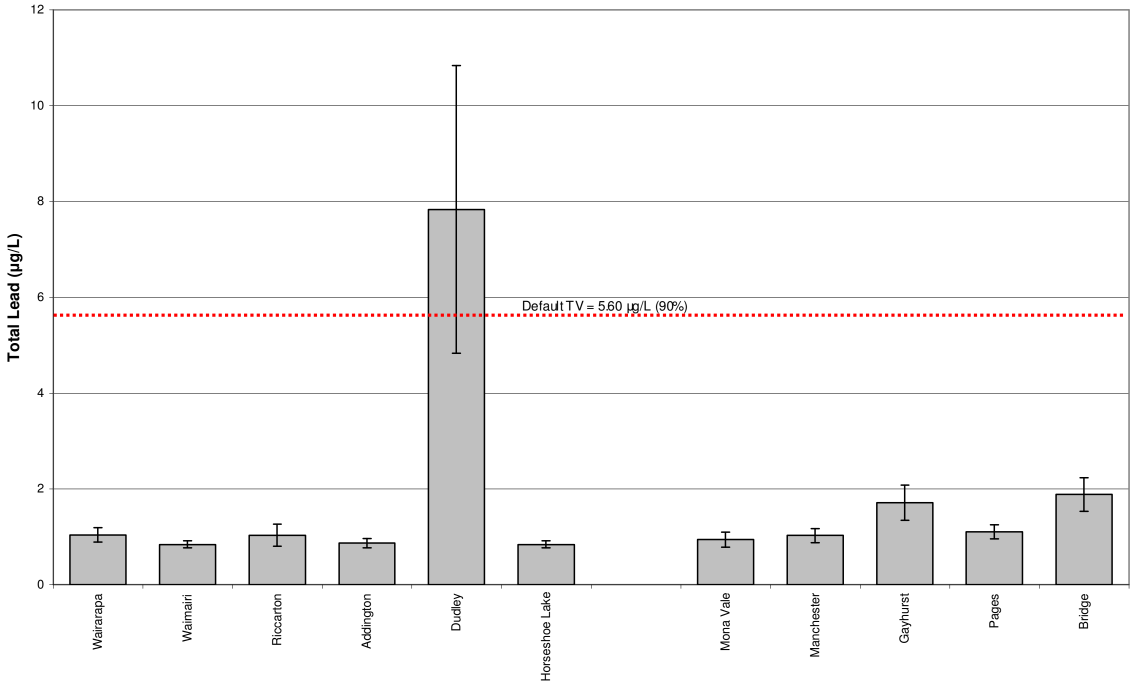

Figure 23 Total lead concentrations for sites in the Avon catchment, mean ± SE for monthly samples between May 2011 and December 2011. Tributary sites are displayed on the left side of the graph and mainstem sites to the right, arranged from upstream to downstream (left to right). The ANZECC (2000) default trigger value is displayed as a red dotted line on the graph. The calculated hardness modified trigger value (HMTV) for the Avon catchment is 15.54 µg/L, which is greater than the scale on this graph.

All monitoring sites within the Heathcote, Halswell, Styx and Otukaikino catchments had average lead concentrations that were below the default and HMTV (Figure 24, Figure 25). The monitoring site on Curletts Drain, upstream of the confluence with the Heathcote River was the only site that exceeded the default trigger value for several individual sampling rounds, but even this site never exceeded the HMTV.

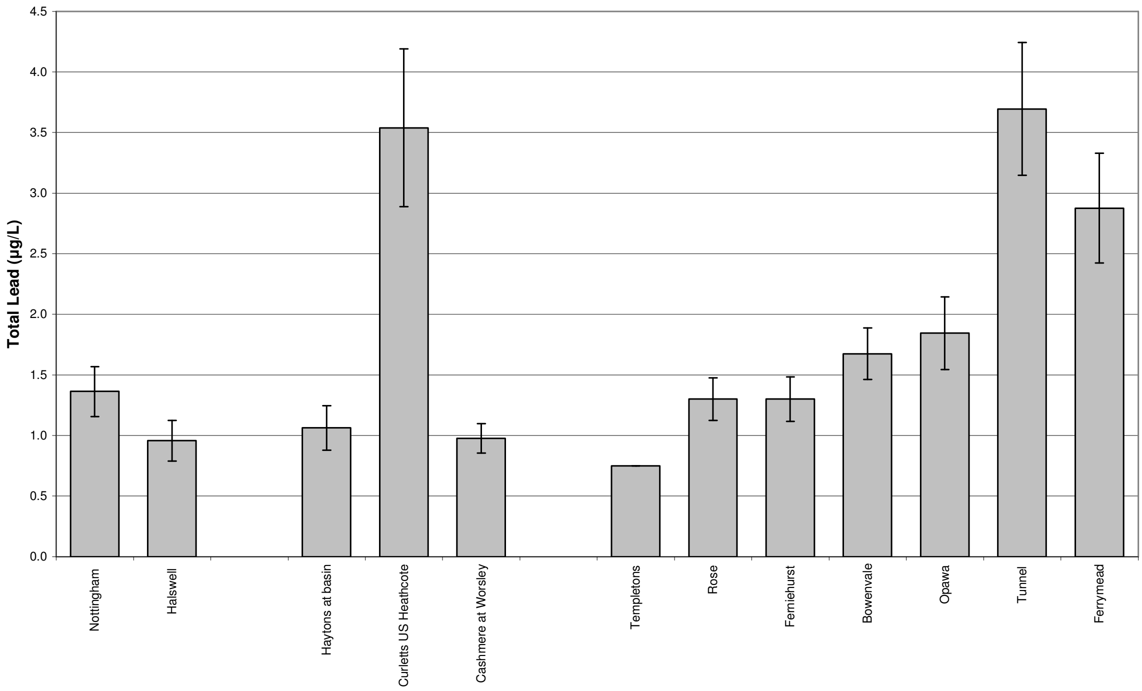

Figure 24 Total lead concentrations for sites in the Heathcote and Halswell catchments, mean ± SE for monthly samples between May 2011 and December 2011. Halswell sites are to the left of the graph, followed by Heathcote tributary sites and then Heathcote mainstem sites to the right, arranged from upstream to downstream (left to right). ANZECC (2000) default and hardness modified trigger values are not displayed on the graph, because all trigger values are greater than the extent of the scale on this graph.

