Water quality in the Tokomairiro catchment:
Trends and comparison with water quality standards

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Overview

Concerns have been raised in recent years over water quality in the Tokomairiro River catchment. This study looks at how water quality has changed at a range of locations in the catchment over the past 12 years and how the present water quality compares with Schedule 15 standards and Schedule 16 discharge limits in Plan Change 6A (water quality).

State of the environment (SOE) monitoring in the West Branch at SH8 suggests that water quality has remained relatively constant between 2001 and 2013, the exception being dissolved reactive phosphorus (DRP), which increased during that period. However, intensive water quality studies conducted in 1995/96, 2001/02, 2005/06 and 2011/12 have indicated that water quality has, in fact, declined in many parts of the catchment, due to land-use changes that have occurred below the long-term SOE monitoring site.

Water quality in the catchment was compared to Schedule 15 standards in 2011/12. Many sites exceeded the expected standard, in particular, with respect to their levels of the bacteria, *Escherichia coli* (*E. coli*), and the nutrient, phosphorus.

Estimates of nutrient and *E. coli* loads indicate that the West Branch is the main contributor of nitrogen (66%) and phosphorus (49%) to the lower Tokomairiro. The East Branch contributes 28% and 22%, respectively, and the Milton Waste Water Treatment Plant (Milton WWTP) contributes 7% and 29%, respectively, accounting for a much smaller proportion of nutrient loads. The Milton WWTP discharge contributes most of the load of ammoniacal nitrogen (NH_4-N) (86%) to the lower river. The East and West branches account for a similar proportion of the *E. coli* load to the lower river, while the Milton WWTP accounts for a very small proportion (>0.5%).

Overall, the upper sites of the catchment had coarse substrate and macroinvertebrate community index (MCI) scores, suggesting 'good-excellent' water quality. The other sites on the West Branch and Gorge and Salmonds creeks had high proportions of fine sediment and MCI scores that indicated 'poor' water quality.

The results of this report will be used to guide water quality strategic planning. They will also be shared with the community and other stakeholders to promote good practices to maintain and enhance water quality in and around the Tokomairiro catchment.

Technical summary

In the last 15 years, land-use intensity has increased in the Tokomairiro catchment, with the potential to affect water quality. To assess water quality in the catchment, a seven-month, intensive monitoring programme was undertaken between August 2011 and March 2012, with the results outlined in Otago Regional Council (ORC) (2012). This present report expands on the earlier report by:

- determining how water quality has changed in the catchment
- considering how existing water quality in the catchment compares with Schedule 15 standards and Schedule 16 discharge limits in Plan Change 6A
- identifying current spatial water quality patterns within the catchment and their causes.

State of the environment (SOE) monitoring in the West Branch at SH8 indicates that most water quality parameters have not changed between 2001 and 2013. The exception was dissolved reactive phosphorus (DRP), which increased significantly over the period. Intensive water quality studies in 1995/96, 2001/02, 2005/06 and 2011/12 indicate that water quality has declined in many parts of the catchment, with increases in total nitrogen (TN), total phosphorus (TP) and DRP in the West Branch at Black Bridge, and in TN and nitrate-nitrite nitrogen (NNN) at both sites in the main stem (Tokoiti and Coal Gully Road). Concentrations of DRP have also increased in the West Branch at the SH8 bridge and East Branch at Fletts Road. The amount of ammoniacal nitrogen (NH_4-N) was shown to be low, or where it was elevated, it had decreased over time at most sites. This finding suggests that, in general, effluent management has improved in parts of the catchment.

Limited results from Gorge and Salmond creeks suggest that water quality has improved, with lower TN and NNN concentrations in 2011/12 than in 2001/02. However, the concentration of DRP in Gorge Creek in 2011/12 was higher than in 2001/02.

Water quality in the catchment in 2011/12 was compared to the Schedule 15 standards in Plan Change 6A, and the following results were found:

- All sites in the West and East branches of the Tokomairiro complied with the Schedule 15 standard for NNN (0.444 mg/l). However, the site in the main stem at Coal Gully Road and Falla Burn approached the standard, while the main stem at Tokoiti, Gorge Creek and Salmond Creek exceeded it.

- Only the main stem site at Tokoiti exceeded the Schedule 15 standard for NH_4-N (0.1 mg/l).

- The Schedule 15 standard for DRP (0.026 mg/l) was exceeded in the West Branch at SH1, downstream of Moneymore 1 and 2, East Branch at SH1, and at both sites in the main stem and Gorge Creek. The 80th percentile for DRP concentration West Branch upstream of Moneymore 1 also approached this standard.

- All sites exceeded the Schedule 15 standard for *E. coli* (260 cfu/100 ml).

Estimates of nutrient and *E. coli* loads indicate that the West Branch is the main contributor of

nitrogen (66%) and phosphorus (49%) to the lower Tokomairiro, with the East Branch (28% and 22%, respectively) and the Milton WWTP (7% and 29%, respectively) accounting for a much smaller proportion of nutrient loads. The Milton WWTP discharge contributes most of the load of NH_4-N (86%) to the lower river. The East and West branches account for a similar proportion of the *E. coli* load to the lower river, while the Milton WWTP accounts for a very small proportion (>0.5%).

Physical habitat, biomonitoring and water quality surveys indicate that water and habitat quality in the upper sites (West Branch at SH8, Falla Burn and East Branch at Fletts Road) had coarse substrate and MCI scores that suggested 'good-excellent' water quality. In comparison, other sites on the West Branch and Gorge and Salmonds creeks had high proportions of fine sediment and MCI scores indicative of 'poor' water quality.

The present SOE monitoring site does not fairly reflect water quality trends in the greater Tokomairiro catchment. It is recommended that more SOE sites be established in the catchment, for example, in the lower East (SH1) and West branches (Black Bridge), and in the lower river (Tokoiti).

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1. Introduction

Land-use intensification, driven by advances in farming technology and changing markets, has been observed to have an adverse effect on water quality in a number of catchments around New Zealand (Ministry for the Environment, 2007). State of the environment (SOE) monitoring in the Tokomairiro River at West Branch state highway (SH) 8 bridge found that water quality was 'good' between 2001 and 2006, but had declined to 'fair' between 2006 and 2011. In particular, a significant increasing trend for dissolved reactive phosphorus (DRP) was noted (ORC, 2012a). However, because the existing SOE site is located upstream of intensive land use, it does not accurately reflect changes in water quality throughout the catchment.

The Tokomairiro catchment has been subject to a number of Otago Regional Council (ORC) water quality investigations in the past decade. In 2002, Milne (2002) published a memorandum summarising results from an intensive investigation between December 2001 and April 2002. This investigation found 'poor' water quality, particularly high bacteria counts, at the West Branch bridge flow site and at Tokoiti. 'Poor' water quality was also found in Gorge Creek and in the Moneymore drains (Milne 2002). In 2007, a second report was published summarising data collected between November 2005 and March 2006 (ORC, 2007). 'Poor' water quality was found in the main stem, downstream of Tokoiti, which was partly attributed to the discharge from the Milton Waste Water Treatment Plant (WWTP). 'Poor' water quality was also found in the East Branch. In response to these findings, over the past ten years, ORC's land resources team has been advising farmers on how to improve environmental management.

The Milton WWTP is a large point-source discharge into the main stem of the Tokomairiro River, located about 1.5 km upstream of the Tokoiti monitoring site. In 2009, a new consent was granted to the Clutha District Council to operate the plant. ORC's audit of the facility in 2012 found that, in general, the quality of the discharge had improved, particularly as to *Escherichia coli* (*E. coli*) concentrations.

In response to concerns over declining water quality in the catchment, a seven-month, intensive water quality monitoring programme was undertaken between August 2011 and March 2012, with the results outlined in ORC (2012b). This report expands on the earlier ORC (2012) report by:

- determining how water quality has changed in the Tokomairiro catchment
- considering how existing water quality in the catchment compares with Schedule 15 standards and Schedule 16 discharge limits in Plan Change 6A (water quality)
- identifying current spatial water quality patterns within the catchment and their causes.

2. Background

2.1 The Tokomairiro catchment

The Tokomairiro River, located about 48 km south-west of Dunedin, has a catchment area of 403 km^2.

The catchment has indistinct boundaries, with no dividing mountain ranges between it and neighbouring catchments. It is bordered to the east by tributaries of the Waihola-Waipori wetland complex (including Meggat Burn and Boundary Creek) and a number of coastal tributaries (including Akatore Creek) (Figure 2.1). The Waitahuna River borders the catchment to the north, while, to the west, it is bordered by tributaries of Lake Tuakitoto (such as Lovells Creek) and Rocky Valley Creek, which enters the Pacific Ocean south of Toko Mouth (Figure 2.1).

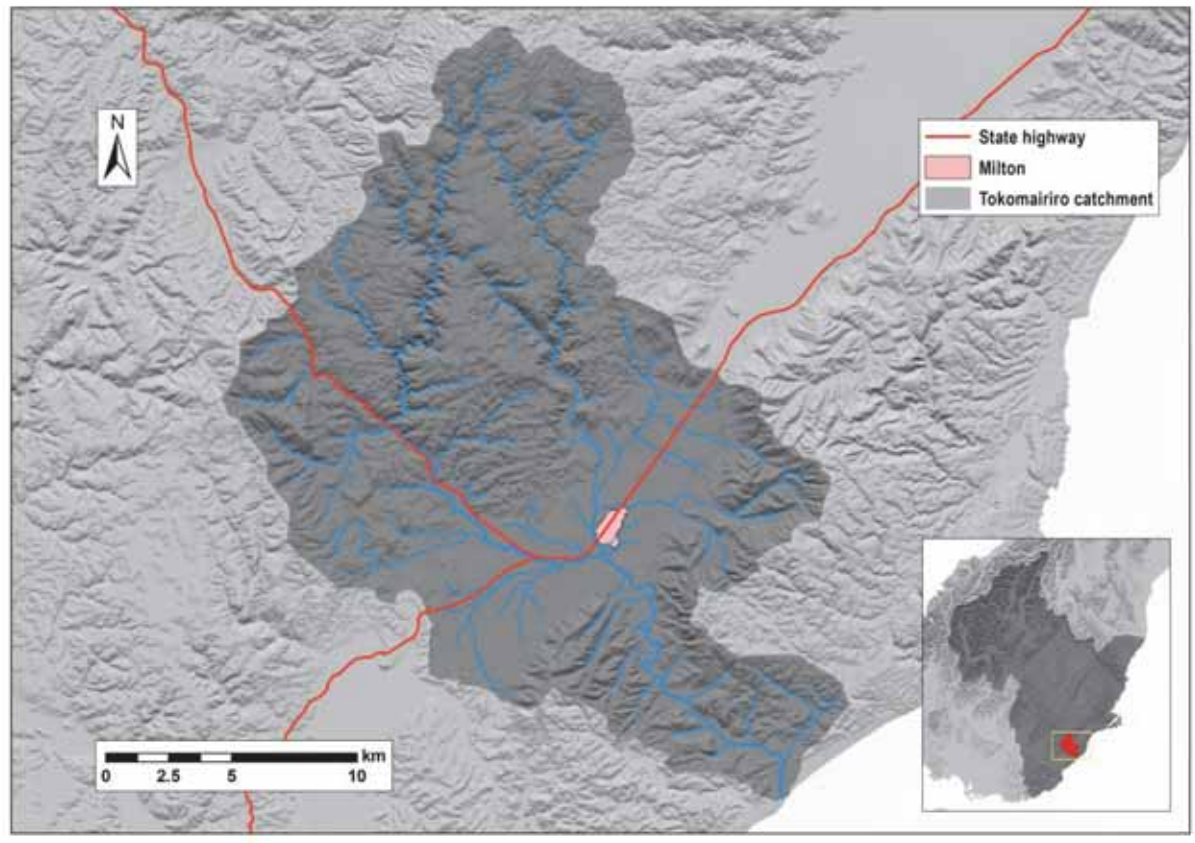

Figure 2.1 The Tokomairiro catchment

The Tokomairiro River splits into two branches (East and West), downstream of state highway (SH) 1, before flowing for 21 km into the sea. The East Branch has a catchment area of 139 km^2, while the West Branch drains a catchment of 201 km^2.

2.1.1 Vegetation

Before European times, the Tokomairiro Plain would have been a wetland complex. However, the plain has been drained to allow for pasture development. To facilitate farming on the heavy peat soils, tile-mole drains are used extensively.

The catchment is dominated by high- and low-producing grasslands on the Tokomairiro Plain and much of the surrounding hill country (Figure 2.2). There are also substantial areas of exotic forestry, with large tracts in the upper reaches of both branches and in the coastal ranges (Figure 2.2). Several small tracts of native bush are scattered throughout the catchment.

2.1.2 Land use

Sheep and beef farming is the dominant land use, although there is a substantial amount of dairying on the Tokomairiro Plain (Figure 2.2). There are also large areas of forestry. Both branches flow out of Berwick Forest, while the lower river is flanked by forestry, and some tributaries of the East Branch (including Narrowdale Stream) flow from Otago Coast Forest. There is also a small amount of conservation land (56 ha).

2.1.3 Point-source discharges

The Milton WWTP discharges into the main stem of the Tokomairiro River at the confluence of the East and West branches. The Clutha District Council has two discharge permits associated with the operation of the plant. Resource Consent 2007.090.V1 allows for the discharge of up to 1.625 m^3 of treated waste water per day into the Tokomairiro River, while Resource Consent 2002.369 allows up to 9.150 m^3 of untreated waste water per day to be discharged into the river during heavy rainfall events.

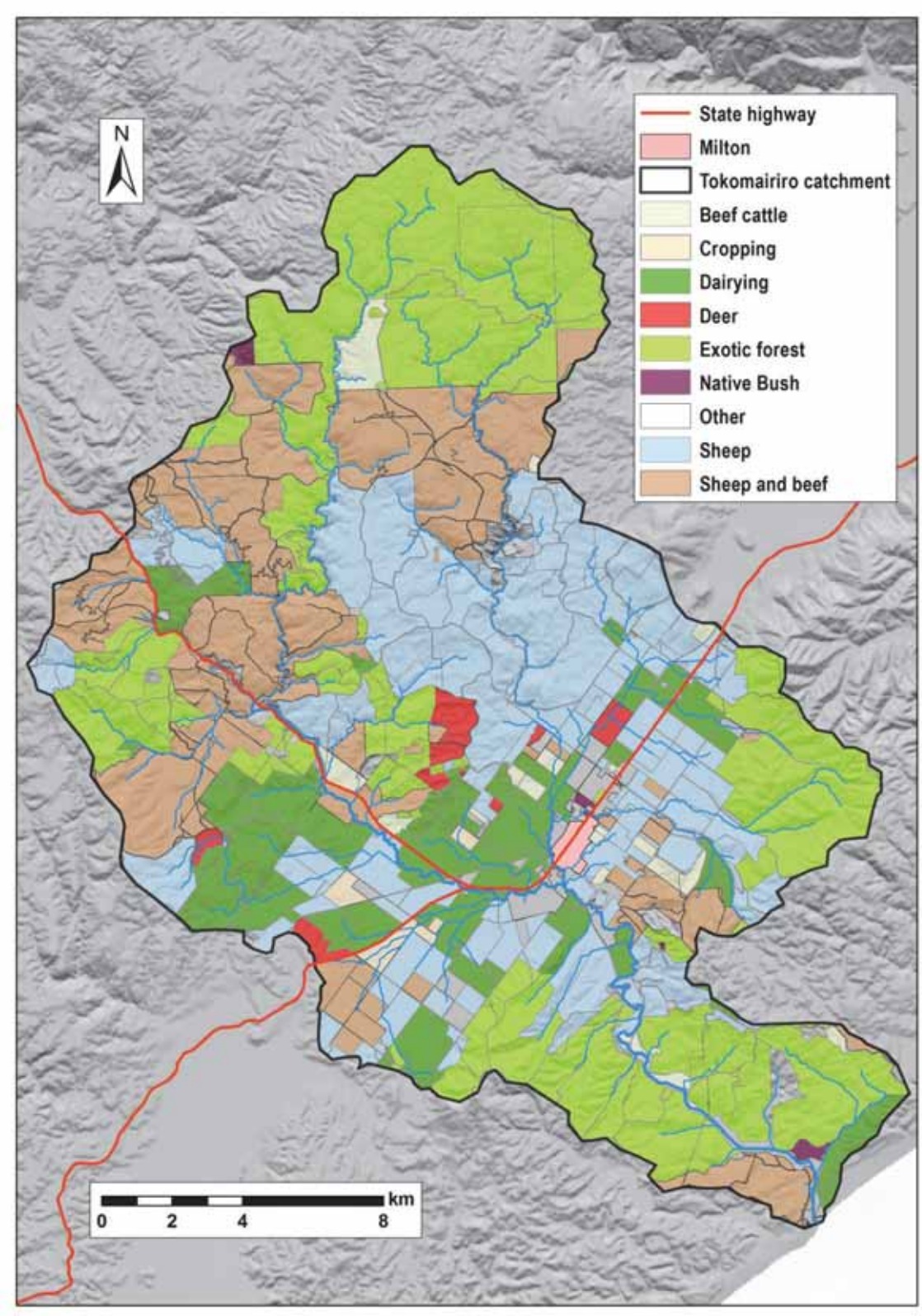

Figure 2.2 Land use in the Tokomairiro catchment

2.2 Natural values of the Tokomairiro

Thirteen fish species are present in the catchment, of which 12 are native. The only introduced fish is brown trout. Of the native fish, six species are listed as 'endangered', with the most critical being Eldon's galaxias, classified as 'nationally endangered', and the Clutha flathead galaxias, classified as 'nationally vulnerable'. The longfin eel, lamprey, inanga and redfin bully are listed as 'declining' (Table 2.1).

The upper Tokomairiro River main stem (including East and West branches) is listed in Schedule 1A of the Water Plan, with eels and trout listed as 'significant ecosystem values'. The area is also considered to be an important habitat for trout spawning and juvenile trout (ORC, 2004). An unnamed tributary of Fishers Stream, a tributary of the East Branch (NZTM E1360826 N4902777) and an unnamed tributary of the West Branch (NZTM E1359524 N4903775) are listed as providing significant habitat for Eldon's galaxiid. An unnamed tributary of the Tokomairiro River West Branch, also known as Nuggety Gully, provides significant habitat for Clutha flathead galaxias (Table 2.1).

Table 2.1 Fish species present within the Tokomairiro catchment (Sources: New Zealand Freshwater Fish Database, ORC records and Fish and Game Otago records). Conservation status is based on Allibone *et al*. (2010).

Common name	Species name	Conservation status
Brown trout	*Salmo trutta*	Introduced and naturalised
Longfin eel	*Angullia dieffenbachii*	Declining
Shortfin eel	*Angullia australis*	Not threatened
Lamprey	*Geotria australis*	Declining
Common smelt	*Retropinna retropinna*	Not threatened
Inanga	*Galaxias maculatus*	Declining
Eldon's galaxias	*Galaxias eldoni*	Nationally endangered
Clutha flathead galaxias	*Galaxias* sp. D	Nationally vulnerable
Redfin bully	*Gobiomorphus huttoni*	Declining
Common bully	*Gobiomorphus cotidianus*	Not threatened
Upland bully	*Gobiomorphus breviceps*	Not threatened
Black flounder	*Rhombosolea retiaria*	Not threatened
Yellow-eyed mullet	*Aldrichetta forsteri*	Not threatened

Figure 2.3 shows the distribution of freshwater fish within the catchment. Longfin eels are widely distributed in the West Branch and have been recorded from the lower East Branch and lower reaches of the main stem. Shortfin eels have been recorded near the mouth and at the SH8 bridge in the West Branch.

Eldon's galaxias is found in small tributaries in the upper East and West branches. Clutha flathead galaxias have been recorded in two tributaries of the West Branch: Manuka Stream and Nuggety Gully. Lampreys have been recorded in both the East and West branches.

Black flounder and common smelt have been collected in the lower river, while inanga and yellow-eyed mullet have been recorded in the main stem, almost as far upstream as the confluence.