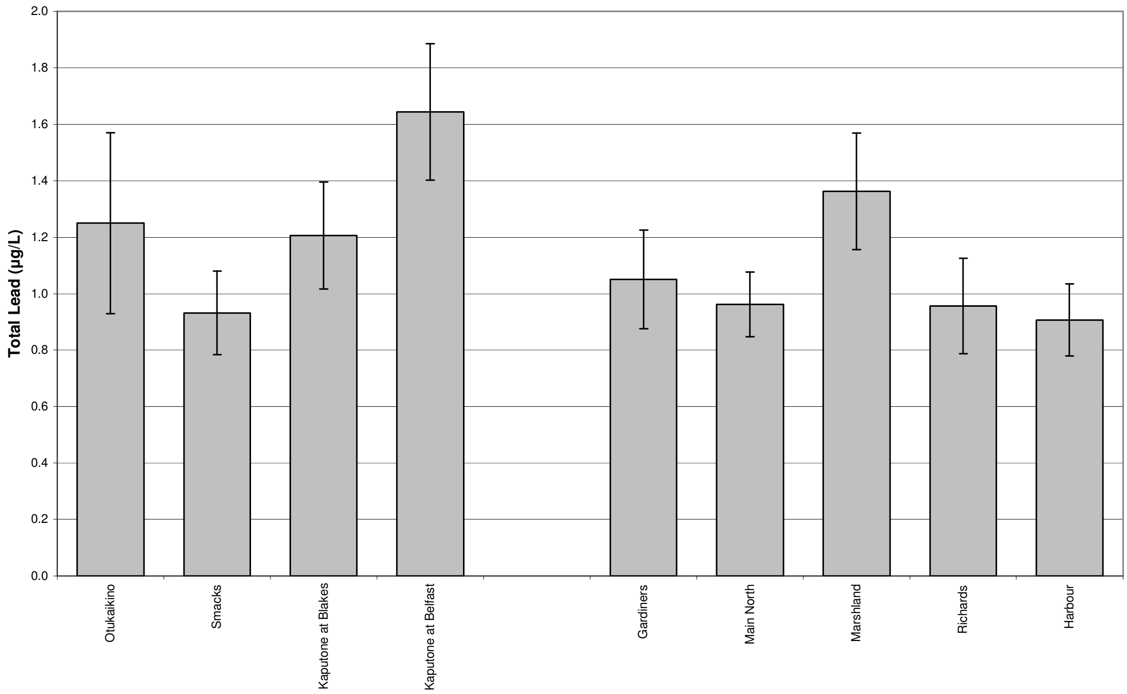

Figure 25 Total lead concentrations for sites in the Styx and Otukaikino catchments, mean ± SE for monthly samples between May 2011 and December 2011. Otukaikino and Styx tributary sites are displayed on the left side of the graph and Styx River mainstem sites to the right, arranged from upstream to downstream (left to right). ANZECC (2000) default and hardness modified trigger values are not displayed on the graph, because all trigger values are greater than the extent of the scale on this graph.

2.7.3 Total Zinc

Default trigger values for zinc range from 2.4 to 15 µg/L, depending on the level of species protection provided at each location (90-99% species protection) (ANZECC 2000). These default trigger values are based on the toxicity of dissolved zinc, which would be expected to be lower than the total zinc concentrations that have been measured in this sampling programme. Hardness modified trigger values for zinc range from 7.24 µg/L for Cashmere Stream (Banks Peninsula water quality management unit, 99% species protection), to 45.26 µg/L in the Heathcote River (spring-fed-plains-urban water quality management unit, moderate to hard water).

Average zinc concentrations for seven of the Avon catchment sites were below the default zinc trigger value for the year, but sites on Riccarton Drain, Addington Drain, Dudley Creek and Avon River at Gayhurst Road were above this value (Figure 26). Sites on Addington Drain and Dudley Creek also exceeded the HMTV on average.

Average zinc concentrations for most sites in the Heathcote catchment exceeded the default zinc trigger value (Figure 27). Cashmere Stream and the upstream most site on the Heathcote River at Templetons Road were below this trigger value on average, as were both monitoring sites within the Halswell catchment. Three sites in the Heathcote catchment also exceeded the HMTV for zinc, including Haytons Drain, Curletts Drain and Heathcote River at Rose Street. Of these, zinc concentrations for Curletts Drain were well above the other sites, with an average concentration of 347 µg/L recorded for the year.

Sites on the Styx River at Gardiners Road, Main North Road, and Richards Bridge, as well as the two sites on Kaputone Stream, at Blakes Road and Belfast Road, all exceeded the default trigger value of 8 µg/L for the spring-fed-plains water quality management unit (95% species protection) (Figure 28). The average concentration of zinc for Kaputone Stream at Blakes Road also exceeded the HMTV of 12.14 µg/L, while all other sites in the catchment were below this value.