Common bullies have been found upstream as far as the lower reaches of both branches, while redfin bullies have been recorded in the lower reaches of the East Branch. Upland bullies have been recorded in various sites in the lower East Branch and at some sites in the Falla Burn and at the SH8 bridge in the West Branch catchment.

Brown trout are distributed throughout much of the catchment.

2.3 Recreational values

The Tokomairiro River supports a brown trout fishery, and angling occurs in the West Branch and the lower reaches, where trout are common. A user survey for the 2007/2008 fishing year estimated that there were 520 ± 320 angler days on the river. This number is well down on the estimated 4090 ± 1680 days in 2001/2002, and the 850 ± 270, estimated for the 1994/1995 fishing season (Urwin, 2009).

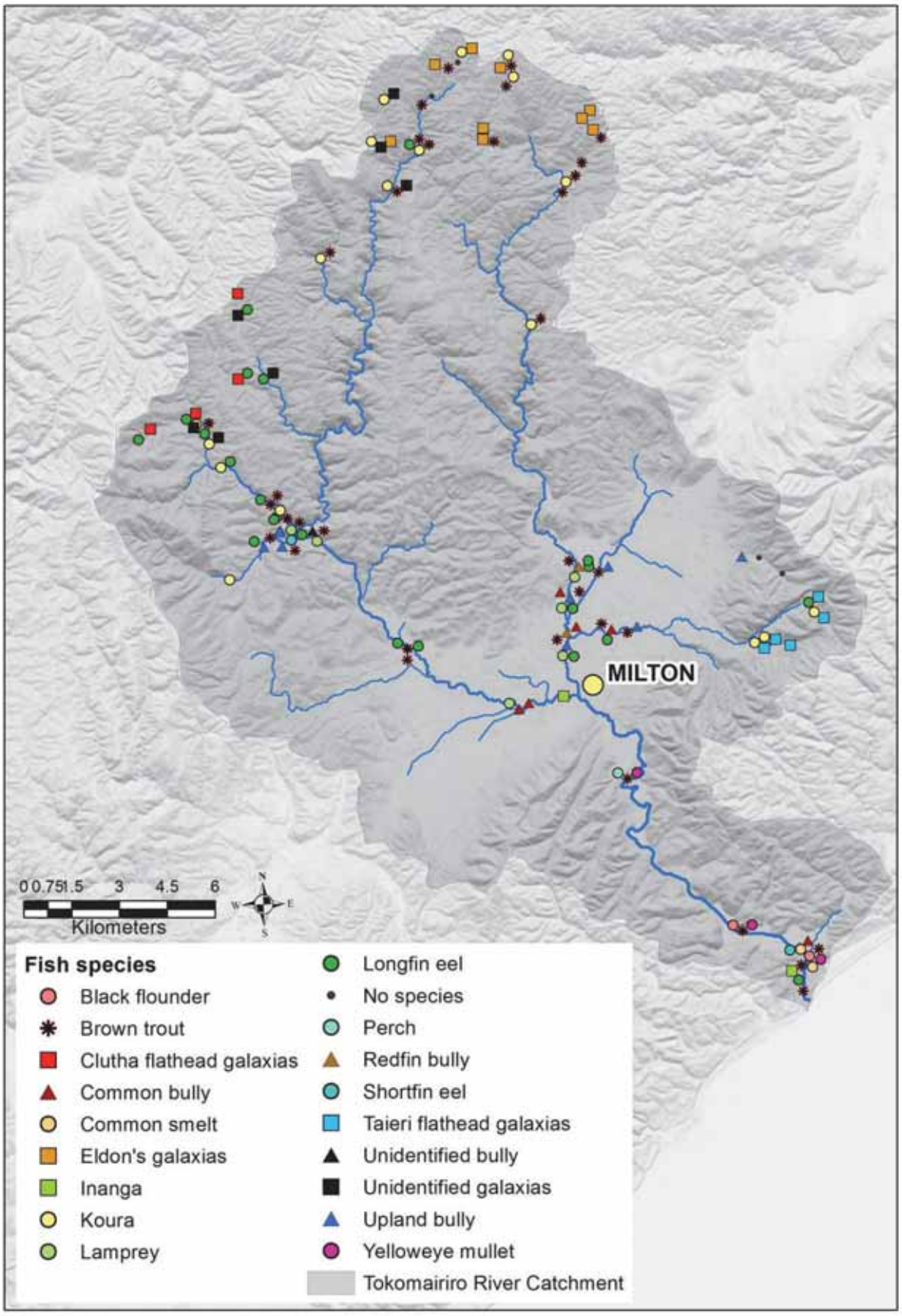

Figure 2.3 Distribution of freshwater fish within the Tokomairiro catchment, based on the New Zealand Freshwater Fish Database (downloaded 3 May 2013)

3. Regional planning

3.1.1 Water quality guidelines – Plan Change 6A (water quality)

Plan Change 6A, notified on 31 March 2012, sets out numerical water quality standards for all catchments in the Otago region (Schedule 15), as well as establishing limits for all discharges to lakes, rivers, wetlands and drains in two discharge limit areas (Schedule 16). The Tokomairiro catchment is in 'receiving water group 1'. Table 3.1 outlines the numerical water quality standards for this group.

The receiving water standards, outlined in Table 3.1, are applied as 5-year, 80th percentiles when flows are at or below median flow (0.44 m^3/s), with flows in the catchment set at the gauging site in the West Branch at the SH8 bridge.

The discharge limits outlined in Table 3.2 are to be applied when flows in the West Branch at the SH8 bridge are below median flow (0.44 m^3/s).

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

	Nitrate-nitrite nitrogen	Dissolved reactive phosphorus	Ammoniacal nitrogen	*Escherichia coli*	Turbidity
Numerical standard	0.444 mg/l	0.026 mg/l	0.1 mg/l	260 cfu/100 ml	5 NTU
Timeframe	31 March 2012	31 March 2012	31 March 2012	31 March 2025	31 March 2012

Table 3.2 Discharge limits for the Tokomairiro catchment. These limits come into effect on 1 April 2020.

	Nitrate-nitrite nitrogen	Dissolved reactive phosphorus	Ammoniacal nitrogen	*Escherichia coli*
Numerical standards	3.6 mg/l	0.045 mg/l	0.2 mg/l	550 cfu/100 ml

4. Methods

4.1 Water quality assessment

Between August 2011 and April 2012, 15 sites in the catchment (Figure 4.1) were sampled fortnightly, using standard collection protocols (APHA, 2006), with 'grab' samples supplying the physical, chemical and microbiological parameters. These parameters included total phosphorus (TP), total nitrogen (TN), nitrite-nitrate nitrogen (NNN), ammoniacal nitrogen (NH_4-N), dissolved reactive phosphorus (DRP), *Escherichia coli* (*E. coli*) and suspended solids (SS).

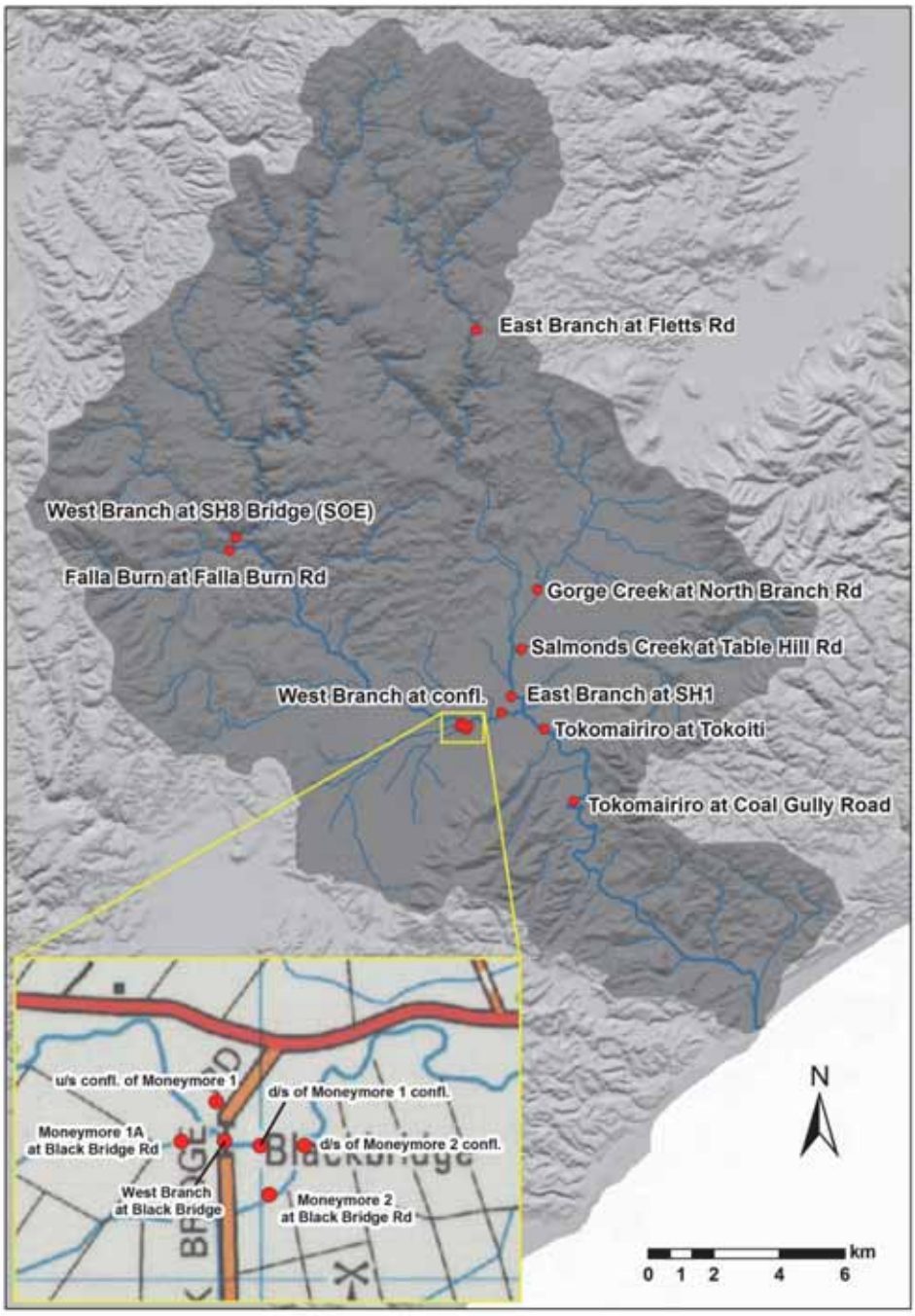

Figure 4.1 The Tokomairiro River catchment and the water quality sampling sites

4.2 Hydrological information

As well as monitoring water quality, permanent flow was monitored by establishing permanent flow sites, or temporary flow recorders, at most sites (Table 4.1 and Table 4.2). For sites with no flow recording, virtual flows were generated. A 'virtual flow' or 'synthetic flow' is created by spot-gauging a site over a period of time and carrying out a regression with a nearby permanent or long-term flow site.

Table 4.1 Flow statistics for the sites used during this study during the 2011/12 hydrological year

Site name	Upstream catchment area (ha)	Minimum flow (m^3/s)	Min 7-day low flow (m^3/s)	Catchment yield at min. 7-day low flow (l/s/ha)	Median flow (m^3/s)	Mean flow (m^3/s)
West Branch at SH8 bridge	6851	0.102	0.120	0.018	0.436	0.568
Falla Burn at Falla Burn Road	1934	0.002	0.003	0.002	0.045	0.118
West Branch at u/s confluence of Moneymore 1	15323	0.126	0.147	0.010	0.580	1.126
Moneymore 1 at Black Bridge Road	1897	0.000	0.000	0.000	0.007	0.175
West Branch at d/s of Moneymore 1 confluence	17220	0.126	0.147	0.009	0.587	1.301
Moneymore 2 at Black Bridge Road	1173	0.000	0.000	0.000	0.005	0.028
West Branch at d/s of Moneymore 2 confluence	18395	0.126	0.147	0.008	0.592	1.329
West Branch at confluence	19504	0.133	0.155	0.008	0.628	1.408
Main stem at Tokoiti	33652	0.534	0.629	0.019	2.288	2.928
Main stem at Coal Gully Road	35086	0.562	0.662	0.019	2.408	3.081
East Branch at SH1 bridge	13530	0.239	0.282	0.021	1.022	1.283
Salmond Creek at Table Hill Road	2021	0.001	0.002	0.001	0.019	0.119
Gorge Creek at North Branch Road	3625	0.003	0.006	0.002	0.057	0.357
East Branch at Fletts Road	3576	0.098	0.132	0.037	0.328	0.671

Table 4.2 Long-term flow statistics for the Tokomairiro at West Branch bridge site (1981-2012)

Site name	Minimum flow (m^3/s)	7-day MALF (m^3/s)	Catchment yield at 7-day MALF (l/s/ha)	Median flow (m^3/s)	Mean flow (m^3/s)
West Branch at SH8 bridge	0.044	0.162	0.024	0.450	0.786

4.3 Assessment of the physical habitat

Assessments of fine sediment were conducted at all sites in December 2011, using the methods of Clapcott *et al.* (2011).

Proportion of fine sediment

The proportion of the bed covered by fine sediment was assessed using 'Sediment Assessment Method 2' (instream visual estimate of % sediment cover (Clapcott *et al*. (2011)). Five transects were established in a 30 m reach consisting of the run habitat. At the furthest transect downstream, the proportion of fine sediment (defined as 'sediment less than 2 mm in diameter') was estimated at four points along each transect using an underwater viewer.

Shuffle Index

In the same reach, three Shuffle indices were completed using 'Sediment Assessment Method 5' (resuspendible sediment (Shuffle Index) of Clapcott *et al*. (2011)). This method involves placing a white marker in the stream bed, moving 3 m upstream, disturbing the sediment vigorously and then assigning a rank of 1-5, depending on how long the sediment took to clear (see Clapcott *et al.* 2011 for more detail).

Sediment depth

Sediment depth was assessed using 'Sediment Assessment Method 6' (sediment depth of Clapcott *et al*. (2011)). In the 30 m reach, five randomly distributed transects were established at four locations on each transect. A pipe was inserted as far as practicable into the stream bed, and its depth was recorded. This procedure was repeated along each transect.

4.4 Biological assessment

4.4.1 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). These 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-two years to complete their life-cycle). Thus, the presence or absence of such taxa can provide significant insight into long-term changes in water quality.

Macroinvertebrate communities were sampled in 14 streams in December 2011. 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 to be processed. Following Protocol P1, 'semi-quantitative coded abundance',

macroinvertebrate samples were coded into one of five 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 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, high species richness may be considered 'good'; however, mildly impacted or polluted rivers, with slight nutrient enrichment, can have higher species richness than unaffected, 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. As these groups of insects are often the most sensitive to organic pollution, low numbers might indicate a polluted environment. Comparing the percentage of EPT species to the total number of species found at a site can indicate 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, dividing the total by the number 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 4.4.1).

- '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 classes proposed by Stark *et al.* (2001) (Table 4.4.1).

Table 4.4.1 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

4.4.2 Fish communities

Fish populations were sampled at six sites. Two sites were unable to be fished as the water level was too high. Each site was three-pass electric fished, using a pulsed DC Kainga EFM300 backpack electro-shocker. Each pass was undertaken in a downstream direction. A 15-minute rest period between electric-fishing passes allowed the 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 kept separate, counted and then released after the third electric fishing pass. At each site, native fish were identified and counted, while trout were counted, weighed in grams and measured from the tip of the snout to the caudal fork (total length).

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 4.4.1.

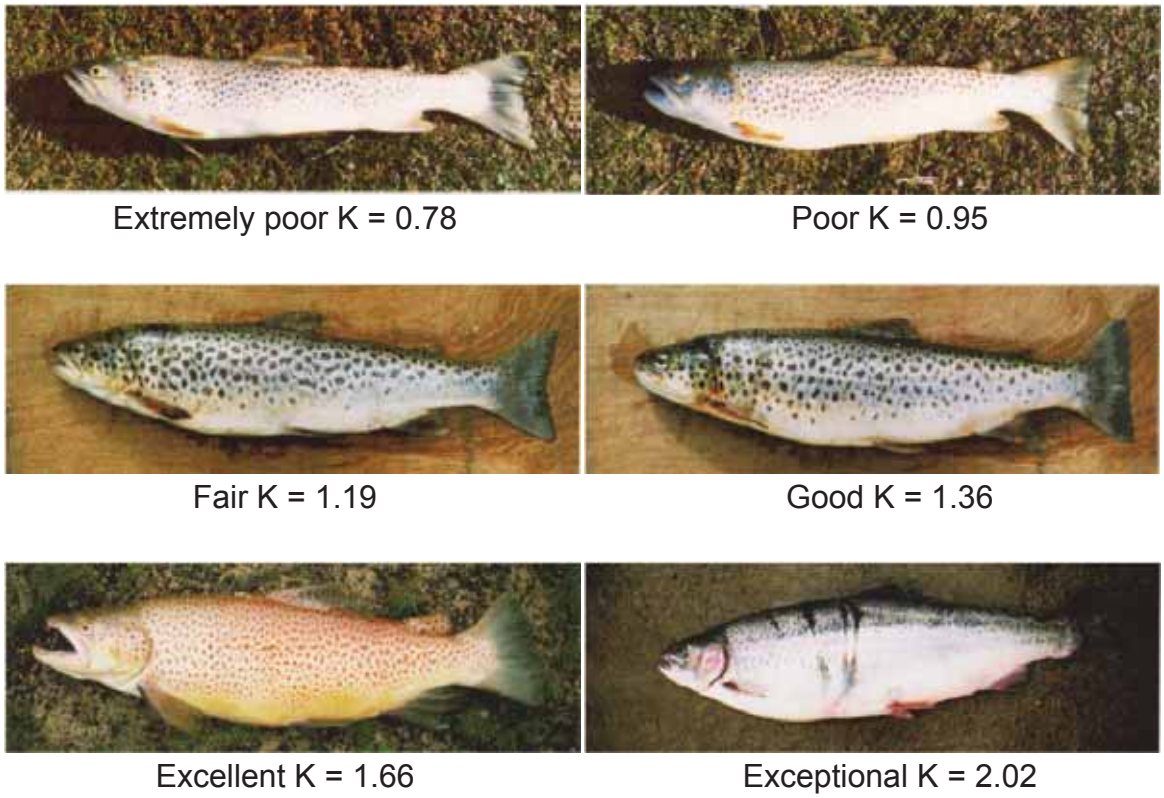

Figure 4.4.1 Photo representation of trout with different condition factors (Barnham and Baxter, 1998)

4.4.3 Fish density classes

Brown trout and native fish density was 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 devised 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), using the New Zealand Freshwater Fish Database and data collected by ORC and Fish and Game Otago. All sites were ranked on fish density per square metre (total fish density, brown trout density) and then broken into quartiles.

5. Long-term water quality monitoring results

5.1 State of the environment monitoring

The SOE monitoring network includes one site in the Tokomairiro catchment: West Branch at SH8 bridge. Analysis of the results of SOE monitoring data collected between August 2002 and April 2013 found no trend in most water quality parameters (Table 5.1.1). The exception was DRP, for which a significant increasing trend was detected (Figure 5.1.1).

When interpreting these results, it should be kept in mind that the existing SOE monitoring site (at the SH8 bridge over the West Branch) is located upstream of the Tokomairiro Plains, where much of the intensive farming is located (Figure 2.2). As such, trends in water quality at this site are unlikely to be representative of water quality trends elsewhere in the catchment.

Table 5.1.1 **Long-term (2002-2013) trends in water quality parameters at the West Branch at SH8. Statistics are flow-adjusted seasonal Kendall tests. Significant trends are highlighted in red.**

Parameter	Units	*Z*	*P*	Trend
TN	mg/L	0.44	0.66	-
NNN	mg/L	-0.52	0.6	-
TP	mg/L	0.26	0.79	-
DRP	mg/L	2.44	0.01	Increasing
SS	mg/L	0.09	0.93	-
Turbidity	NTU	1.61	0.11	-
E. coli	cfu/100 mL	0.96	0.34	-

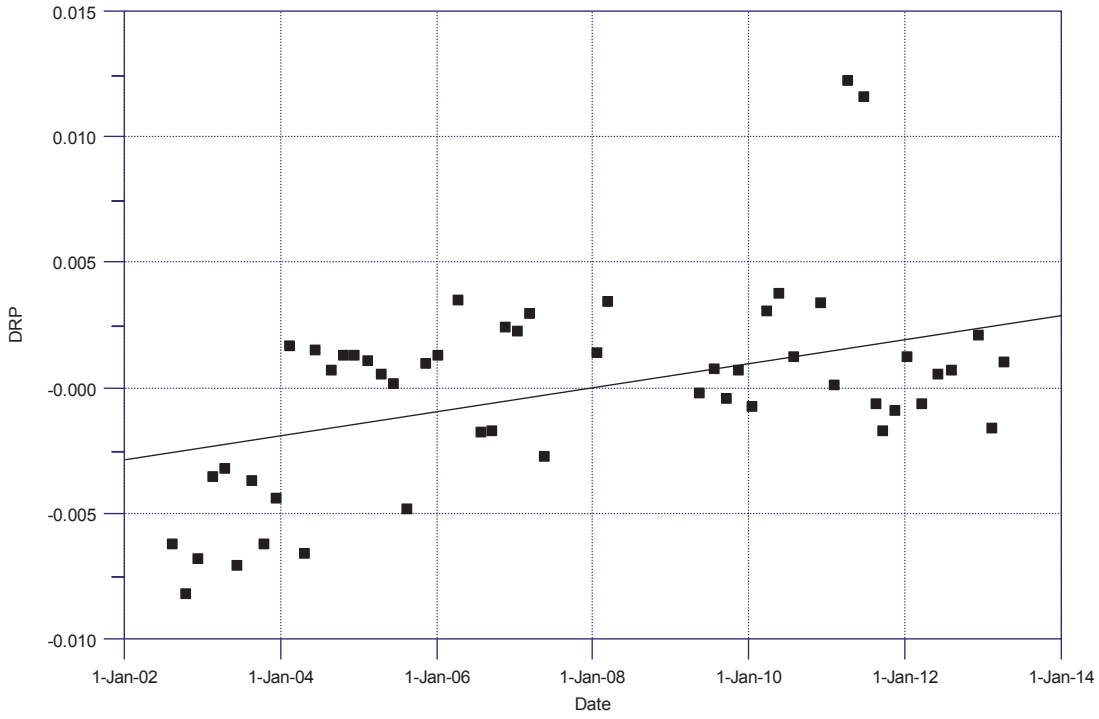

Figure 5.1.1 Long-term trend in flow-adjusted dissolved reactive phosphorus concentrations between 2002 and 2013. Statistics are outlined in Table 5.1.1.

5.2 Catchment water quality study results

As well as SOE monitoring conducted at the West Branch at the SH8 bridge site, four other catchment studies have been carried out in the catchment: February 1995-May 1996, December 2001-April 2002, July 2006-March 2007, and the most recent study (August 2011-April 2012, ORC, 2012b). The next section considers how water quality parameters have changed through time at individual, and among different, sites. The measured data at each site are also compared to Schedule 15 standards in Plan Change 6A (as per Table 3.1). Only water quality data collected when flows were below the reference flow for the catchment (440 l/s) are presented to allow comparison between sampling occasions and with the standards in Plan Change 6A (which are to be applied when flows are less than median flow).

5.2.1 Nitrogen

Total nitrogen (TN)

TN concentrations remained relatively constant at the upper sites in the branches (West Branch at SH8 bridge and East Branch at Fletts Road) between 2001 and 2012. This is consistent with the lack of a trend for TN found in continuous SOE monitoring conducted in the West Branch at SH8 bridge in Section 5.1. However, downstream, on the West Branch at Black Bridge, and at the two main stem sites (Tokoiti and Coal Gully Road), TN has

increased between 2006/07 and 2011/12 (Figure 5.2.1). Data collected from Gorge and Salmond creeks suggest that TN concentrations in 2011/2012 were lower than those measured in 2001/2002 (Figure 5.2.1).

As expected, TN concentrations were higher at downstream sites than at the upper sites, with the highest concentrations recorded in Gorge and Salmond creeks (Figure 5.2.1).

Nitrate-nitrite nitrogen (NNN)

Concentrations of NNN have remained relatively constant in the sites in the West Branch (SH8 bridge and Black Bridge) between 1995/96 and 2011/2012, and in the East Branch at Fletts Road, between 2001/02 and 2011/12 (Figure 5.2.2). This is consistent with the lack of trend found for NNN during continuous SOE monitoring of the West Branch at SH8 bridge, discussed in Section 5.1. However, at the Tokoiti main stem site, NNN concentrations during the 2011/12 period were higher than on previous sampling occasions (Figure 5.2.1). Similarly, these data suggest that NNN concentrations at Coal Gully Road in 2011/12 were higher than in 2006/07 (Figure 5.2.2). Data collected from Gorge and Salmond creeks suggest that NNN concentrations in 2011/2012 were lower than those measured in 2001/02 (Figure 5.2.2).

As expected, NNN concentrations were higher at downstream sites than at upper sites, with the highest concentrations recorded in Gorge and Salmond creeks (Figure 5.2.2). NNN concentrations at all sites in the two branches were below the standard in Schedule 15 of Plan Change 6A, as were most readings in the main stem (Figure 5.2.2). The Schedule 15 values are intended to be applied as the 5-year 80th percentile value of samples taken when flows are below the reference flow (440 l/s at the West Branch at SH8 bridge recorder in the case of the Tokomairiro). Therefore, all sites in the two branches or main stem of the Tokomairiro River probably comply with the standard. However, while Gorge Creek exceeded the standard on most sampling occasions, the reduction in concentrations observed in Salmond Creek between 2001/02 and 2011/2012 means that it too probably complies with the standard (Figure 5.2.2).

Ammoniacal nitrogen (NH_4-N)

In most surface waters, elevated concentrations of NH_4-N usually reflect inputs of effluent from waste water treatment systems (either municipal or agricultural). NH_4-N consists of the non-ionic form (free ammonia, NH_3) and ionic form (ammonium, NH_4^+). The ratio of these forms is dependent on water temperature and pH, and the non-ionic form is highly toxic to aquatic life. Concentrations of NH_4-N were found to be very low at the two upper sites (West Branch at SH8 bridge and East Branch at Fletts Road) (Figure 5.2.3). NH_4-N concentrations at most other sites have declined. The most notable decline occurred at the main stem site at Tokoiti (Figure 5.2.3), probably because of improvements to the Milton WWTP.

As expected, concentrations of NH_4-N were higher at downstream sites than at upper sites, with the highest concentrations recorded in the main stem at Tokoiti (Figure 5.2.1). Concentrations of NH_4-N at most sites were below the Schedule 15 standard in Plan Change 6A, with the exception of the main stem at Tokoiti (Figure 5.2.3). The decline in NH_4-N in the main stem at Tokoiti observed between 1995/96 and 2011/2012 means that it too probably complies with the standard (Figure 5.2.2).

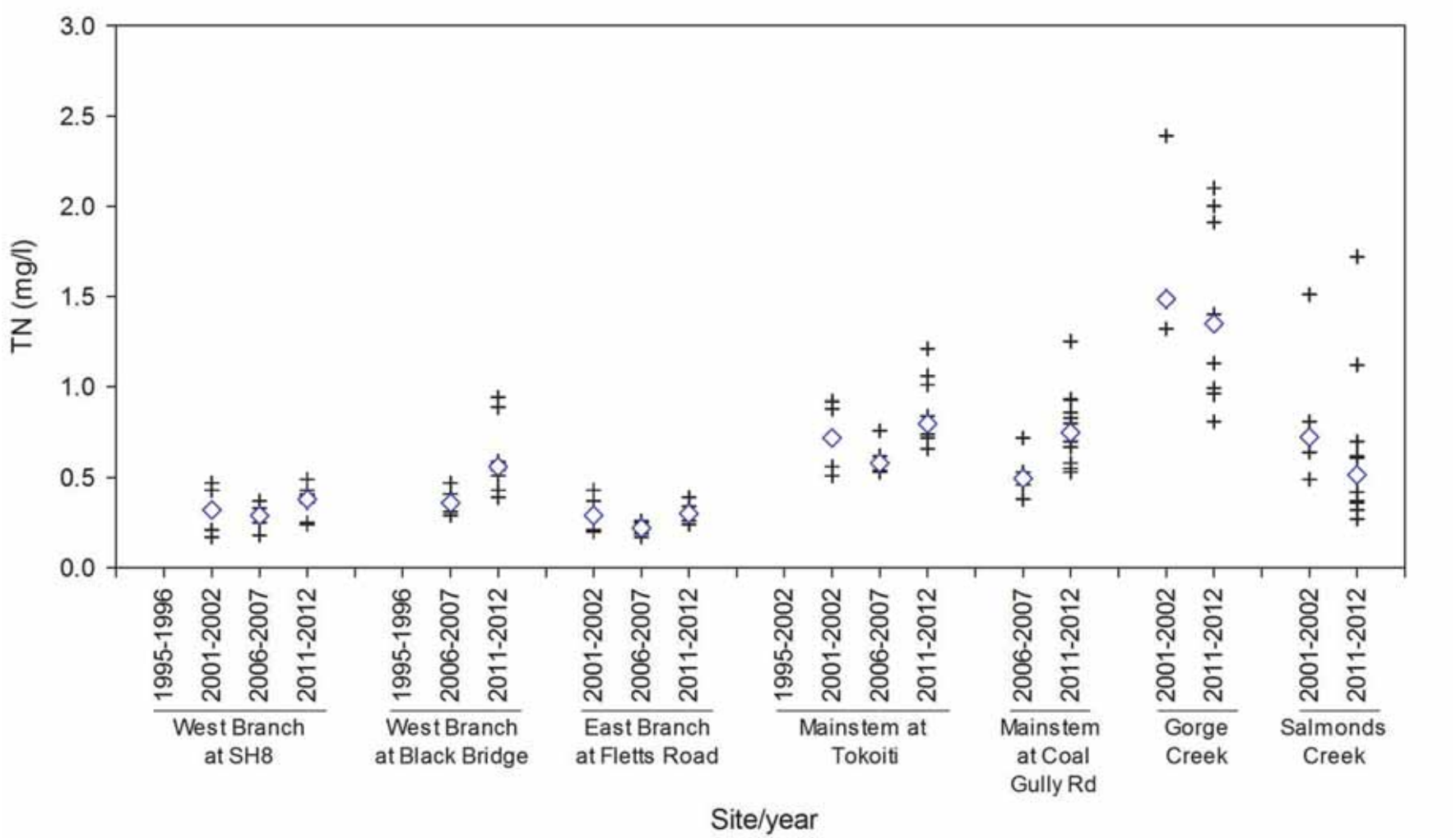

Figure 5.2.1 Total nitrogen concentrations at seven sites in the Tokomairiro catchment when flows are below the reference flow (440 l/s). Black crosses represent individual sampling occasions, while dark blue diamonds represent median values for each sampling period.

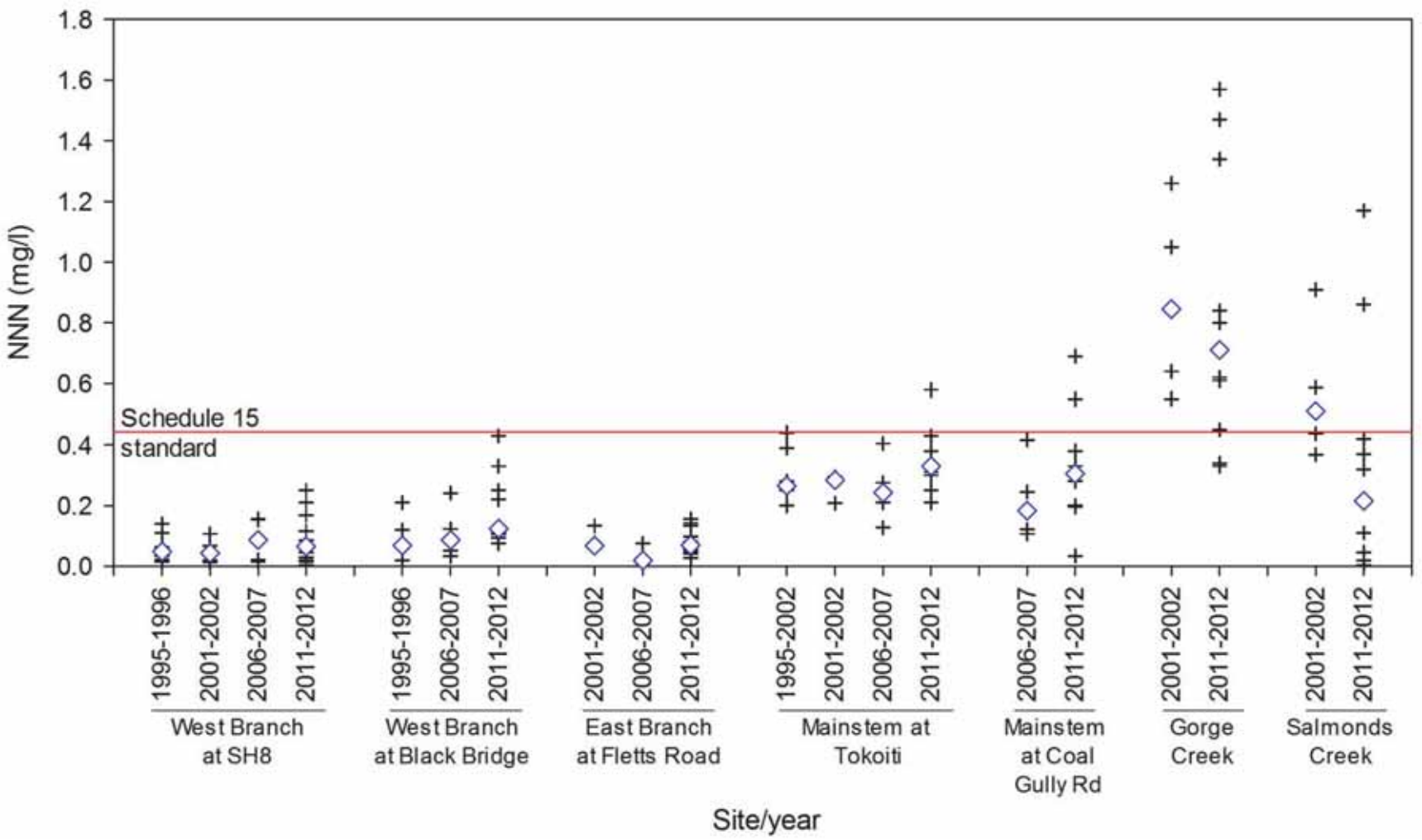

Figure 5.2.2 Nitrate-nitrite nitrogen concentrations at seven sites in the Tokomairiro catchment when flows are below the reference flow (440 l/s). Black crosses represent individual sampling occasions, while dark blue diamonds represent median values for each sampling period. The red line is the Plan Change 6A Schedule 15 standard (Table 3.1).

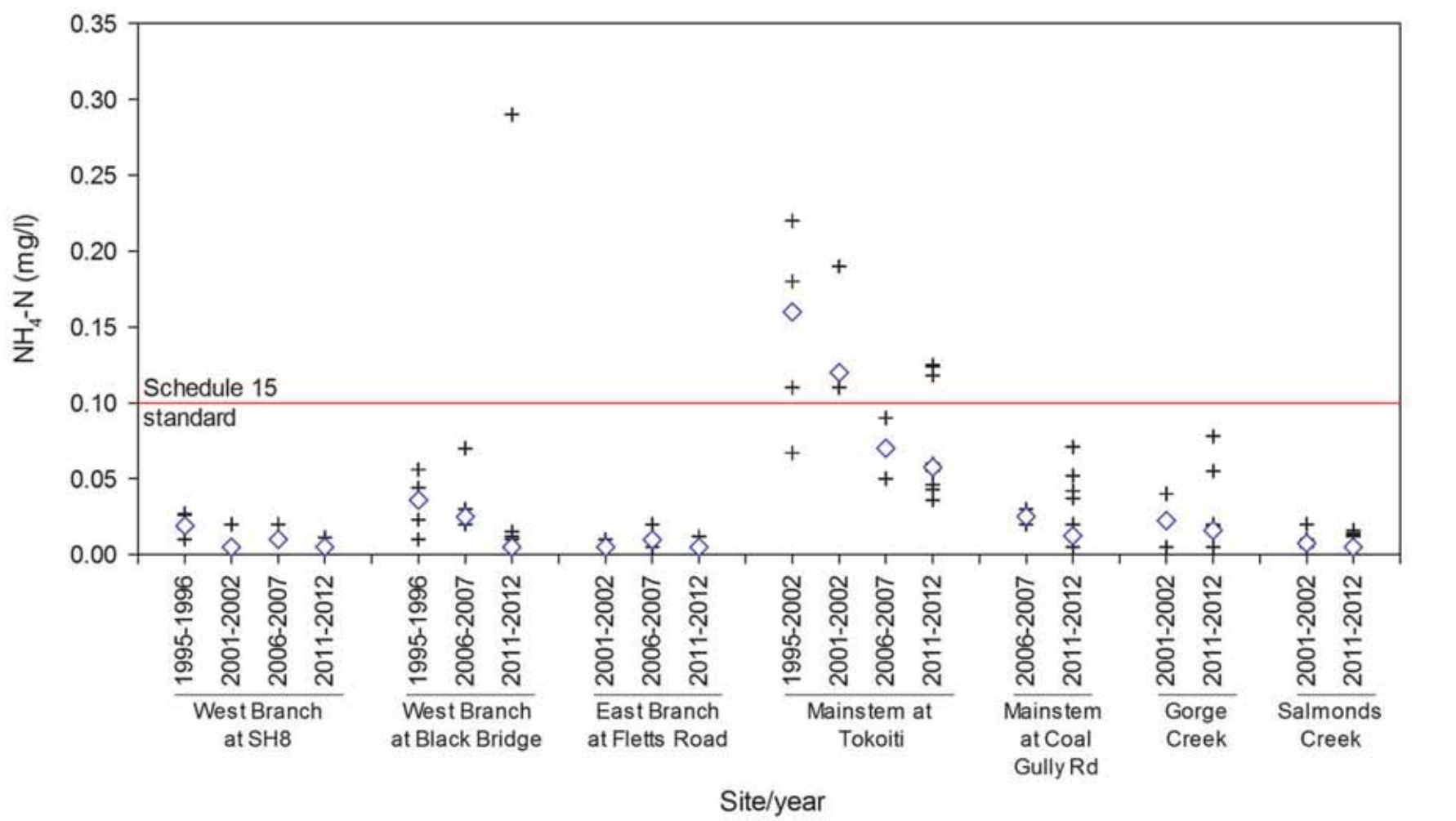

Figure 5.2.3 Ammoniacal nitrogen concentrations at seven sites in the Tokomairiro catchment when flows are below the reference flow (440 l/s). Black crosses represent individual sampling occasions, while dark blue diamonds represent median values for each sampling period. The red line is the Plan Change 6A Schedule 15 standard (Table 3.1).

5.2.2 Phosphorus

Total phosphorus (TP)

TP concentrations were consistently low at the upper sites (Figure 5.2.4). In the case of the West Branch at SH8, this result is consistent with the lack of trend in TP found by analysing the continuous SOE monitoring (Section 5.1). TP concentrations in the West Branch at Black Bridge increased between 2006/07 and 2011/12 (Figure 5.2.4). TP concentrations at main stem sites were higher than at upper sites (Figure 5.2.4). TP concentrations in the main stem at Tokoiti showed little trend between 1995/96 and 2011/12 (Figure 5.2.4).

Data collected from Gorge and Salmond creeks suggest that TP concentrations in 2011/2012 were lower than those measured in 2001/02 (Figure 5.2.4).