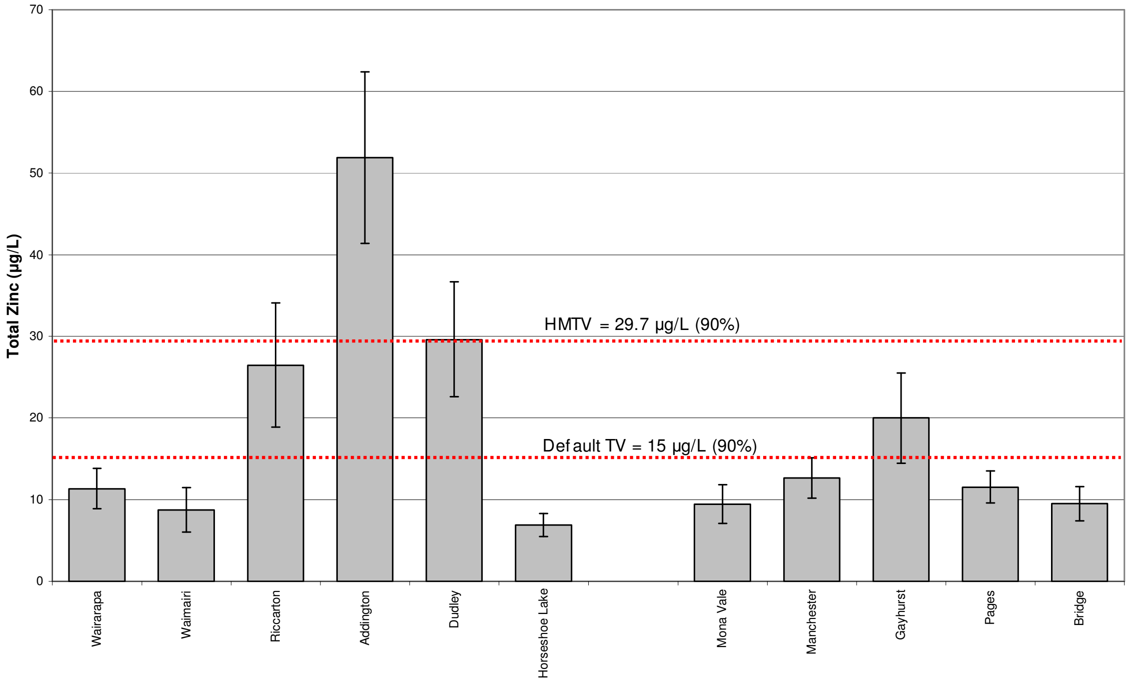

Figure 26 Total zinc concentrations for sites in the Avon catchment, mean ± SE for monthly samples between May 2011 and December 2011. Tributary sites are displayed on the left side of the graph and mainstem sites to the right, arranged from upstream to downstream (left to right). The ANZECC (2000) default trigger value is displayed as a red dotted line on the graph.

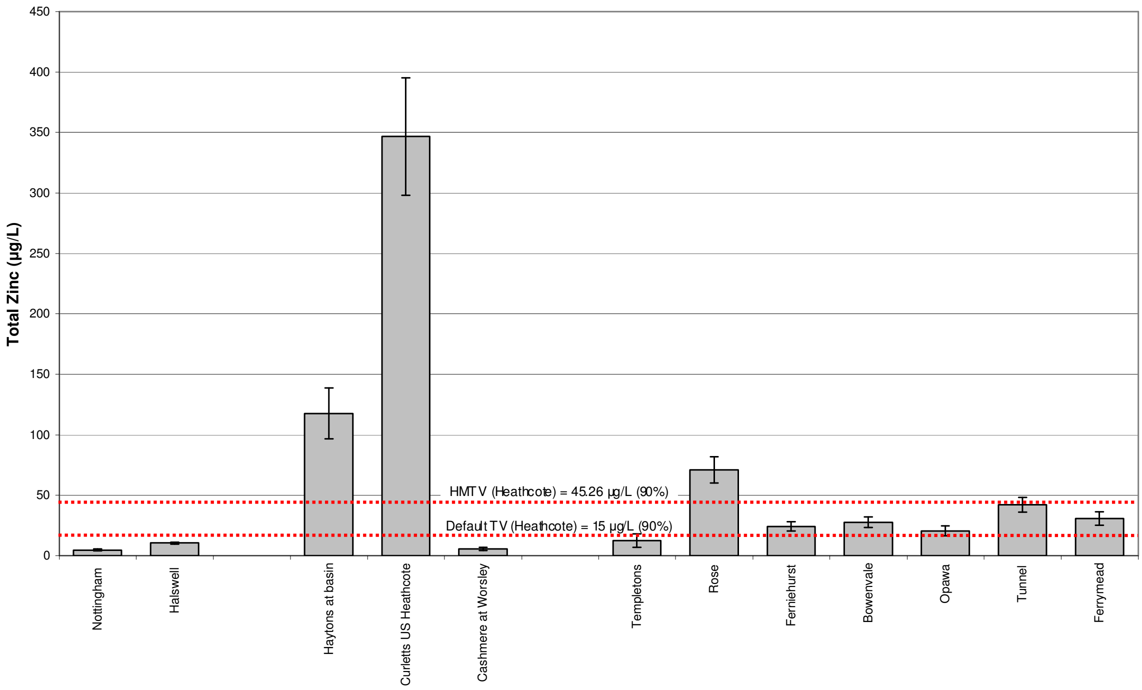

Figure 27 Total zinc concentrations for sites in the Heathcote and Halswell catchments, mean ± SE for monthly samples between May 2011 and December 2011. Halswell sites are to the left of the graph, followed by Heathcote tributary sites and then Heathcote mainstem sites to the right, arranged from upstream to downstream (left to right). ANZECC (2000) default and hardness modified trigger values for the Heathcote River are displayed on the graph. Not shown are the hardness modified trigger values for the Cashmere Stream (7.24 µg/L, 99%) and Halswell catchment (19.19 µg/L, 95%).