Dissolved reactive phosphorus (DRP)

DRP concentrations in the West Branch at SH8 bridge in 2006/07 and 2011/12 were higher than in 1995/96 and 2001/02, although the concentrations were still low (Figure 5.2.2). This is consistent with the increasing trend in DRP found by analysing the continuous SOE monitoring of the West Branch at SH8 bridge (Section 5.1). There was a much stronger trend in DRP at the West Branch at Black Bridge between 1995/96 and 2011/12 (Figure 5.2.2). There was also an increase in DRP in the East Branch at Fletts Road between 2001/02 and 2006/07. Concentrations of DRP at the two main stem sites (Tokoiti and Coal Gully Road) were much higher than those at the upper sites on all sampling occasions (Figure 5.2.2). Data collected from Gorge Creek suggest that DRP concentrations in 2011/12 were higher than in 2001/02, while concentrations in Salmond Creek were similar in 2001/02 and 2011/12 (Figure 5.2.2).

DRP concentrations at all sites in the West and East branches were below the Schedule 15 standard (Figure 5.2.2). In contrast, the Tokoiti site in the main stem exceeded the standard for DRP on all occasions, while the Coal Gully Road site exceeded the standard for DRP on most occasions. DRP concentrations in Gorge Creek exceeded the standard on most occasions, while concentrations in Salmond Creek in 2011/12 were below the standard on all occasions (Figure 5.2.2).

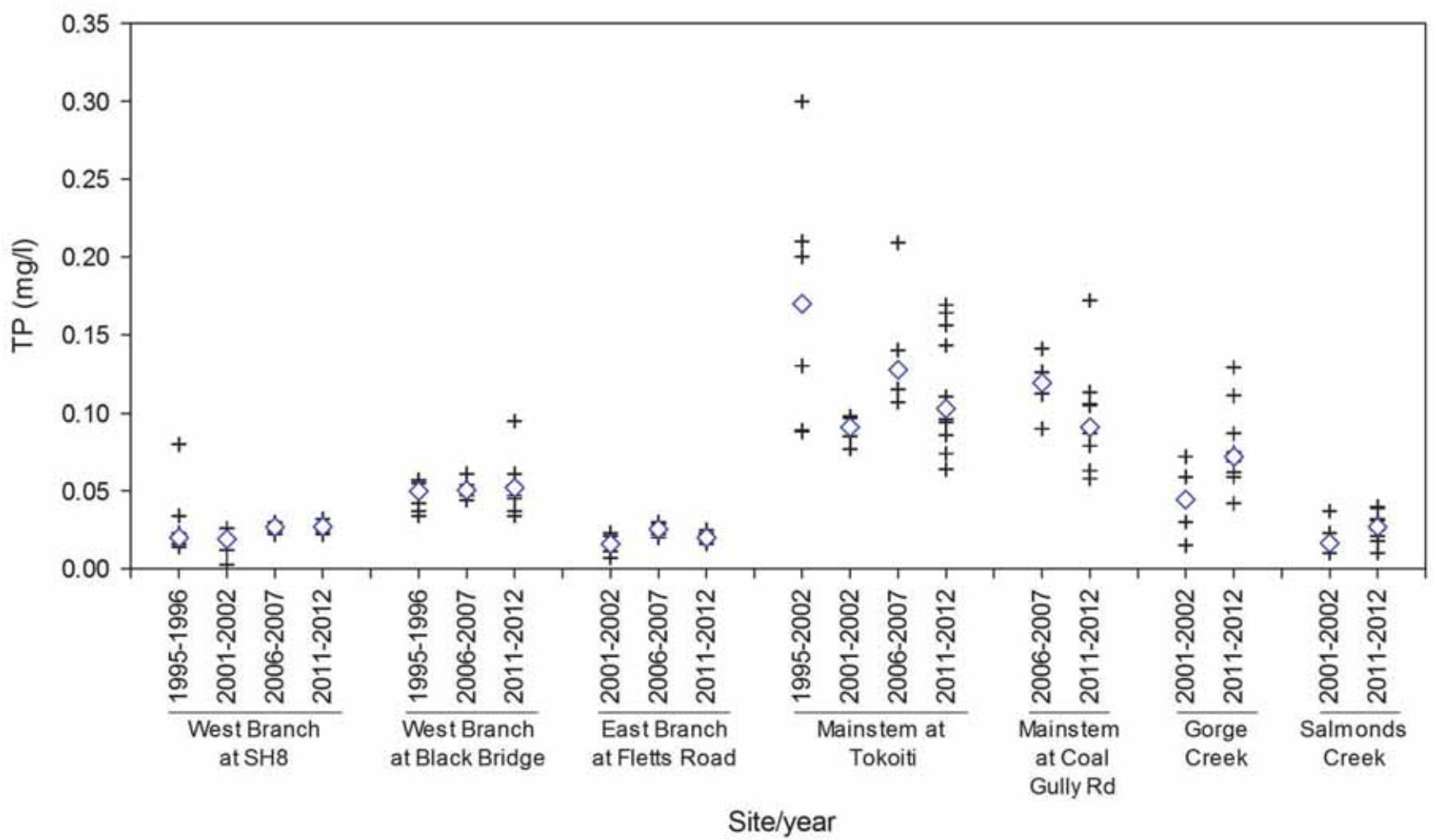

Figure 5.2.4 Total phosphorus concentrations at seven sites in the Tokomairiro catchment when flows are below the reference flow (440 l/s). Black crosses represent individual sampling occasions, while dark blue diamonds represent median values for each sampling period.

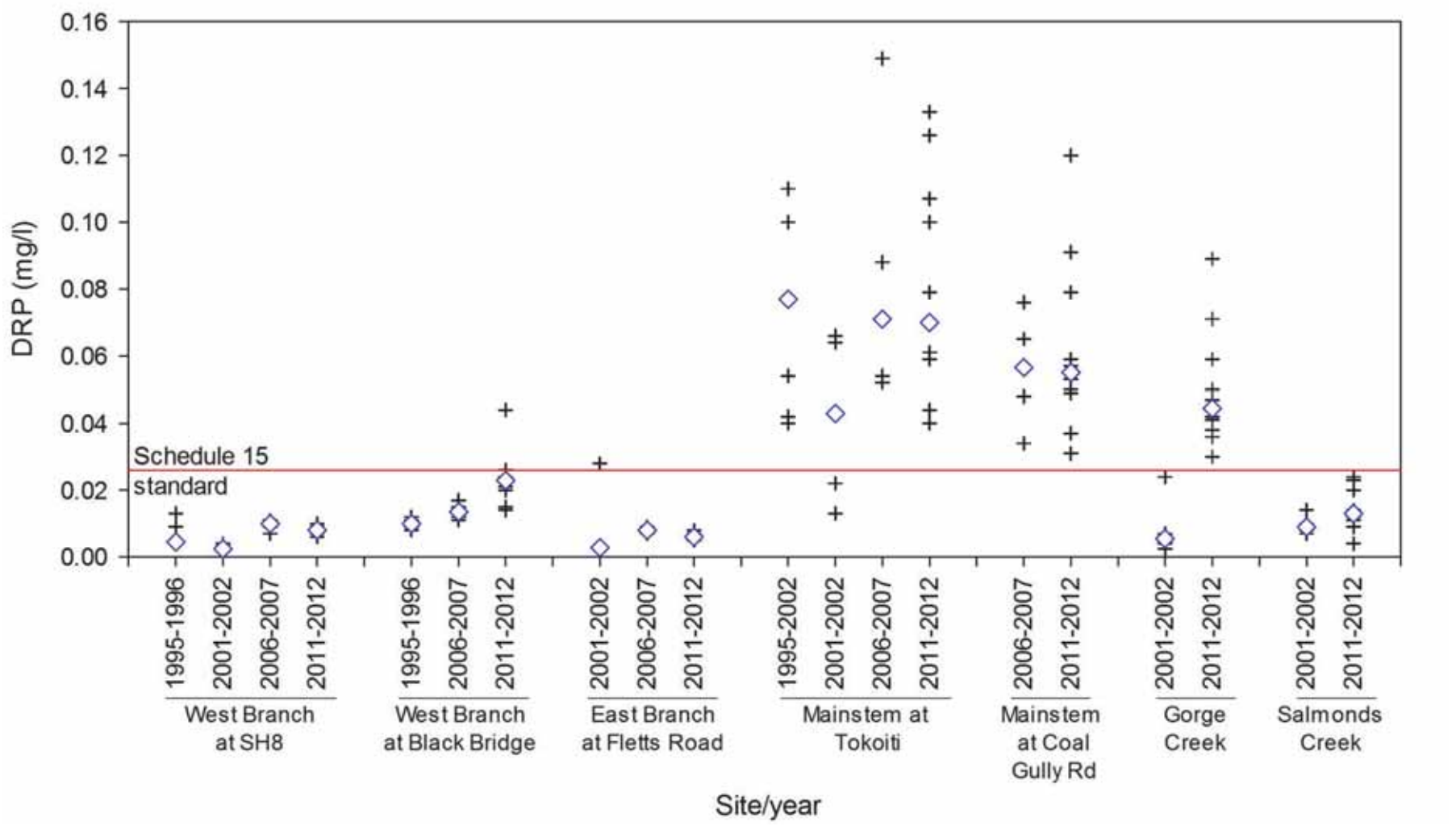

Figure 5.2.5 Dissolved reactive phosphorus concentrations at seven sites in the Tokomairiro catchment when flows are below the reference flow (440 l/s). Black crosses represent individual sampling occasions, while dark blue diamonds represent median values for each sampling period. The red line is the Plan Change 6A Schedule 15 standard (Table 3.1).

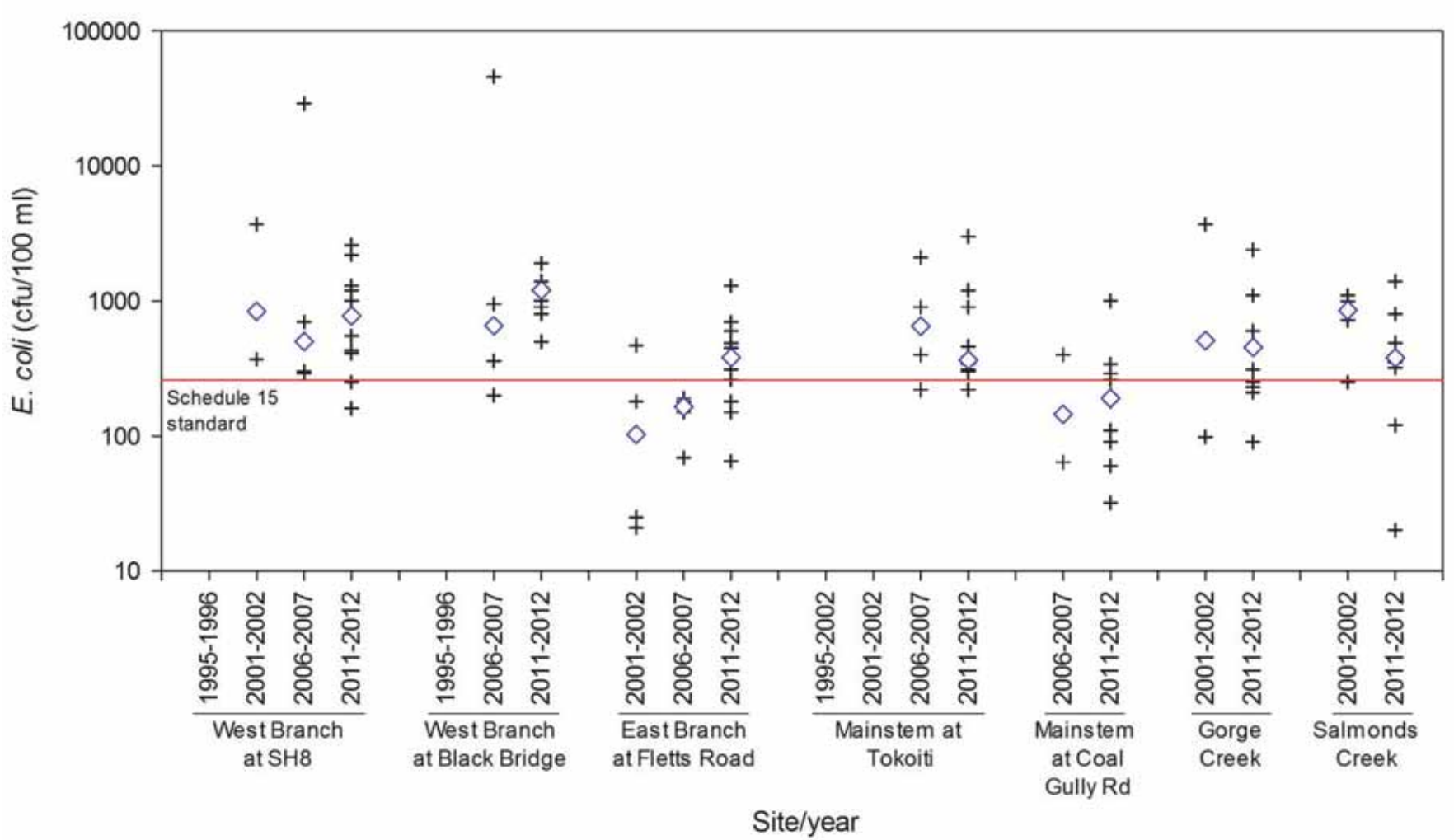

Figure 5.2.6 ***Escherichia coli*** **concentrations (logarithmic scale) at seven sites in the Tokomairiro catchment when flows are below the reference flow (440 l/s). Black crosses represent individual sampling occasions, while dark blue diamonds represent median values for each sampling period. The red line is the Plan Change 6A Schedule 15 standard (Table 3.1).**

5.2.3 *Escherichia coli*

As *E. coli* were sampled on two occasions only at most sites, it is not possible to consider trends in concentrations. However, *E. coli* were sampled in 2001/02, 2006/07 and 2011/12 in the West Branch at SH8 and the East Branch at Fletts Road. No trend was apparent in the West Branch at SH8, while there was an increasing trend in the East Branch at Fletts Road (Figure 5.2.6). The lack of a trend in the West Branch at SH8 is consistent with the results of analysis of continuous SOE monitoring conducted in the West Branch at SH8 bridge in Section 5.1.

E. coli concentrations at all sites in 2011/12 exceeded the Schedule 15 standard (Figure 5.2.6). The site with the lowest median in 2011/12 was the main stem at Coal Gully Road (Figure 5.2.6, median=190 cfu/100 ml), which had an 80th percentile value of 300 cfu/100 ml).

5.3 Water quality in drains

During detailed catchment surveys in 2001/02 and 2011/12, water quality was sampled in two drains near Black Bridge. Section 5.3 looks at how water quality parameters have changed through time at individual sites and how the measured data at each site compare to the discharge limits in Plan Change 6A (Table 3.2). Only water quality data collected when flows at the West Branch at SH8 bridge hydrological site were below the reference flow (440 l/s) are presented to allow comparison among sampling occasions and with the standards in Plan Change 6A (to be applied when flows are less than median flow).

5.3.1 Nitrogen

Total nitrogen (TN)

TN concentrations in Moneymore 1 in 2011/12 were similar to those measured in 2001/02, while TN concentrations in Moneymore 2 were slightly lower than in 2001/02 (Figure 5.3.1)

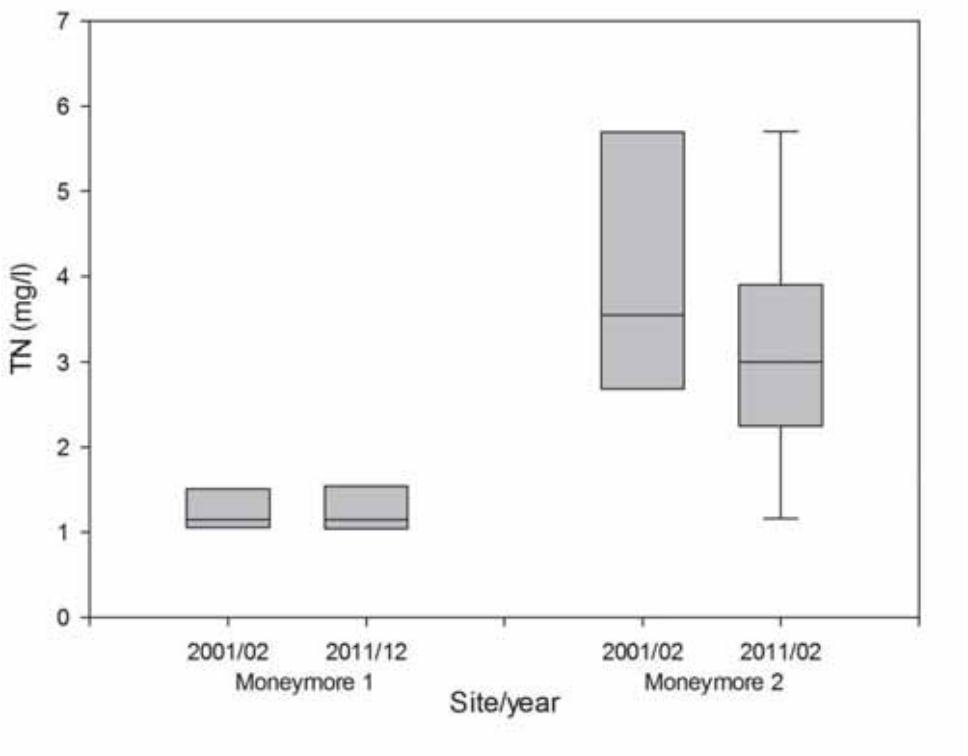

Figure 5.3.1 Total nitrogen concentrations in two drains in the Tokomairiro catchment when flows in the West Branch at the SH8 bridge are below the reference flow (440 l/s).

Nitrate-nitrite nitrogen (NNN)

Concentrations of NNN measured in both drains in 2011/12 were higher than observed in 2001/02, but remained below the discharge limit in Schedule 15 (Figure 5.3.2).

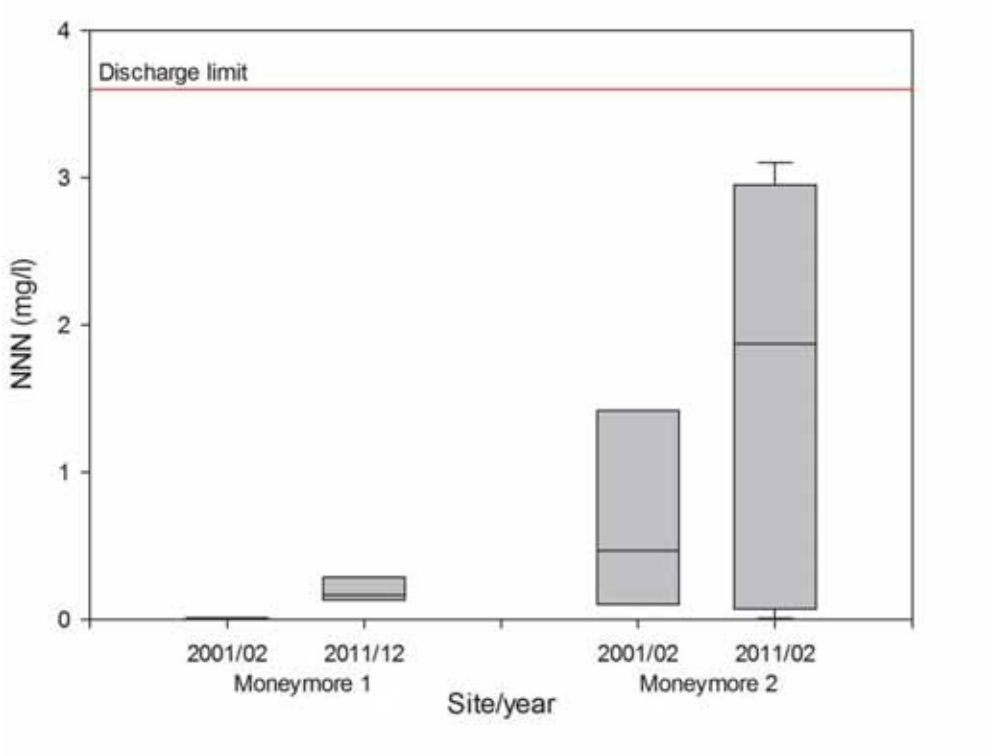

Figure 5.3.2 Nitrate-nitrite nitrogen concentrations in two drains in the Tokomairiro catchment when flows in the West Branch at the SH8 bridge are below the reference flow (440 l/s). The red line is the Plan Change 6A discharge limit (Table 3.2).

Ammoniacal nitrogen (NH_4-N)

NH_4-N concentrations measured in Moneymore 1 in 2011/12 were similar to those observed in 2001/02 and remained well below the discharge limits (Figure 5.3.3). In contrast, NH_4-N concentrations in Moneymore 2 in 2011/12 were much lower than observed in 2001/02 and generally within the limit (Figure 5.3.3).

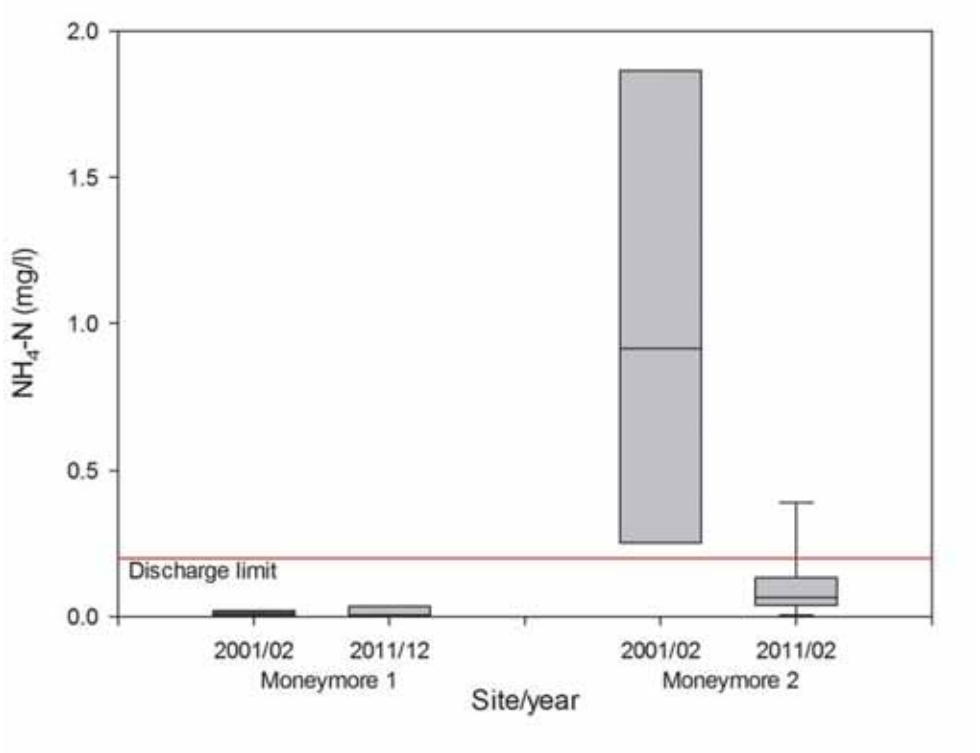

Figure 5.3.3 Ammoniacal nitrogen concentrations in two drains in the Tokomairiro catchment when flows in the West Branch at the SH8 bridge are below the reference flow (440 l/s). The red line is the Plan Change 6A discharge limit (Table 3.2).

5.3.2 Phosphorus

Total phosphorus (TP)

TP concentrations in Moneymore 1 in 2011/12 were similar to those measured in 2001/02, while TP concentrations in Moneymore 2 were lower than in 2001/02 (Figure 5.3.4)

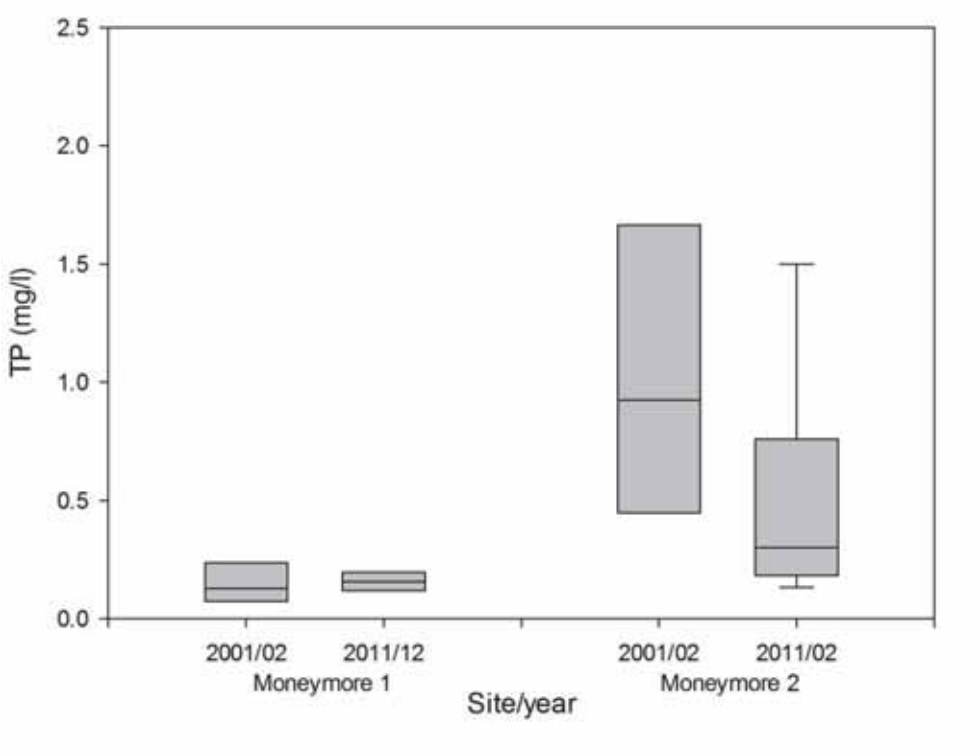

Figure 5.3.4 Total phosphorus concentrations in two drains in the Tokomairiro catchment when flows in the West Branch at the SH8 bridge are below the reference flow (440 l/s).

Dissolved reactive phosphorus (DRP)

Concentrations of DRP measured in Moneymore 1 in 2011/12 were higher than in 2001/02, and most readings exceeded the discharge limit in Schedule 15 (Figure 5.3.5). Concentrations of DRP measured in Moneymore 2 in 2011/12 were slightly lower than in 2001/02, and all readings in 2011/12 exceeded the discharge limit in Schedule 15 (Figure 5.3.5).

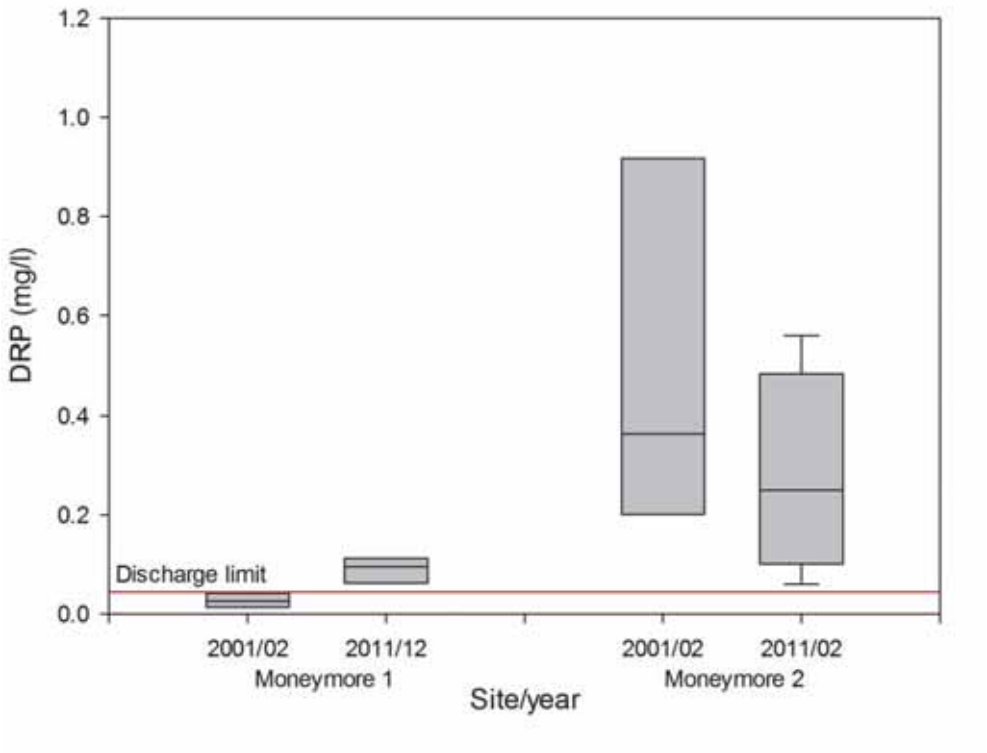

Figure 5.3.5 Dissolved reactive phosphorus concentrations in two drains in the Tokomairiro catchment when flows in the West Branch at the SH8 bridge are below the reference flow (440 l/s). The red line is the Plan Change 6A discharge limit (Table 3.2).

6. Results of 2011/12 catchment study

Many water quality variables respond to changes in season, flows, rainfall events or land-use practices (e.g. effluent disposal). Because of the effect of flow on water quality, the graphs in the following section present the median concentration under all flows and median concentrations taken when flows were at or below the median flow. Concentrations are not flow adjusted to allow comparison with the standards in Plan Change 6A. These standards apply when flows at a reference flow site are below median flow. Separating measurements taken when flows are below median flow from other occasions also serves to remove the effects of high flows on water quality parameters.

6.1 Water quality in the Tokomairiro River

6.1.1 Total nitrogen (TN)

TN concentrations were lowest in the uppermost sites in both the West Branch (SH8 bridge) and East Branch (Fletts Road) (Figure 6.1). Concentrations in the Falla Burn are elevated relative to the nearby site in the West Branch at the SH8 bridge, while the median concentrations in the West Branch, downstream of the Falla Burn confluence, were similar to those in the Falla Burn (Figure 6.1). TN concentrations in the East Branch at SH1 were higher than at Fletts Road (Figure 6.1). TN concentrations in both main stem sites were higher than at any site in the West or East branches, probably due to the discharge from the Milton WWTP (Figure 6.1). The highest TN concentrations were found in Gorge Creek, indicating that it is probably a significant source of TN in the East Branch (Figure 6.1).

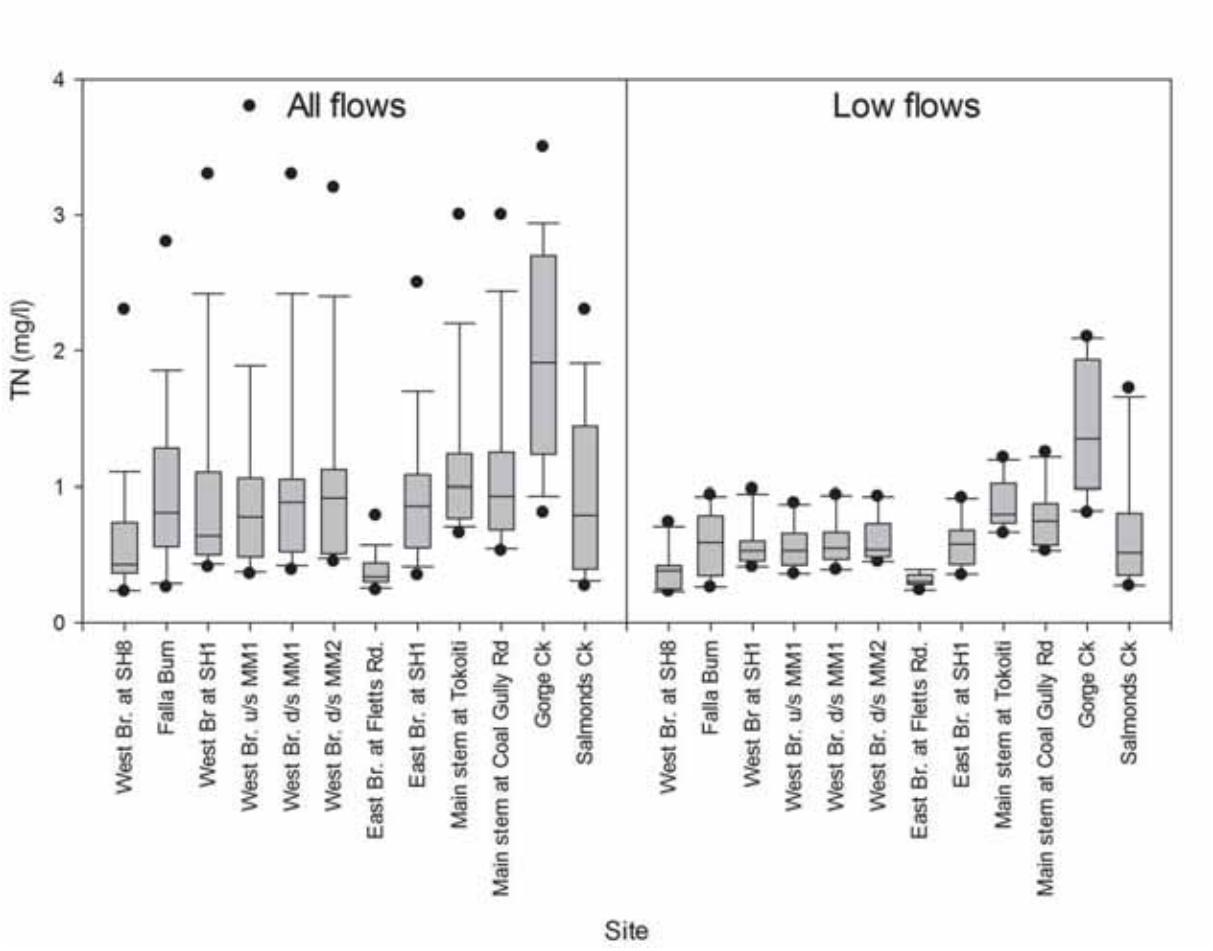

Figure 6.1 Box plots of total nitrogen concentrations at 12 sites in the Tokomairiro catchment for low flows (below the reference flow) and all flows

NNN concentrations were low at both sites in the upper catchment (West Branch at SH8 bridge and East Branch at Fletts Road). While they increased with distance downstream, the 80th percentiles of NNN concentrations at all sites in the West Branch and East Branch were below the Schedule 15 standard when flows were below median flow (Figure 6.2). Concentrations of NNN downstream of the confluence of the two branches were higher than in the two branches, probably due to discharge from the Milton WWTP. The highest NNN concentrations were found in Gorge and Salmond creeks, where the 80th percentile of NNN concentrations exceeded the Schedule 15 standard (Figure 6.2). Concentrations in the Falla Burn were higher than other sites in comparable positions in the catchment, and the 80th percentile of NNN concentrations in the Falla Burn approached the Schedule 15 standard (Figure 6.2).

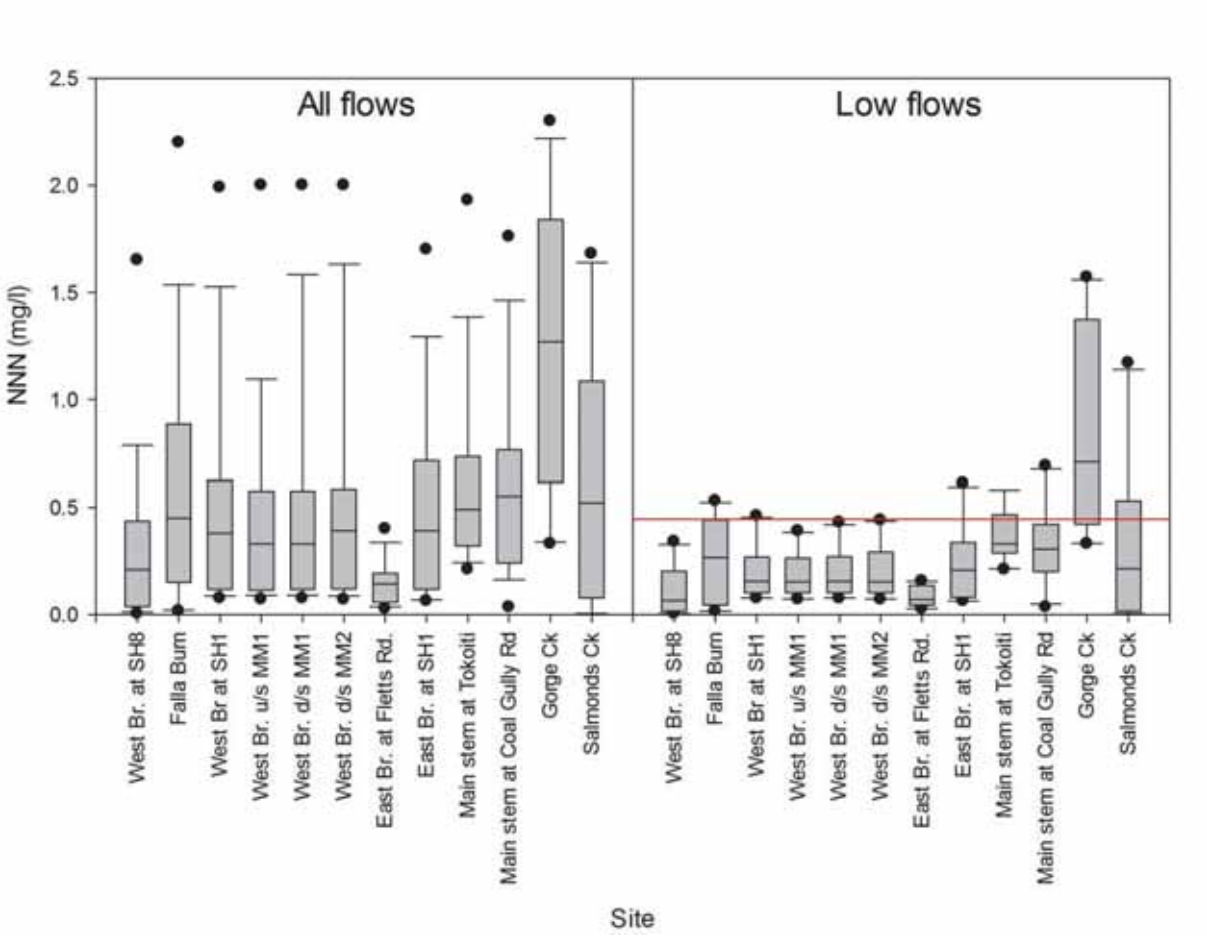

Figure 6.2 **Box plots of nitrate-nitrite nitrogen concentrations at 12 sites in the Tokomairiro catchment during all flows and low flows (below the reference flow). The red line represents the Schedule 15 standard that applies when flows are below the reference flow (Table 3.1).**

Concentrations of NH_4-N were generally low and below the guideline value at almost all sites (Figure 6.3). The main stem site at Tokoiti had much higher concentrations of NH_4-N than the other sites, and the 80th percentile exceeded the Schedule 15 standard (Figure 6.3), probably due to discharge from the Milton WWTP.