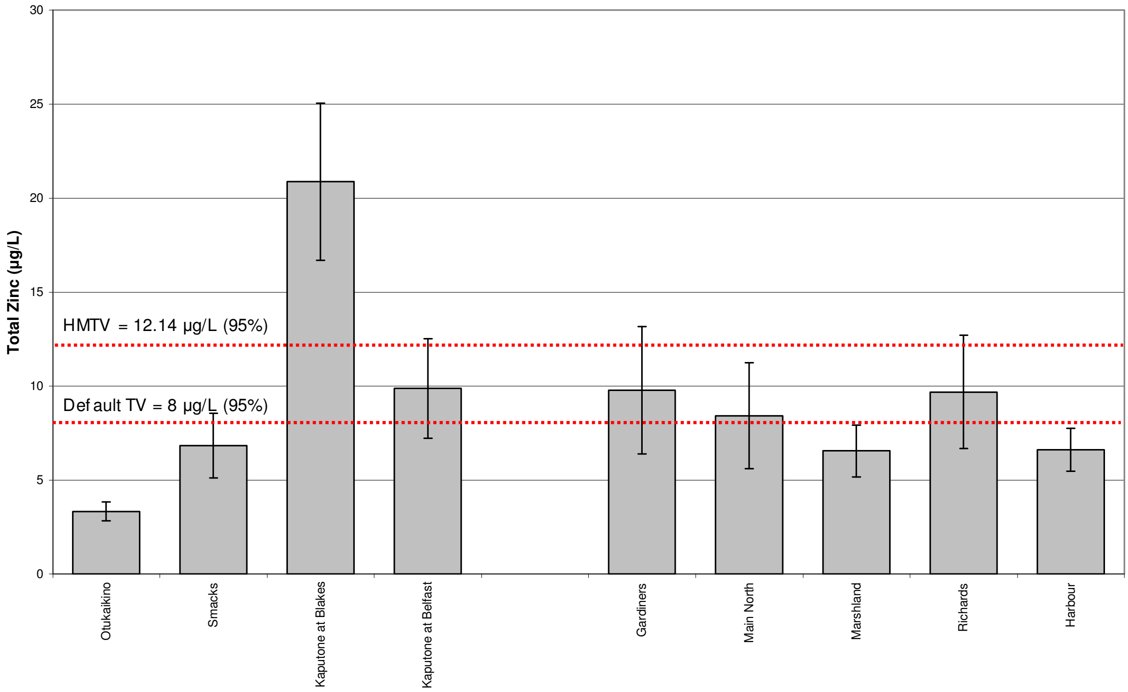

Figure 28 Total zinc concentrations for sites in the Styx and Otukaikino catchments, mean ± SE for monthly samples between May 2011 and December 2011. Otukaikino and Styx tributary sites are displayed on the left side of the graph and Styx River mainstem sites to the right, arranged from upstream to downstream (left to right). ANZECC (2000) default and hardness modified trigger values are displayed as red dotted lines on the graph.

3 Water Quality Trends

Results of monthly water quality monitoring over the five year period from January 2007 to December 2011 have been used to assess trends in key water quality parameters at monitoring sites in each catchment. Results showed a mixture of increasing and decreasing trends among the parameters tested, although there were no significant trends for the majority of cases (Table 3). A summary of these trends is shown as Table 3.

Table 3 Direction and significance ($p<0.05$) of trends for *E. coli*, turbidity, electrical conductivity (EC), nitrate-nitrite nitrogen (NNN), and dissolved reactive phosphorus (DRP) at river water quality monitoring sites in Christchurch City for the five years from January 2007 to December 2011 (since monthly sampling was initiated).

Catchment	Site Description	E. coli	Turbidity	EC	NNN	DRP
Avon	Avon River at Mona Vale	↑ +16%				
	Avon River at Carlton Mill corner				↓ -5%	
	Avon River at Manchester St	↑ +38%			↓ -6%	
	Avon River at Gayhurst Rd	↑ +17%	↓ -15%	↑ +2%		↑ +14%
	Avon River at Avondale Rd					
	Avon River at Pages/Seaview Bridge	↑ +48%				↑ +14%
	Avon River at Bridge St	↑ +47%			↓ -17%	
	Wairarapa Stream				↑ +5%	
	Waimairi Stream	↑ +27%				
	Riccarton Drain			↑ +14%	↑ +21%	
	Addington Drain					
	Dudley Creek		↑ +67%			
	Horseshoe Lake discharge				↓ -6%	
Heathcote	Heathcote River at Templetons Rd			↑ +3%	↑ +10%	
	Heathcote River at Rose St		↓ -22%			
	Heathcote River at Ferniehurst St					
	Heathcote River at Bowenvale Ave		↓ -9%			
	Heathcote River at Opawa Rd		↓ -26%			
	Heathcote River at MacKenzie Ave					
	Heathcote River at Catherine St				↓ -11%	
	Heathcote River at Tunnel Rd				↓ -15%	
	Heathcote River at Ferrymead Bridge	↑ +24%			↓ -35%	
	Haytons Drain at Wigram Rd					
	Haytons Drain at Retention Basin		↓ -25%			
	Curletts Road Drain at Motorway	↑ +34%				
	Curletts Road Drain US Heathcote					
	Cashmere Stream at Worsleys Rd		↓ -26%			
Styx	Styx River at Gardiners Rd	↑ +19%	↓ -19%	↓ -4%	↓ -10%	
	Styx River at Main North Rd		↓ -31%	↓ -2%	↓ -9%	
	Styx River at Marshland Rd Bridge		↓ -28%			↑ +8%
	Styx River at Richards Bridge	↑ +20%				
	Styx River at Harbour Rd Bridge					↑ +2%
	Smacks Creek at Gardiners Rd		↓ -41%	↓ -5%	↓ -13%	
	Kaputone at Blakes Rd			↑ +4%	↑ +11%	↑ +7%
	Kaputone at Belfast Rd		↓ -19%	↑ +1%	↑ +5%	
Halswell	Nottingham Stream at Candys Rd	↑ +33%			↓ -21%	
	Halswell River at Akaroa Highway			↑ +1%		
Otukaikino	Otukaikino at Groynes inlet					↓ -43%
City Outfall	City Outfall Drain					

3.1 E. coli

For the five year period between January 2007 to December 2011, *E. coli* concentrations showed significantly increasing trends for 11 of the 39 monitoring sites across Christchurch City, indicating a decline in water quality at those sites (Table 3). For the Avon River, the greatest increases were observed in the lower river sites, with recent earthquake related wastewater discharges to the rivers likely to have had a considerable influence on the observed trends. With the exception of Waimairi Stream, the Avon tributary sites showed no significant trends for *E. coli* concentration. In the Heathcote catchment, the Ferrymead Bridge and Curletts Road Drain sites both showed increasing trends for *E. coli*, as did the Styx River at Gardiners Road and Richards Bridge, and Nottingham Stream in the Halswell catchment.