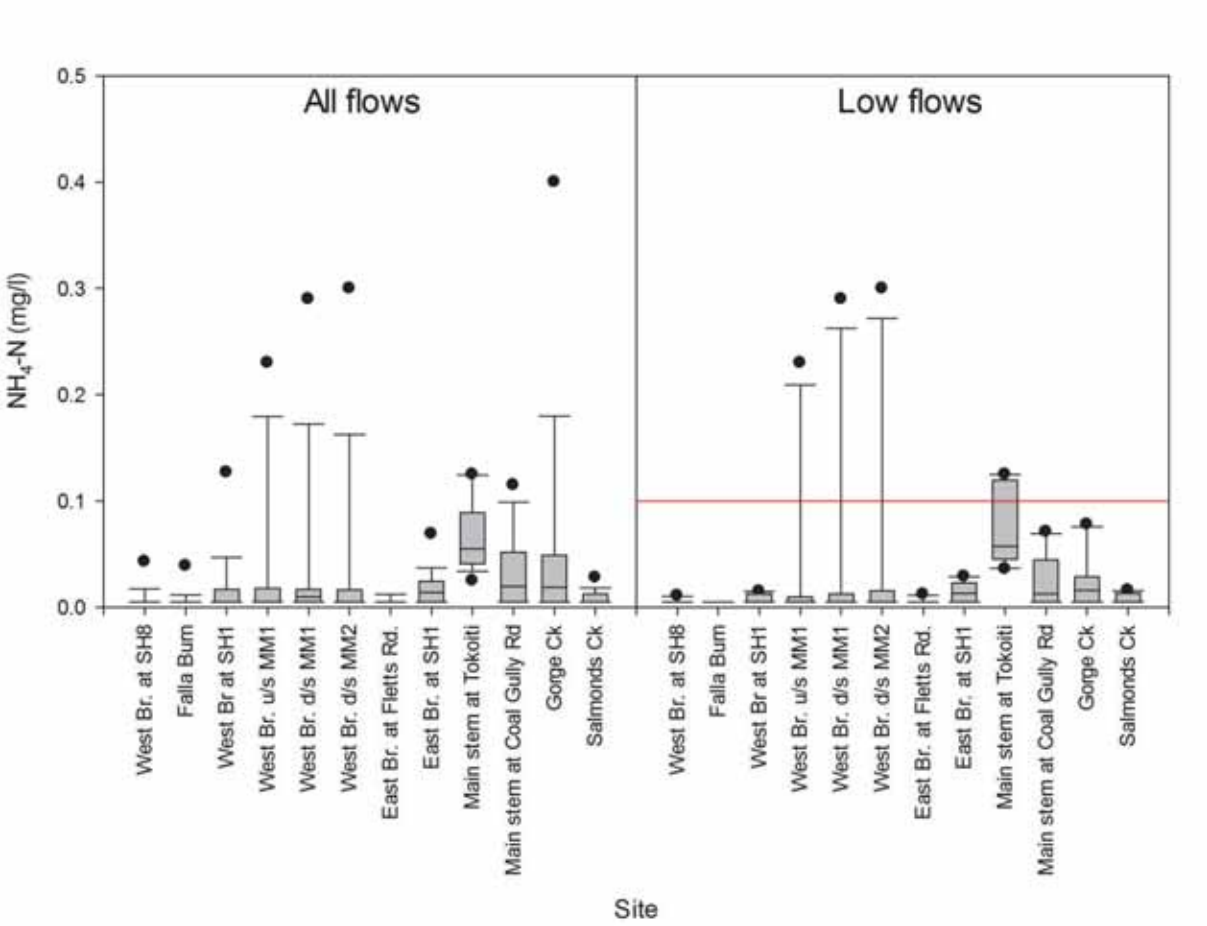

Figure 6.3 Box plots of concentrations of ammoniacal nitrogen at 12 sites in the Tokomairiro catchment during low flows (below the reference flow) and all flows. The red line represents the Schedule 15 standard that applies when flows are below the reference flow (Table 3.1).

6.1.2 Phosphorus

TP concentrations at upper sites were very low. However, higher concentrations were observed at other sites in each of the branches, and concentrations in the main stem were higher again (Figure 6.4). High concentrations of TP were observed in Gorge Creek, while concentrations in Salmond Creek were relatively low (Figure 6.4).

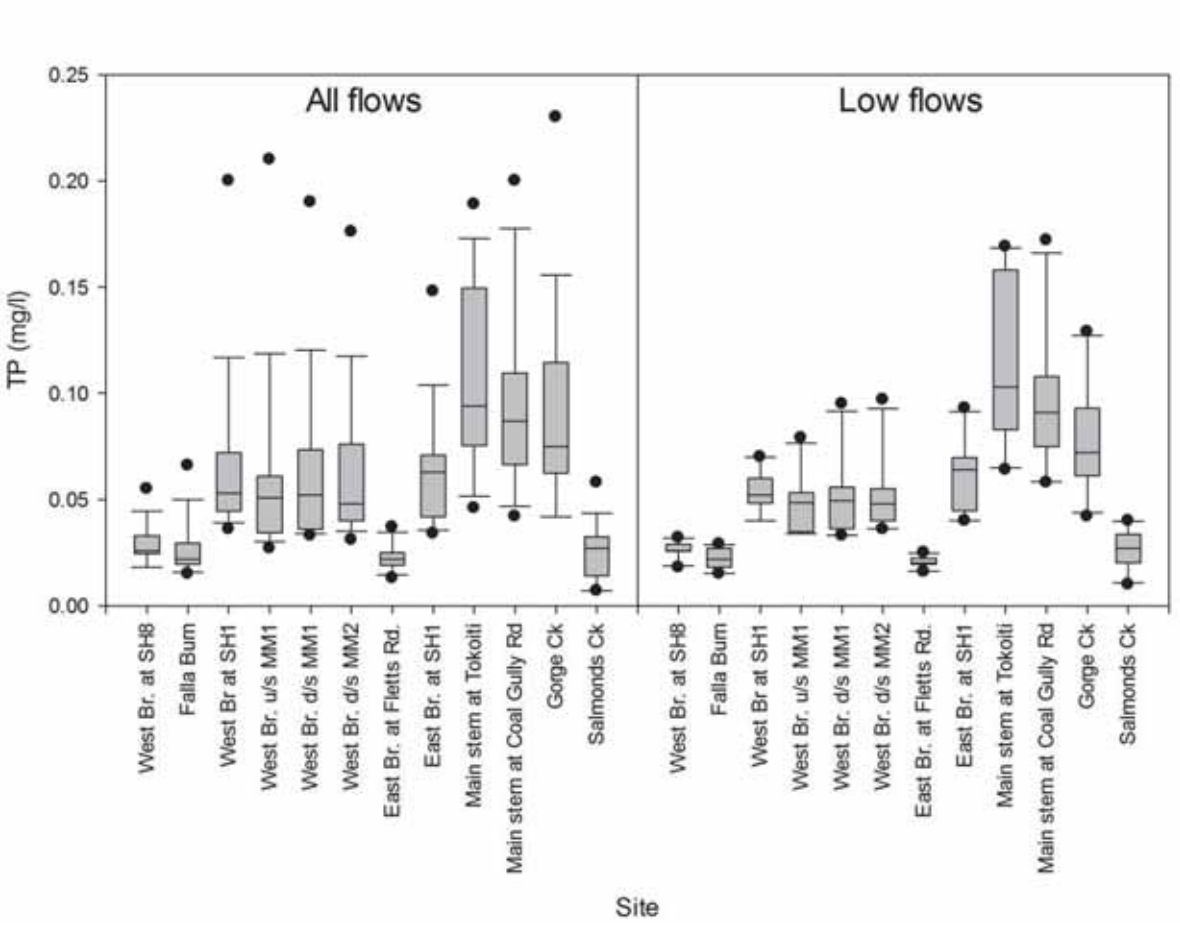

Figure 6.4 **Box plots of total phosphorus concentrations at 12 sites in the Tokomairiro catchment during low flows (below the reference flow) and all flows. The red line represents the Schedule 15 standard that applies when flows are below the reference flow (Table 3.1).**

Concentrations of DRP were very low at the upper sites (West Branch at SH8 bridge and East Branch at Fletts Road) and were well within the Schedule 15 standard (Figure 6.5). Concentrations of DRP in the other West Branch sites were similar, and the 80th percentiles of DRP concentration were equal to or exceeded the standard (Figure 6.5). The DRP concentration in the East Branch at SH1 exceeded the standard on most occasions, while concentrations at both main stem sites (Tokoiti and Coal Gully Road) and Gorge Creek exceeded it on all sampling occasions (Figure 6.5). Concentrations of DRP in the Falla Burn and Salmond Creek were quite low and were within the standard (Figure 6.5).

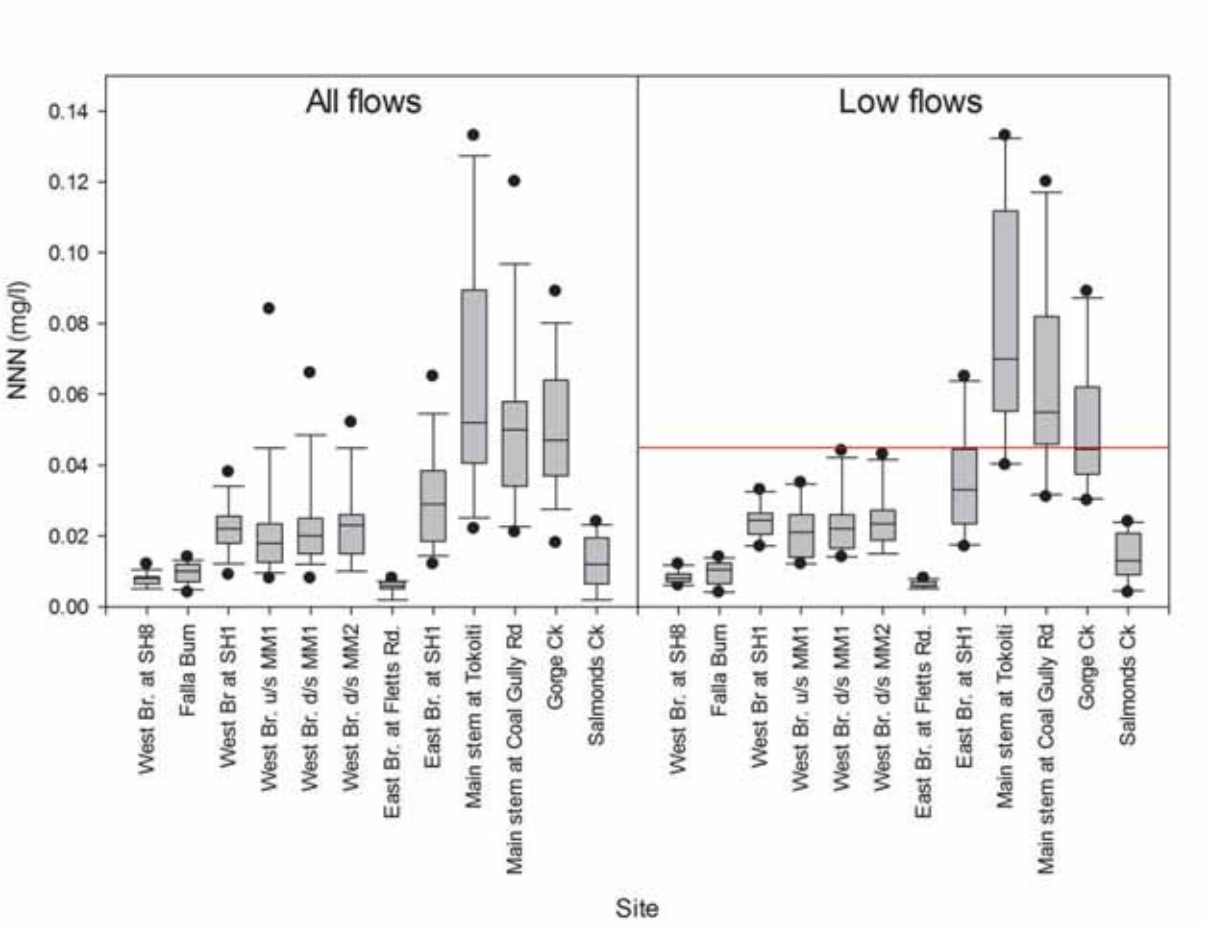

Figure 6.5 Box plots of dissolved reactive phosphorus concentrations at 12 sites in the Tokomairiro catchment during low flows (below the reference flow) and all flows. The red line represents the Schedule 15 standard that applies when flows are below the reference flow (Table 3.1).

6.1.3 Microbes

E. coli concentrations at all sites exceeded the Schedule 15 standard (Figure 6.6). The lowest concentrations were observed at Coal Gully Road, although the 80th percentile of readings also exceeded the standard (Figure 6.6). The highest counts were observed at East Branch at SH1, with all counts exceeding the standard (Figure 6.6).

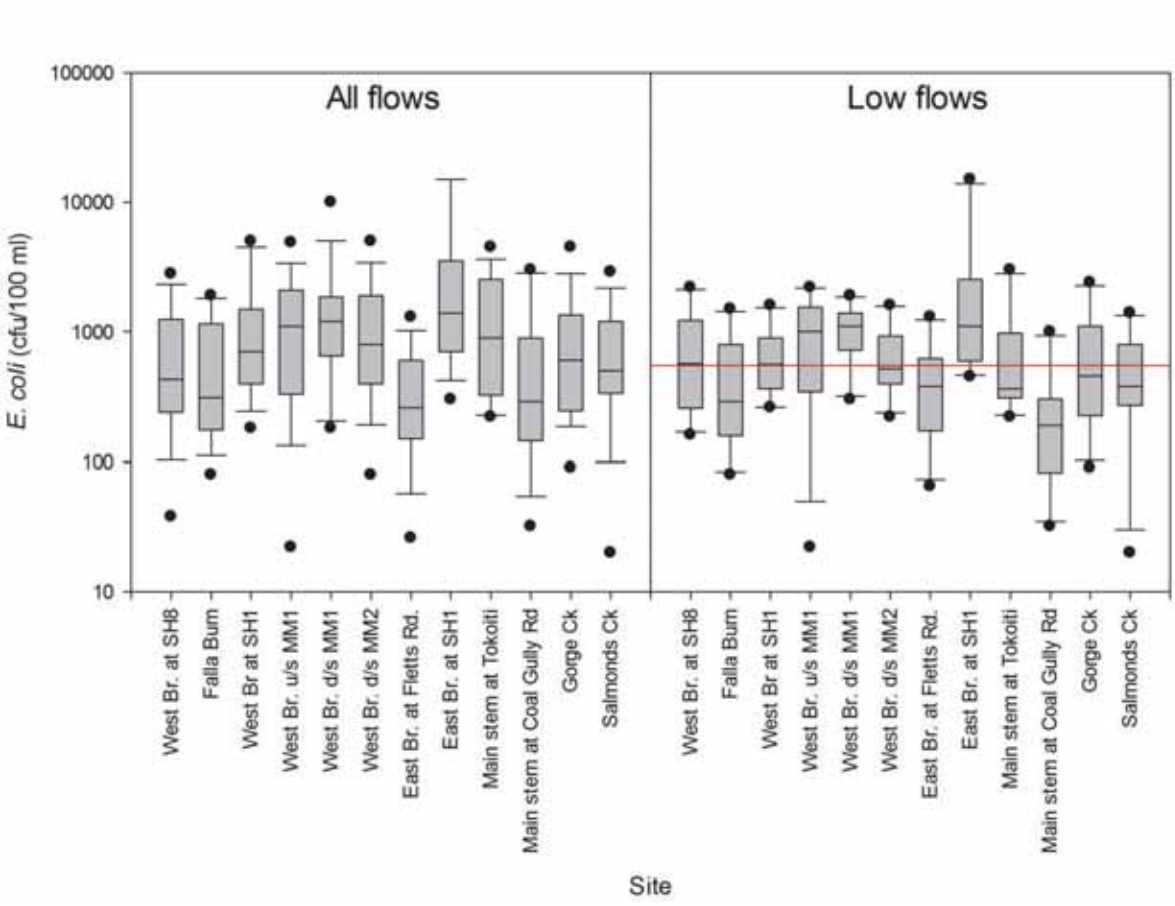

Figure 6.6 Box plots of *Escherichia coli* concentrations at 12 sites in the Tokomairiro catchment during low flows (below the reference flow) and all flows. The red line represents the Schedule 15 standard that applies when flows are below the reference flow (Table 3.1).

6.2 Effluent contamination

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

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

Values exceeding 1.554 indicate the presence of effluent contamination in surface waters. Twenty-nine percent of samples from Moneymore 1 and 35% from Moneymore 2 collected during all flows were classified as being contaminated by effluent. During periods when flows

were below median flow, no samples from Moneymore 1, and 11% of samples from Moneymore 2, were classified as being contaminated by effluent.

6.3 Milton Waste Water Treatment Plant discharge

The Milton WWTP discharges to the Tokomairoriro River downstream of the confluence of the East and West branches and is located upstream of Tokoiti. The Milton WWTP serves a population of about 2,000, as well as the Otago Corrections Facility. It is consented to discharge up to 1,625 m^3 of treated effluent per day into the main stem of the Tokomairiro River, immediately downstream of the confluence of the East and West branches.

Clutha District Council completed a significant upgrade of the Milton WWTP in June 2010. This upgrade substantially improved the level of treatment of waste water from the Milton township. A comparison of annual loads for the Milton WWTP to the sites monitored during this project is provided in Table 6.3.1.

The West Branch is the main contributor to loads of most contaminants (TN, TP, SS and *E. coli*) into the main stem, while the East Branch contributes significantly to loads of TN, TP and *E. coli* (Table 6.3.1). In comparison, the Milton WWTP makes a minor contribution to loads of TN and *E. coli*. However, it makes a more substantial contribution to TP loads (Table 6.3.1). The Milton WWTP is the main source of NH_4-N to the lower river (Table 6.3.1).

Table 6.3.1 **Comparison of annual contaminant loadings from the Milton WWTP with those of the East and West branches of the Tokomairiro River**

	E. coli **(billion cfu/y)**	**TN (kg/y)**	**NH4 (kg/y)**	**TP (kg/y)**
Milton WWTP	39.8 0%	5621 7%	3632 86%	1657 29%
West Branch at SH1	599,000 50%	54025 66%	366 9%	2815 49%
East Branch at SH1	610,000 50%	22783 28%	242 6%	1231 22%

6.4 Physical habitat

The beds at the East Branch at Fletts Road, West Branch at SH8 and Falla Burn sites had the lowest proportion of fine sediment cover (<2 mm) and the thinnest deposits of fine sediment (Table 6.3.2). In contrast, a high proportion of the bed was covered by fine sediments and thick deposits were evident at sites in the West Branch, downstream of the Moneymore Drain 1, downstream of the Moneymore Drain 2 and at the confluence, as well as Gorge Creek (Table 6.3.2).

Table 6.3.2 Summary results of physical habitat from the monitoring sites in the Tokomairiro catchment

Site name	Fine sediment cover (%)	Sediment depth (mm)	Shuffle Index
West Branch at SH8	4	6	2
Falla Burn	5	20	3
West Branch u/s Moneymore 1	18	180	3
West Branch d/s Moneymore 1	13	656	3
West Branch d/s Moneymore 2	34	387	4
West Branch at confluence	29	567	3
Salmond Creek	35	65	4
Gorge Creek	88	368	5
East Branch at Fletts Road	1	0	1

6.5 Macroinvertebrates

Ten of the 14 sites had a macroinvertebrate sample taken in November 2011. The number of taxa at each site ranged from 10 to 23. Taxonomic richness was highest at the upper sites in each of the branches (West Branch at SH8 and East Branch at Fletts Road), which contained 23 taxa and 19 taxa, respectively. The lowest numbers of macroinvertebrate taxa were recorded at the West Branch at SH1 (10 taxa), followed by Salmond Creek and the West Branch, downstream of Moneymore 2 (each with 11 taxa). The percentage of EPT taxa was highest at the East Branch at Fletts Road, with 58%, followed by the West Branch at SH8, with 52%. Moneymore 2 had the lowest proportion, with 13% (Figure 6.3.1).