The Avon, Heathcote, Styx and Halswell catchments were all affected to varying extents by discharges of raw wastewater following earthquakes during 2010-2011. *E. coli* is one measure of water quality that would be expected to be elevated as a result of these discharges, and this appears to have influenced the observed trends.

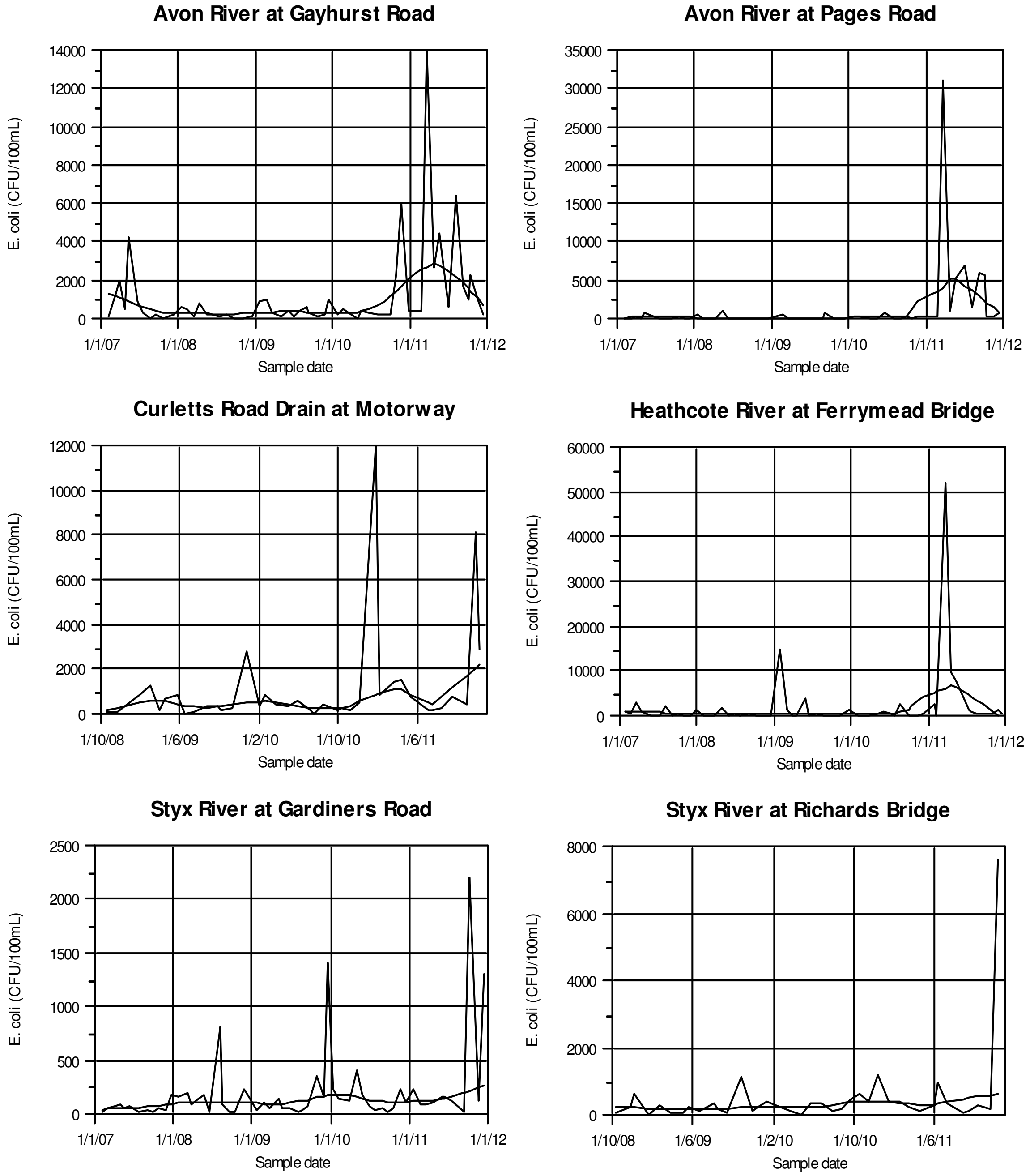

Figure 29 Examples of statistically significant ($p>0.05$) *E. coli* trends over time, for sites in the Avon, Heathcote and Styx catchments between January 2007 and December 2011. Locally Weighted Scatterplot Smoothing (LOWESS) was used to fit a trend line to the raw data.

3.2 Turbidity

Elevated levels of suspended sediment in the water column decrease the clarity of the water and can influence the behaviour of invertebrates and fish, as well as the growth of aquatic plants. Turbidity is a measure of the passage of light through the water column, rather than a direct measure of the quantity of suspended solids in the water column. Turbidity and total suspended solids (TSS) are both measured as part of the ongoing rivers water quality monitoring programme, but turbidity is a more useful measure for looking at trends over time, because TSS is frequently recorded as below laboratory detection limits for many sites, making it unreliable for detecting real trends in the data. ANZECC (2000) provides a guideline of 5.6 NTU for turbidity in lowland rivers.

For the five year period between January 2007 to December 2011, the majority of significant trends for turbidity were decreases, indicating an improvement in water quality (Table 3). Of 12 significant trends detected, only one was an increase and this was for Dudley Creek. Decreasing trends were recorded for sites in the Heathcote, Styx and Avon catchments.

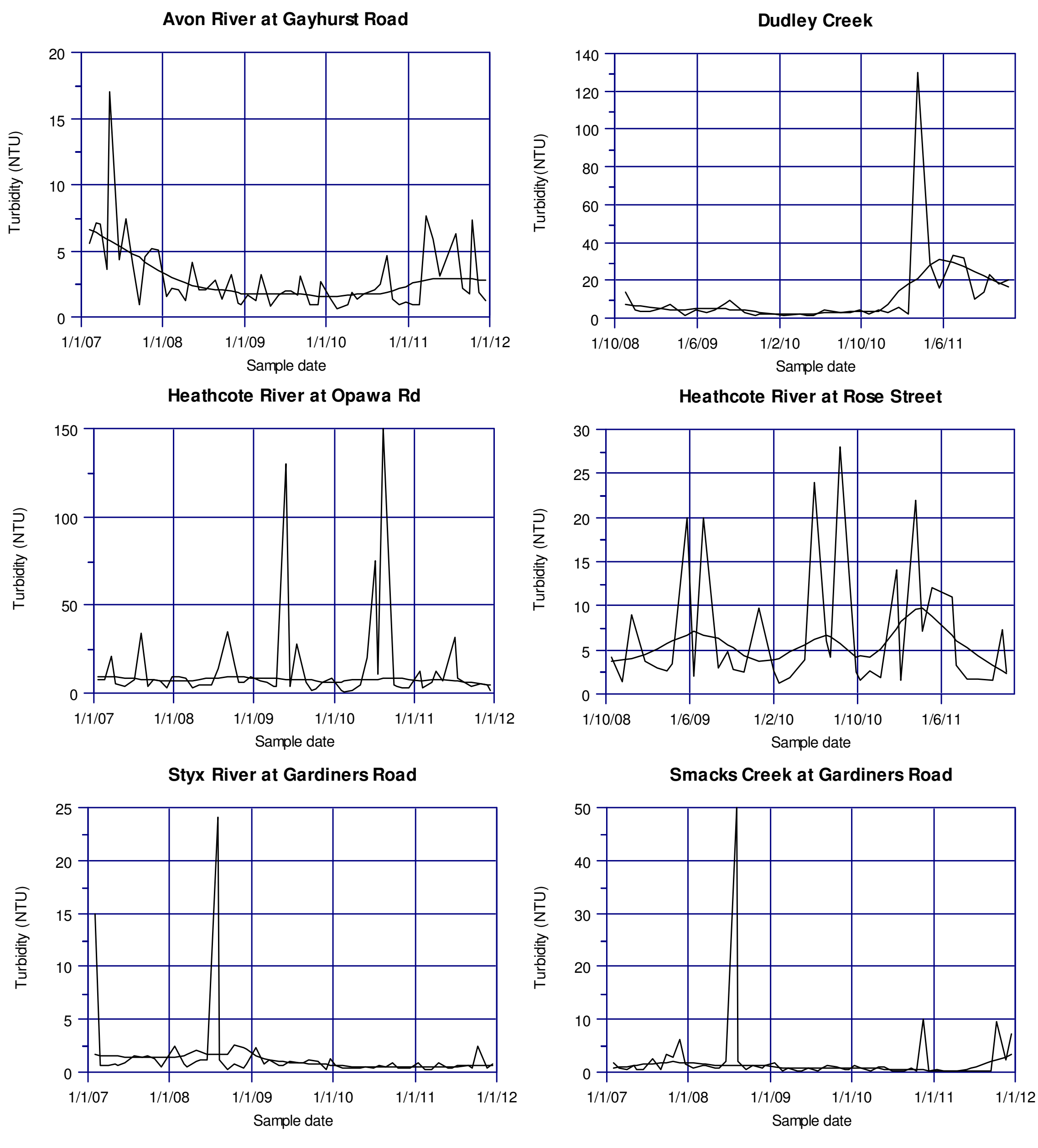

Figure 30 Examples of statistically significant (p>0.05) turbidity trends over time, for sites in the Avon, Heathcote and Styx catchments between January 2007 and December 2011. LOWESS curves are fitted to the data points on each graph to display the trends.

3.3 Electrical Conductivity (EC)

Electrical conductivity is a measure of the waters ability to conduct an electrical current. Pure water has very low conductivity and the presence of dissolved ions in the water increases its ability to conduct electricity. For this reason, conductivity is often used as an indicator of water quality, with higher conductivity generally representing poorer water quality (with the exception of saline water which has very high conductivity).

In the five years to December 2011, EC increased at six monitoring sites across the city and decreased at three sites (Table 3). Increases were recorded for sites on the Avon River, Riccarton Drain, upper Heathcote, Kaputone Stream and Halswell River. The decreasing trends were for the Styx River and Smacks Creek.