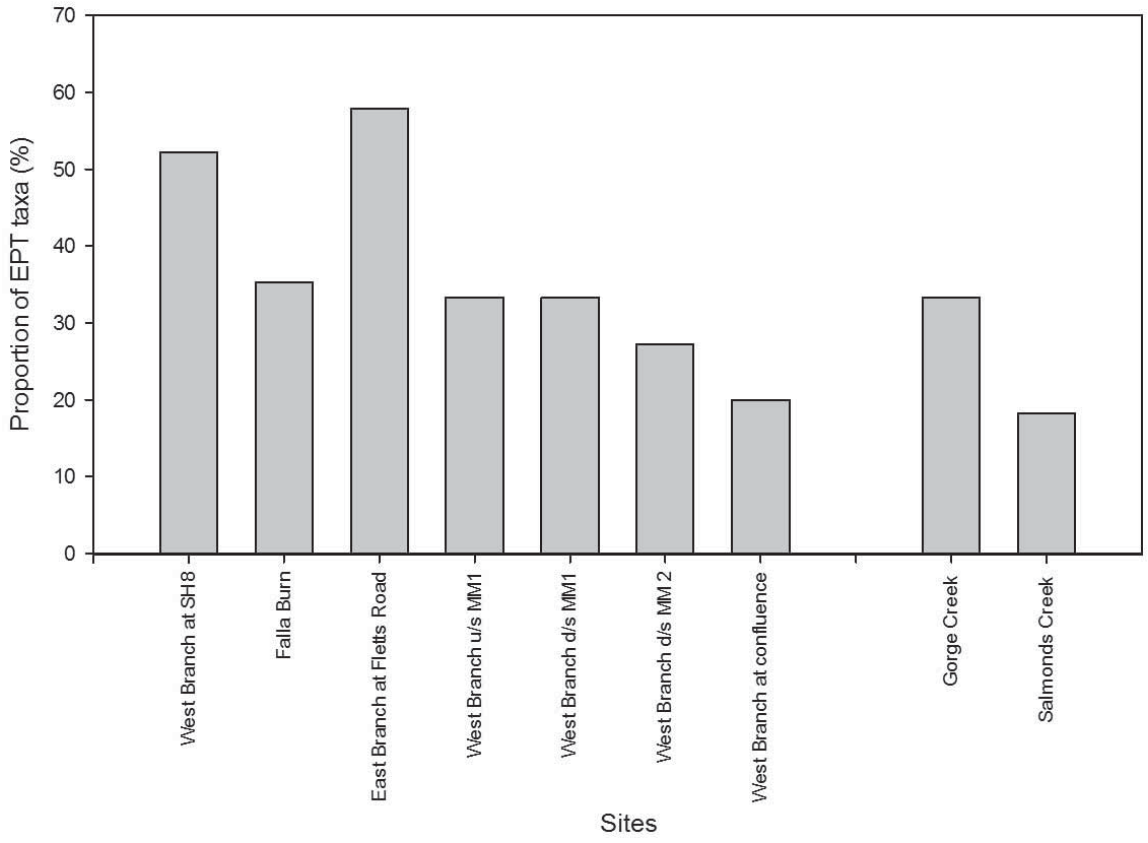

Figure 6.3.1 Proportion of EPT taxa for sampling sites in the Tokomairiro catchment in samples collected in November 2011

MCI scores at the two upper sites (West Branch at SH8 and East Branch at Fletts Road) were indicative of 'fair' to 'good' water quality (Figure 6.3.2). Both sites contained *Deleaditium* species, which are high scoring taxa, while *Olinga* (MCI tolerance score = 9) were present in the West Branch at SH8, and *Polyplectropus* and *Psilochorema* were found in the East Branch at Fletts Road. The Falla Burn had an MCI score of 95, placing it in the 'fair' category (Figure 6.3.2). Similar MCI scores were recorded at the three sites near the two Moneymore drains, with scores indicating 'fair' water quality (Figure 6.3.2). The West Branch at the confluence and Gorge Creek had MCI scores of 80, the cut-off point for the 'fair' category. The MCI score in Salmond Creek (64) indicates 'poor' water quality (Figure 6.3.2). These sites were dominated by amphipods, chironomid midges and snails.

The East Branch at Fletts Road, Falla Burn and the West Branch at SH8 had SQMCI scores in the 'excellent' category (Figure 6.3.3). The SQMCI score at the West Branch, upstream of Moneymore 1, indicates that water quality is 'good'. However, the scores at the two sites downstream of the Moneymore drains were lower, indicating 'fair' water quality. The SQMCI score for the West Branch at the confluence (3.55) indicates 'poor' water quality (Figure 6.3.3).

The SQMCI score for Gorge Creek (4.36) suggests that water quality at this site is 'poor'.

The SQMCI score for Salmond Creek (2.98) indicates that water quality is 'poor' there, too (Figure 6.3.3).

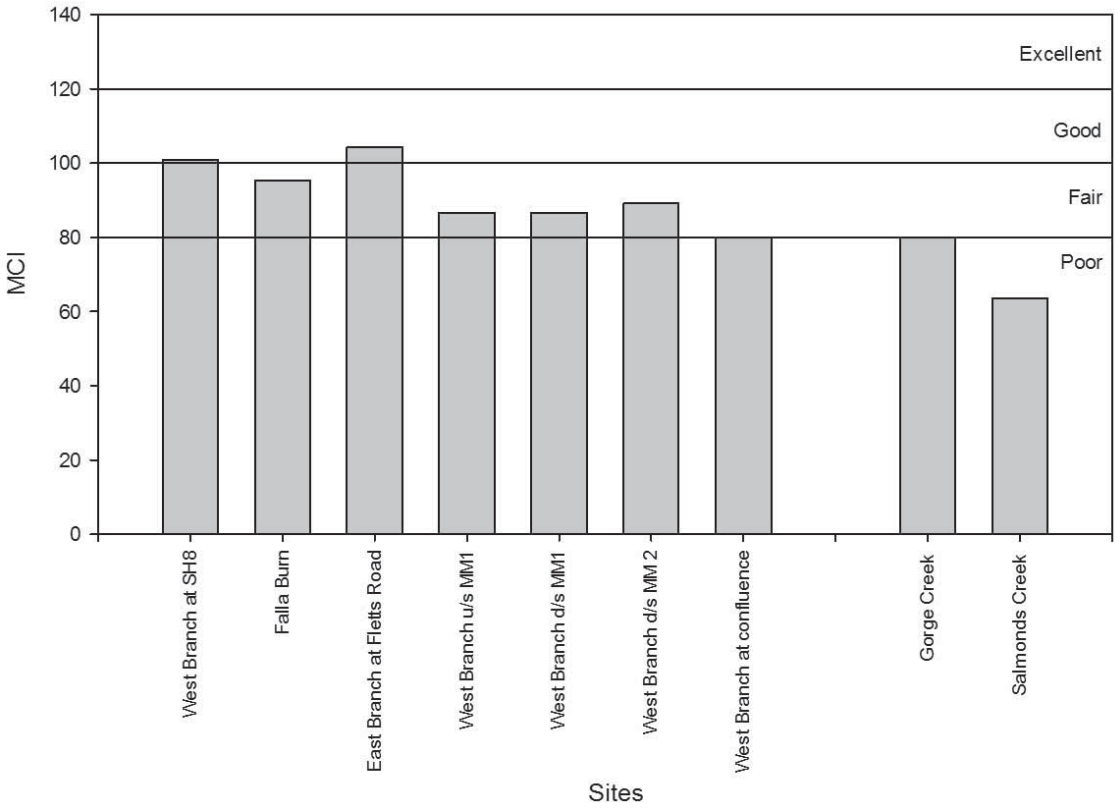

Figure 6.3.2 MCI scores for sampling sites in the Tokomairiro catchment in samples collected in November 2011

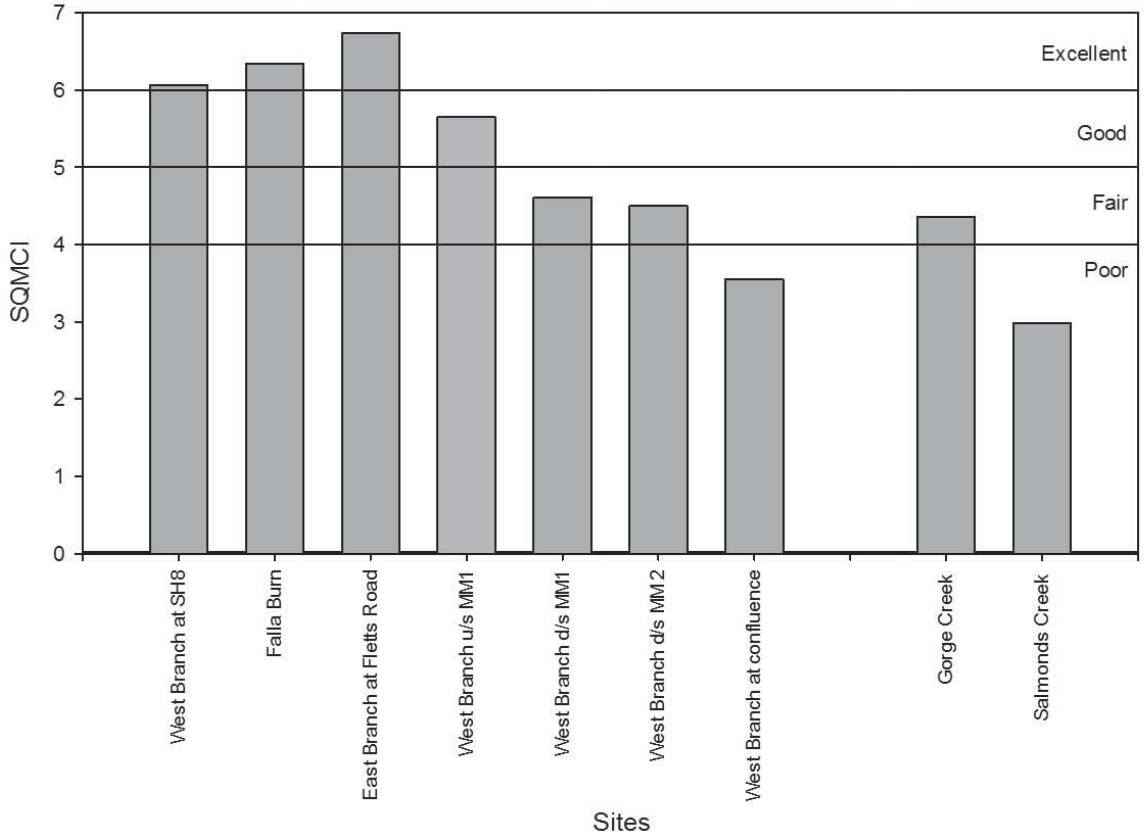

Figure 6.3.3 SQMCI scores for sampling sites in the Tokomairiro catchment in samples collected in November 2011

6.6 Fish

Four fish species were collected during this study: longfin eel (*Anguilla dieffenbachii*), lamprey (*Geotria australis*) common bully (*Gobiomorphus cotidianus*) and brown trout (*Salmo trutta*).

The highest densities were observed in Salmond and Gorge creeks, although both sites were dominated by a single species: common bullies, in Salmond Creek, and longfin eels, in Gorge Creek. Fish densities at the West Branch sites were 'moderate to high' relative to other coastal waterways in Otago (Figure 6.3.4). The East Branch at Fletts Road had the lowest fish density, which was 'low to moderate' relative to other coastal waterways in Otago (Figure 6.3.4).

Of the seven sites able to be fished, only four had brown trout. Of these sites, all sites had 'low to moderate' brown trout populations in relation to the brown-trout condition/density index. The highest condition-density index score occurred at Falla Burn, while the lowest scores were recorded at the East Branch at Fletts Road and West Branch upstream of Moneymore 1 (Figure 6.3.5).

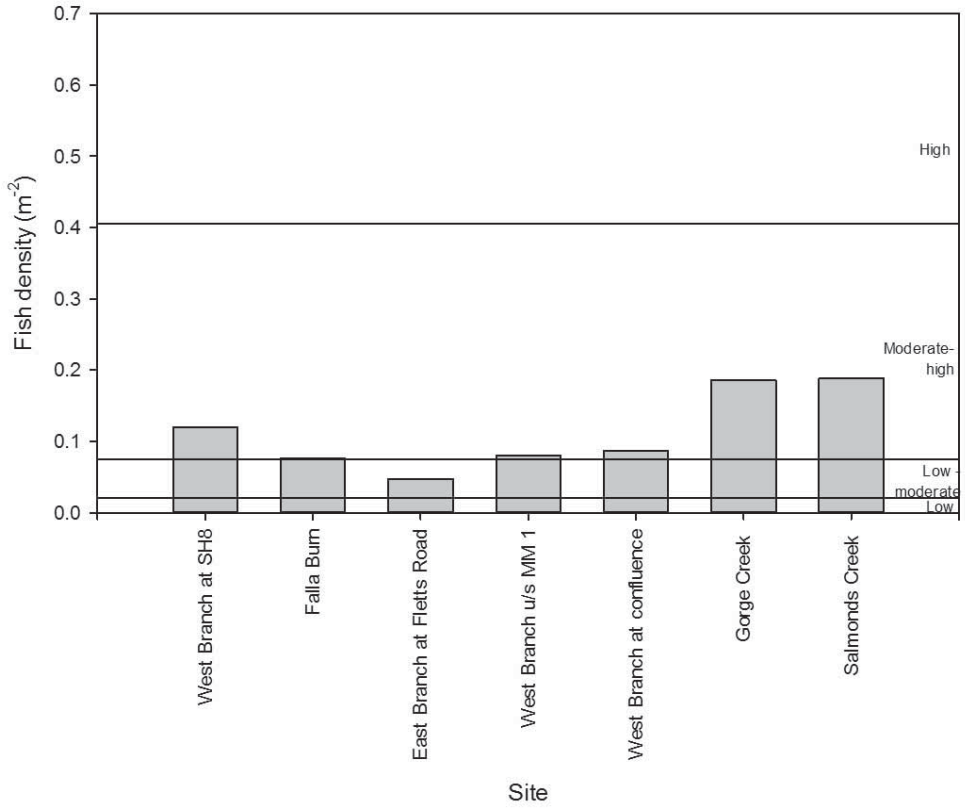

Figure 6.3.4 Fish density (for all species) at the sites sampled in the Tokomairiro catchment

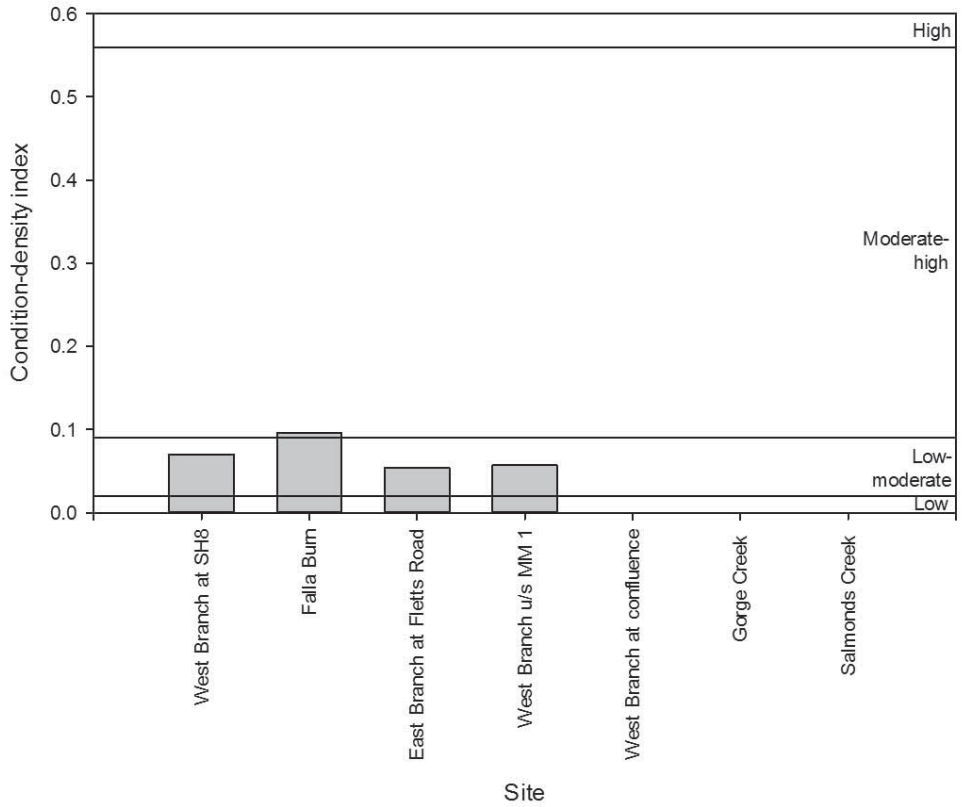

Figure 6.3.5 Brown-trout condition/density index at the sampled sites

7. Discussion

7.1 Trends in water quality

The SOE monitoring network includes a single site in the Tokomairiro River, at the SH8 bridge, over the West Branch. This site is positioned high in the catchment, and the land-use upstream is dominated by exotic forestry, sheep/beef, and limited dairy, farming (Figure 2.2). From 2001 to the present, water quality samples have generally been collected six times per year at this location. Trend analysis of the dataset (Section 5.1) found that most parameters had not changed significantly during this time, with exception of DRP, which had increased. These results are consistent with the analysis of SOE monitoring data for the period 2001 to 2011 (ORC 2012a). However, the area upstream (68.5 km^2) of this site only represents about 17% of the catchment.

As well as continuous monitoring of the SOE site, four periods of intensive water quality monitoring have been conducted within the overall catchment: in 1995/96, 2001/02, 2006/07 and 2011/12. In these studies, several sites were sampled more than once, allowing consideration of change in water quality in the wider catchment over time. The results indicate that water quality has declined in many parts of the catchment, with increases in TN, TP and DRP in the West Branch at Black Bridge and increases in TN and NNN at both sites in the main stem (Tokoiti and Coal Gully Road). Concentrations of DRP have also possibly increased in the West Branch at the SH8 bridge (which is consistent with the results of long-term SOE monitoring) and East Branch at Fletts Road.

The concentration of NH_4-N was found to be low, or where it was elevated, it had decreased at most sites over time. This finding suggests that effluent management has improved in parts of the catchment.

Limited results from Gorge and Salmond creek suggest that water quality has improved, with lower TN and NNN concentrations found in 2011/12 than in 2001/02. However, the concentration of DRP in Gorge Creek was found to be higher in 2011/12 than in 2001/02.

7.2 Compliance with Plan Change 6A standards

Plan Change 6A sets out water quality standards for receiving waters (Schedule 15, Table 3.1) and discharge limits (Schedule 16, Table 4). The receiving water standards Table 3.1) are applied as 5-year, 80th percentiles, when flows are at or below the reference flow (440 l/s). Flows in the catchment are set at the gauging site in the West Branch at the SH8 bridge.

7.2.1 Receiving water quality

Sampling in 2011/12 indicates that most sites in the East and West branches complied with the Schedule 15 standards for NNN and NH_4-N. However, only the West Branch at SH8 and East Branch at Fletts Road were comfortably within the standard for DRP (0.026 mg/l, Table 3.1) (Table 7.2.1). The 80th percentiles of concentrations measured over the 2011/12 period indicate that all other sites in the West Branch were close to, or above, this standard, while the 80th percentile of concentrations from the East Branch at SH1 exceeded it (Table 7.2.1).

Both sites in the main stem, downstream of the East and West Branch confluence, exceeded the standard for DRP, while the Tokoiti site also exceeded standards for NNN, NH_4-N and *E. coli* (Table 7.2.1). The Coal Gully Road site was below, but approaching, the standard for NNN, while the 80th percentile of concentrations of NH_4-N was well below the standard (Table 7.2.1).

Falla Burn approached the NNN standard, but was well within the standards for NH_4-N and DRP (Table 7.2.1). Gorge Creek exceeded the standards for NNN, DRP and *E. coli*, but within the standard for NH_4-N (Table 7.2.1). Salmond Creek exceeded the standard for NNN and *E. coli*, while the 80th percentile of DRP approached it. Concentrations of NH_4-N were well within the standard (Table 7.2.1).

The monitoring undertaken between 2011/12 shows that the 80th percentiles of *E. coli* counts at all sites exceeded the standard (Table 7.2.1). In fact, even the median values at most sites exceeded it. These results suggest that significant improvements in effluent management and/or stock access to waterways are required.

Table 7.2.1 Comparison of 80th percentiles of water quality parameters with Schedule 15 standards in Plan Change 6A (Schedule 15, Table 3.1). Values that exceeded the Schedule 15 standard are highlighted red and values that approached the standard are shaded orange.

		NNN	NH4-N	DRP	*E. coli*
Schedule 15 standard		0.444 mg/l	0.1 mg/l	0.026 mg/l	260 cfu/100 ml
West Branch	SH8 bridge	0.202	0.005	0.009	1220
	SH1 bridge	0.260	0.012	0.026	900
	upstream of Moneymore 1	0.258	0.009	0.026	1520
	downstream of Moneymore 1	0.266	0.013	0.026	1400
	downstream of Moneymore 2	0.286	0.015	0.027	900
East Branch	Fletts Road	0.136	0.005	0.007	620
	SH1	0.330	0.023	0.044	2420
Mainstem	Tokoiti	0.460	0.119	0.111	960
	Coal Gully Road	0.414	0.044	0.081	300
Tributaries	Falla Burn	0.442	0.005	0.012	800
	Gorge Creek	1.366	0.027	0.061	1100
	Salmonds Creek	0.508	0.013	0.021	800

7.2.2 Drains

As well as Schedule 15 standards, Plan Change 6A sets out discharge limits that apply when flows are at or below median flow (Schedule 16, Table 4.1). These standards apply at the point of discharge, either at the property boundary, or at the point where the drain discharges into a natural waterway.