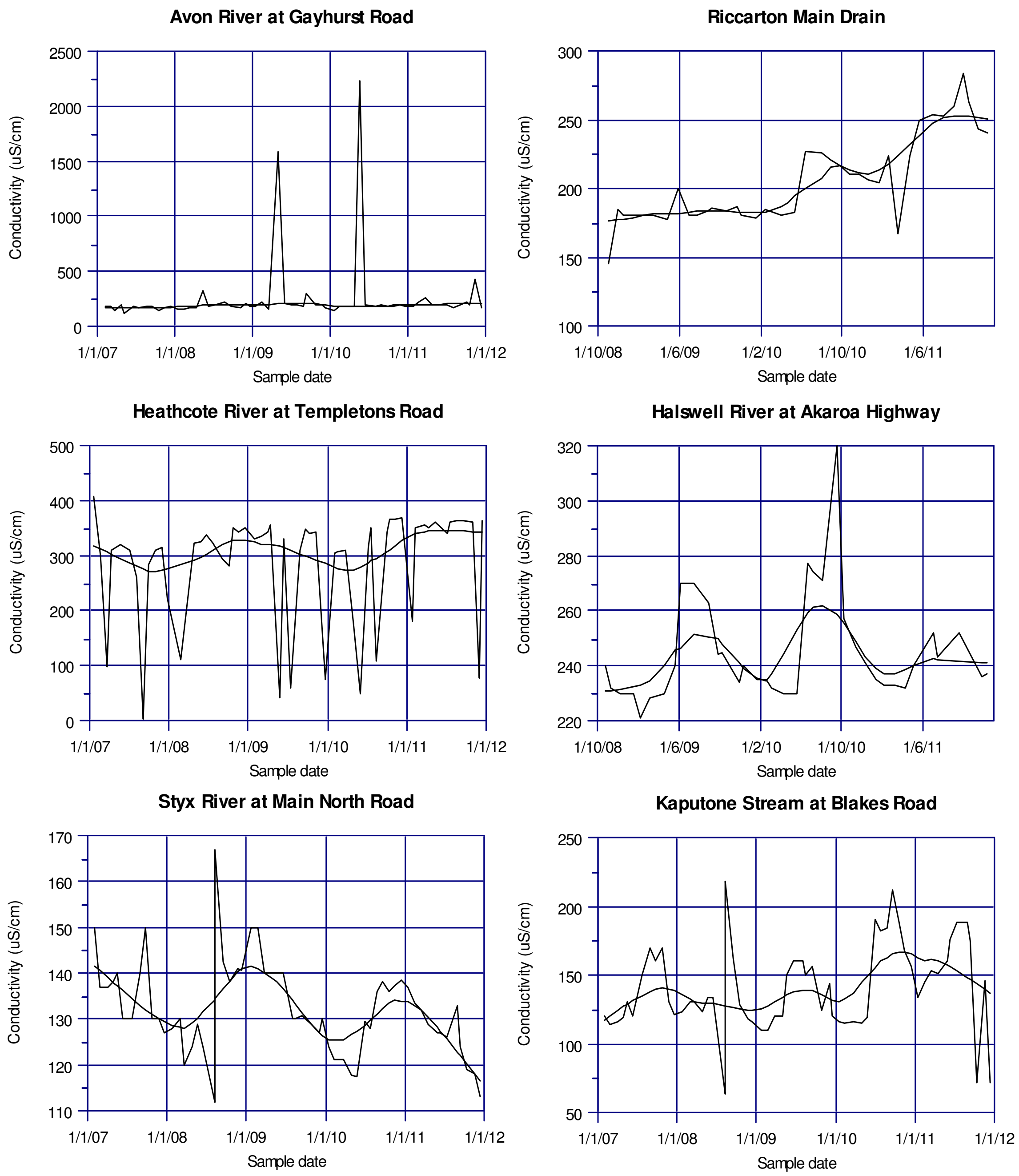

Figure 31 Examples of statistically significant (p>0.05) trends for electrical conductivity over time, for sites in the Avon, Heathcote and Styx catchments between January 2007 and December 2011. LOWESS curves are fitted to the data points on each graph to display the trends.

3.4 Nitrate-Nitrite Nitrogen (NNN)

Elevated concentrations of nitrate-nitrite nitrogen (NNN) can lead to the proliferation of aquatic plants and algae, because nitrate and nitrite are oxidised forms of nitrogen that are readily available to plants.

In the five years to December 2011, NNN decreased at 11 monitoring sites across the city and increased at five sites (Table 3). There was a mixture of increasing and decreasing trends within catchments. For the Avon catchment, sites on the mainstem and the Horseshoe Lake tributary declined, while upper Avon tributaries (Wairarapa Stream and Riccarton Drain) increased. Similarly, sites on the lower Heathcote declined, while a site on the upper Heathcote (Templetons Road) increased. Two sites on Kaputone Stream increased, whereas sites on the Styx River and Smacks Creek declined. All other monitoring sites showed no significant trend for NNN.

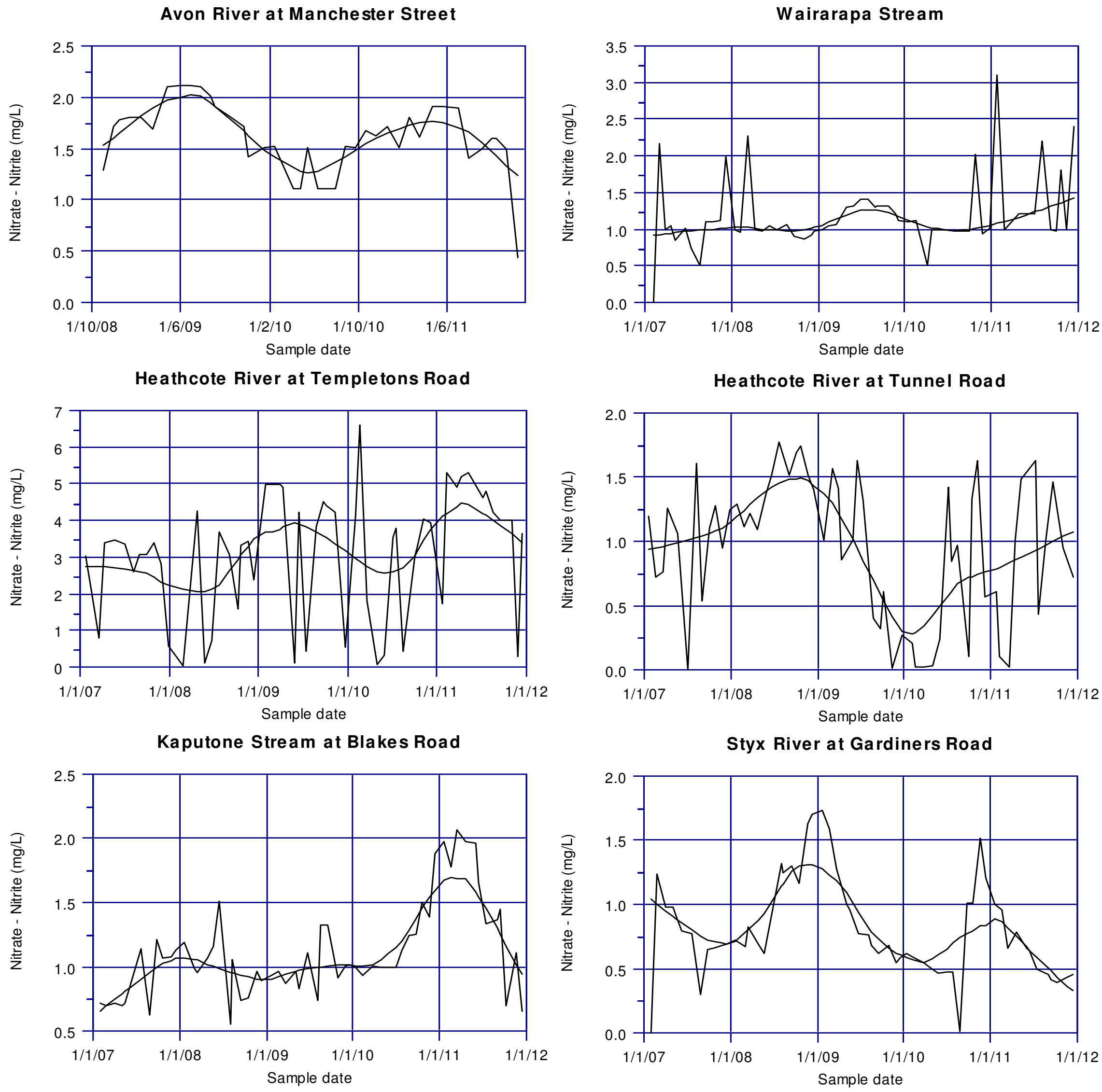

Figure 32 Examples of statistically significant (p>0.05) trends for nitrate-nitrite nitrogen over time, for sites in the Avon, Heathcote and Styx catchments between January 2007 and December 2011. LOWESS curves are fitted to the data points on each graph to display the trends.

3.5 Dissolved Reactive Phosphorus (DRP)

In combination with high nitrogen concentrations, elevated concentrations of dissolved reactive phosphorus (DRP) can lead to the proliferation of aquatic plants and algae. This dissolved form of phosphorus is readily available for plant growth.

DRP increased at two sites in the Avon River and three sites in the Styx catchment, indicating a decline in water quality (Table 3). There was a decreasing trend in DRP for the Otukaikino River monitoring site, indicating an improvement. All other monitoring sites showed no significant trend for DRP.

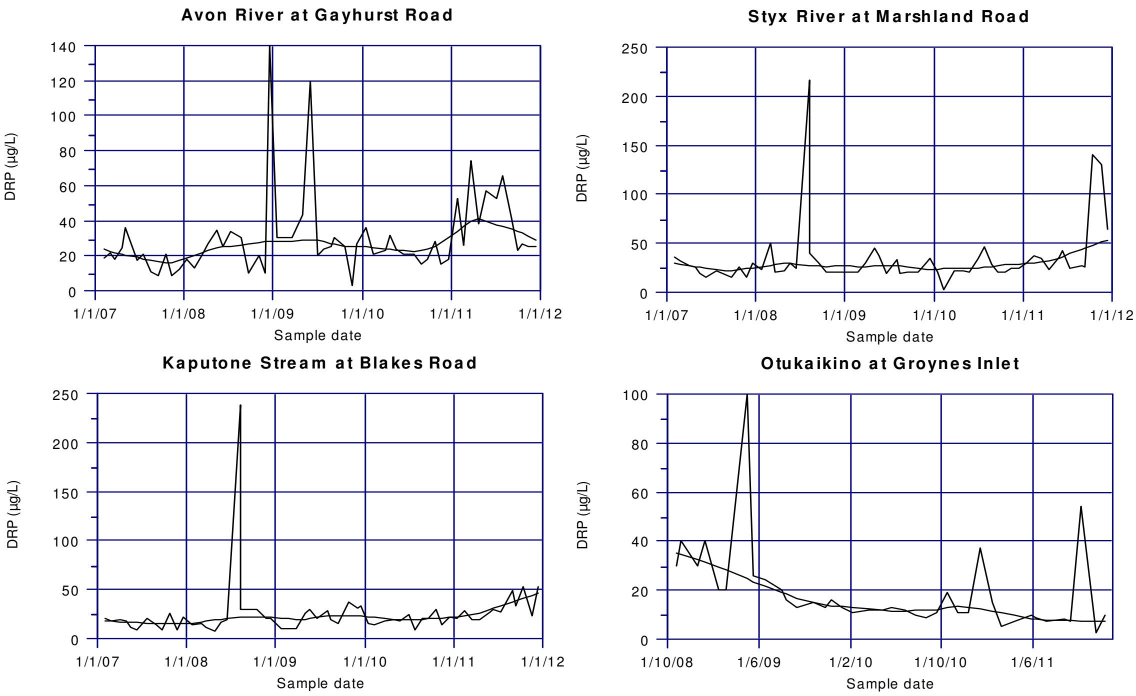

Figure 33 Examples of statistically significant (p>0.05) trends for dissolved reactive phosphorus over time, for sites in the Avon, Heathcote and Styx catchments between January 2007 and December 2011. LOWESS curves are fitted to the data points on each graph to display the trends.

4 References

ANZECC (Australian and New Zealand Environment and Conservation Council), 2000. Australian and New Zealand guidelines for fresh and marine water quality.

Biggs, B.J.F., 1988. Algal proliferations in New Zealand's shallow stony foothills-fed rivers: towards a predictive model. *Verhandlungen der Internationalen Vereinigung fűr Theoretische und Angewandte Limnologie 23:* 1405-1411.

MfE (Ministry for the Environment), 1992. Water Quality Guidelines No. 1: Guidelines for the control of undesirable biological growths in water. Ministry for the Environment, Wellington.

MfE (Ministry for the Environment), 2003. Microbiological water quality guidelines for marine and freshwater recreational areas. Ministry for the Environment, Wellington.

NIWA (2011) Time Trends – Analysis of trends and equivalence in water quality data. Software Version 3.20. http://www.niwa.co.nz/our-science/freshwater/tools/analysis

Ryan, P.A., 1991. Environmental effects of sediment on New Zealand streams: a review. *New Zealand Journal of Marine and Freshwater Research 25:* 207-221.

5 Appendices

Appendix 1: Avon catchment water quality summary statistics
Appendix 2: Heathcote catchment water quality summary statistics
Appendix 3: Styx and Otukaikino catchments water quality summary statistics
Appendix 4: Halswell catchment water quality summary statistics
Appendix 5: Water hardness results for Christchurch rivers