Data collected from two drains that enter the Tokomairiro River near Black Bridge (Moneymore 1 and 2) were compared with the discharge standards in Schedule 16. NNN concentrations were below the limit on all occasions at both drain sites (Table 7.2.2). NH_4-N concentrations were below the limit on all occasions in Moneymore 1 and on most occasions in Moneymore 2 (Table 7.2.2). The DRP concentration in both drains exceeded the limit on most occasions (Table 7.2.2). In Moneymore 1, *E. coli* counts exceeded the discharge limit on half of the sampling occasions, while counts in Moneymore 2 did not exceed the limit (Table 7.2.2).

Table 7.2.2 Comparison of median values of water quality parameters with discharge limits (Schedule 16, Table 3.2) and the percentage of occasions when these values exceeded discharge limits

	NNN	NH_4-N	DRP	*E. coli*
Schedule 16 limit	**3.6 mg/l**	**0.2 mg/l**	**0.045 mg/l**	**550 cfu/100 ml**
Moneymore 1	0.165 0%	0.005 0%	0.096 88%	460 50%
Moneymore 2	1.87 0%	0.066 11%	0.25 100%	150 0%

7.3 Spatial patterns in water quality

7.3.1 West Branch

That the nutrient concentrations in the West Branch at the SH8 bridge were low relative to most other sites is not surprising, given the level of development in the catchment upstream of this site (Table 3.1). Even so, *E. coli* counts exceeded the Schedule 15 standard (550 cfu/100 ml applied as an 80th percentile over five years). In the context of the low nutrient concentrations observed at these sites, the elevated *E. coli* counts probably reflect stock access to waterways upstream of this sampling point.

Falla Burn was sampled near the confluence with the West Branch, a short distance from the sampling point in West Branch at the SH8 bridge. Concentrations of NH_4-N and phosphorus (TP and DRP) were generally low at this site. However, concentrations of NNN (and, as a result, TN) were elevated, and *E. coli* counts exceeded the receiving water quality standard. Given the position of this sampling point, the high NNN concentrations are cause for concern, and the reasons should be investigated further.

Water quality in the remaining sites in the West Branch had similar water quality: moderate concentrations of NNN (and TN) and high concentrations of DRP (and TP). NH_4-N concentrations were low, while *E. coli* counts were high and exceeded the Schedule 15 standard.

Water sampling in the two drains that enter the West Branch near Black Bridge indicates that concentrations of NNN, TN, NH_4-N, DRP and TP in Moneymore 2 were much higher than in Moneymore 1.

7.3.2 East Branch

Low nutrient concentrations were observed in the East Branch at Fletts Road. The observation at the upper West Branch site reflects the level of development upstream (Table 3.1). However, *E. coli* counts exceeded the Schedule 15 standard (550 cfu/100 ml applied as an 80th percentile) over the sampling period, probably reflecting stock access to waterways upstream.

Water quality declined in the East Branch between Fletts Road and SH1, with the SH1 site having moderate concentrations of NNN and TN and high concentrations of DRP and TP. NH_4-N concentrations were low, while *E. coli* counts were high and exceeded the Schedule 15 standard.

Two tributaries of the East Branch were sampled: Gorge and Salmond creeks. Gorge Creek had high concentrations of NNN, TN, DRP, TP and *E. coli*, while Salmond Creek had moderate NNN and TN concentrations, but low TP and DRP concentrations. Although, as discussed in Section 7.1, comparison of water quality in 2001/02 and 2011/12 suggests that water quality in these creeks has improved.

7.3.3 Main stem

Both main stem sites had high concentrations of NNN, TN, DRP, TP and *E. coli*, while the site at Tokoiti also had elevated concentrations of NH_4-N. The water quality at these sites reflects the effect of contaminants from land use upstream of the confluence and the discharge from the Milton WWTP. The nutrient loadings from the two branches and the Milton WWTP indicate that the West Branch accounts for about two-thirds of the TN load and almost half of the TP load, the East Branch for about 28% of TN and 22% of TP, while the Milton WWTP accounts for about 7% of TN and 29% of TP loads immediately downstream of its discharge. The load of *E. coli* from the Milton WWTP was negligible, compared to loads from the branches, which had similar loads at the sampling points on SH1.

7.3.4 Habitat quality and biological monitoring

As well as water quality monitoring, the assessments included surveys of sediment, macroinvertebrates and fish. Many human activities can increase the inflows of fine sediments to surface waters. Once they are in waterways, fine sediments can have a wide range of detrimental effects on habitat quality for aquatic biota. They can also affect instream biogeochemistry.

The beds of the two sites in the upper catchment had a small proportion of fine sediment. The bed at the East Branch at Fletts Road was dominated by coarse cobble/boulder substrate, while in the West Branch, there was a distinct change in substrate from cobble/boulder substrate to coarse sand/small pebbles about 150 m upstream of the SH8 bridge. In contrast, substantial sedimentation was evident in Gorge and Salmond creeks and the other sites surveyed in the West Branch (upstream of Moneymore 1, downstream of Moneymore 1, downstream of Moneymore 2 and at the confluence). The difference in

substrate between the upper site and the other sites in the West Branch is probably related, in part, to geology. The hills around Table Hill are dominated by the Taratu formation, which consists primarily of quartz sand and pebble conglomerate (Bishop 1994). This formation is easily erodible, and land clearance has probably increased the input of sand and pebbles from it into the middle reaches of the catchment. Because of the shallow gradient of much of the Tokomairiro River, it has limited capacity to transport sediment. As well as the natural load of fine sediment, land-use activities contribute a significant proportion of the fine sediment loads in many parts of the catchment.

Figure 7.3.1 An example of the fine sediment smothering the stream bed of Gorge Creek (looking through an underwater viewer) and a sediment core collected from Gorge Creek

Figure 7.3.2 Sediment plume after performing the Shuffle Index method to assess sedimentation

The results of macroinvertebrate biomonitoring are generally consistent with those generated by water quality sampling and physical habitat surveys. The MCI and SQMCI scores indicate that the West Branch at SH8 and the East Branch at Fletts Road have 'good-excellent' water/habitat quality, while Gorge and Salmond creeks and the West Branch at the confluence have 'poor' water/habitat quality.

8. Conclusions and recommendations

- SOE monitoring in the West Branch at SH8 indicates that most water quality parameters have not changed between 2001 and 2013, with the exception of DRP, which has increased.

- Intensive water quality studies in 1995/96, 2001/02, 2005/06 and 2011/12 indicate that water quality has declined in many parts of the catchment. However, the amount of NH_4-N has decreased at most sites, suggesting that effluent management has improved in parts.

- Water quality in the West Branch declined between the SH8 bridge and the next site downstream (SH1), probably reflecting the more intensive land use on the Tokomairiro Plains. Similarly, water quality in the East Branch declined between Fletts Road and SH1, possibly for similar reasons.

- Water quality in the catchment in 2011/12 was compared to the Schedule 15 standards in Plan Change 6A.
    - All sites in the West and East branches of the Tokomairiro complied with the standard for NNN (0.444 mg/l). However, the site in the main stem at Coal Gully Road and Falla Burn approached the standard, and the main stem at Tokoiti, Gorge Creek and Salmond Creek exceeded it.
    - Only the main stem site at Tokoiti exceeded the standard for NH_4-N (0.1 mg/l), probably reflecting the effect of the discharge from the Milton WWTP.
    - The standard for DRP (0.026 mg/l) was exceeded in the West Branch at SH1, downstream of Moneymore 1 and 2, the East Branch at SH1, both sites in the main stem and Gorge Creek.
    - All sites exceeded the standard for *E. coli* (260 cfu/100 ml).

- Water quality monitoring in two drains in the vicinity of Black Bridge on the West Branch were compared with the discharge limits set out in Schedule 16 of Plan Change 6A.
    - NNN concentrations were below the discharge limit on all occasions at both sites, and the NH_4-N concentrations were below the limit on all occasions in Moneymore 1 and on most occasions in Moneymore 2.
    - DRP concentration in both drains exceeded the limit on most occasions.
    - In Moneymore 1, *E. coli* counts exceeded the discharge limit on half the sampling occasions, while the counts in Moneymore 2 did not exceed the limit.
    - On occasions, samples taken from Moneymore 1 and 2 (during periods of low flow) indicate that these drains were contaminated by effluent.

- The site with the poorest water quality in this catchment is Gorge Creek, which failed to meet Schedule 15 standards for NNN, DRP and *E. coli*. Even so, comparison of samples in 2001/02 with those collected in 2011 suggests that water quality in this sub-catchment and Salmond Creek has improved.

- Elevated concentrations of NNN were observed in the Falla Burn, despite the water quality in this catchment generally being 'good'. The causes of this result should be investigated.

- Estimates of nutrient and *E. coli* loads indicate that the West Branch contributes most of the nitrogen (66%) and phosphorus (49%) to the lower Tokomairiro, with the East Branch (28% and 22%, respectively) and the Milton WWTP (7% and 29%, respectively) accounting for a much smaller proportion of nutrient loads. The Milton WWTP discharge contributes most of the load of NH_4-N (86%) to the lower river. The East and West branches account for a similar proportion of the *E. coli* load to the lower river, with the Milton WWTP accounting for a very small proportion (>0.5%).

- Physical habitat surveys showed that several sites were affected by sedimentation. The upper sites (West Branch at SH8, Falla Burn and East Branch at Fletts Road) had coarse substrate and MCI scores, suggesting 'good-excellent' water/habitat quality. The other sites sampled on the West Branch and Gorge and Salmonds creeks had high proportions of fine sediment and MCI scores, suggesting 'poor' water/habitat quality.

- Fish densities in the East Branch at Fletts Road were 'low to moderate' compared to other coastal Otago rivers. Fish densities observed at all other sites were 'moderate to high' compared to other coastal Otago rivers.

- More SOE sites should be established in the Tokomairiro catchment. The present site (West Branch at SH8 bridge) does not accurately reflect water quality trends in the catchment. Possible sites could include the lower East Branch (SH1), lower West Branch (Black Bridge) or a site in the lower main stem of the river (Tokoiti).

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Appendix 1 – Trends in water quality

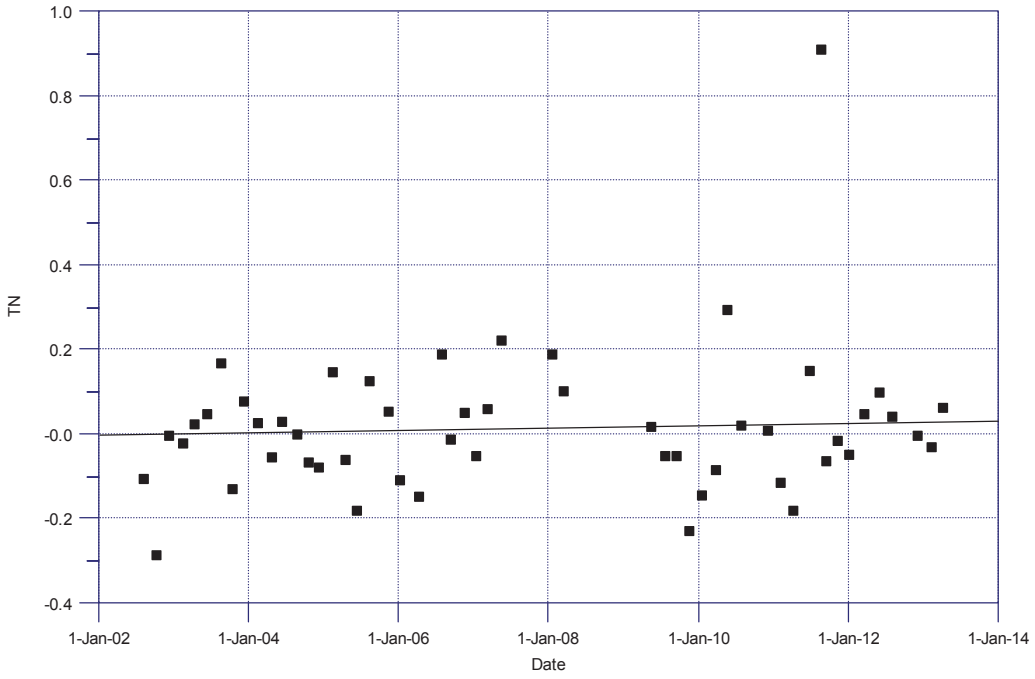


Figure A1.1 Long-term trend in flow-adjusted dissolved reactive phosphorus concentrations between 2002 and 2013. Statistics are outlined in Table 5.1.1.

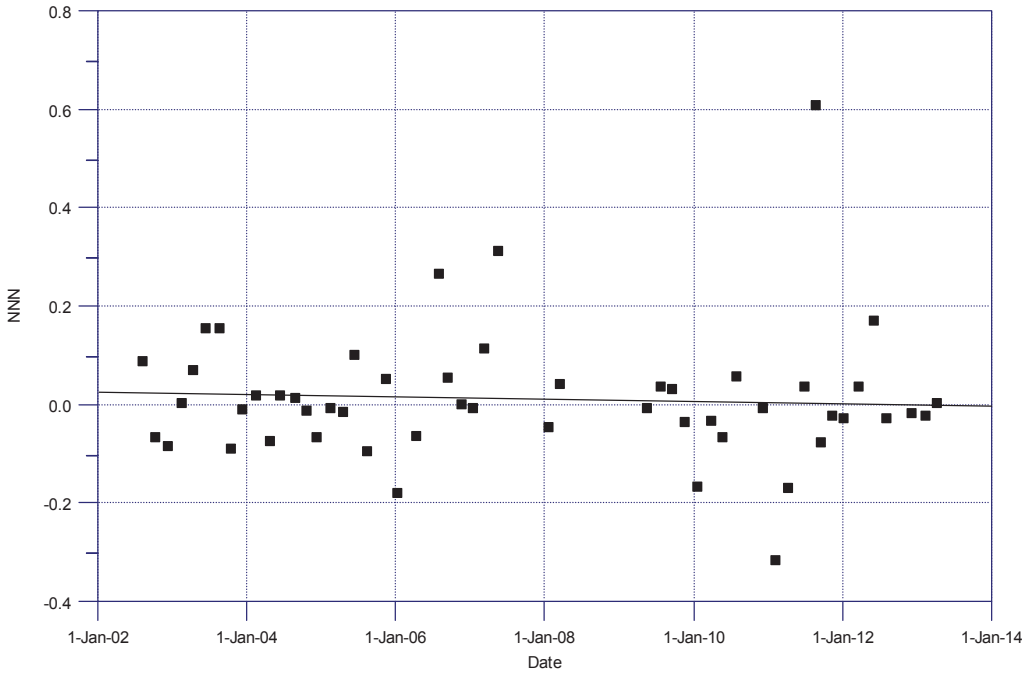


Figure A1.2 Long-term trend in flow-adjusted dissolved reactive phosphorus concentrations between 2002 and 2013. Statistics are outlined in Table 5.1.1.

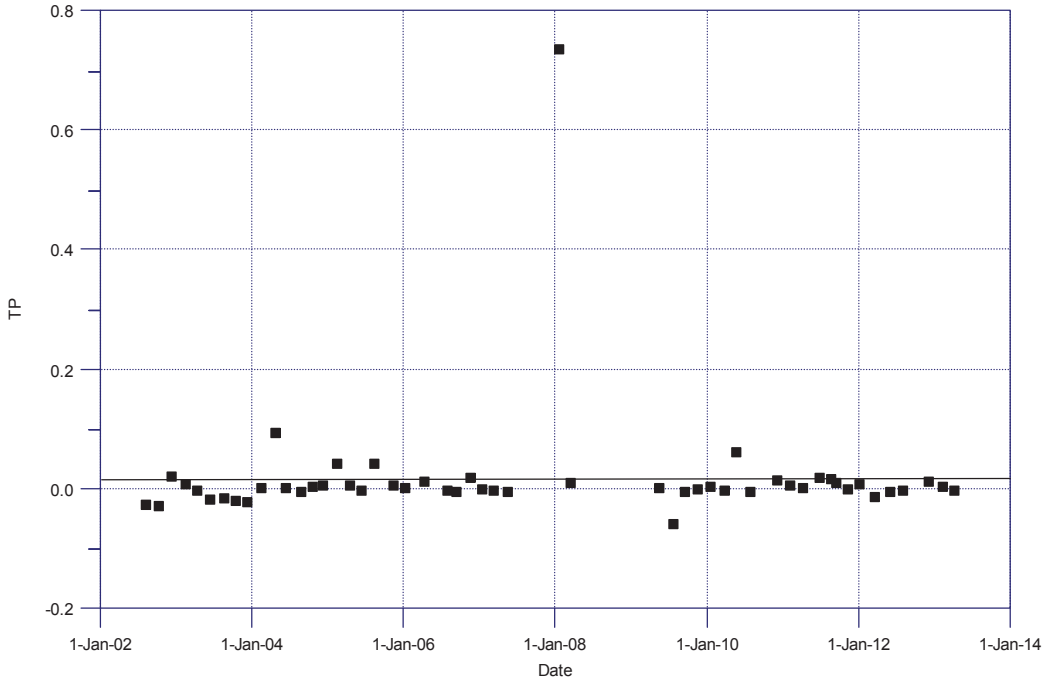
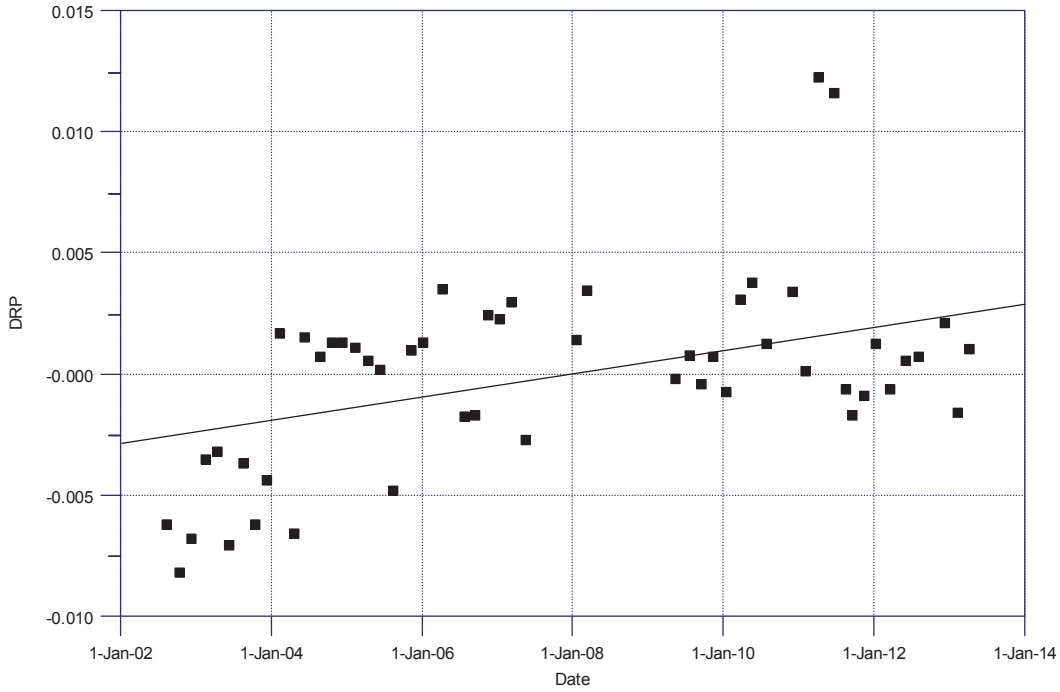


Figure A1.3 Long-term trend in flow-adjusted dissolved reactive phosphorus concentrations between 2002 and 2013. Statistics are outlined in Table 5.1.1.



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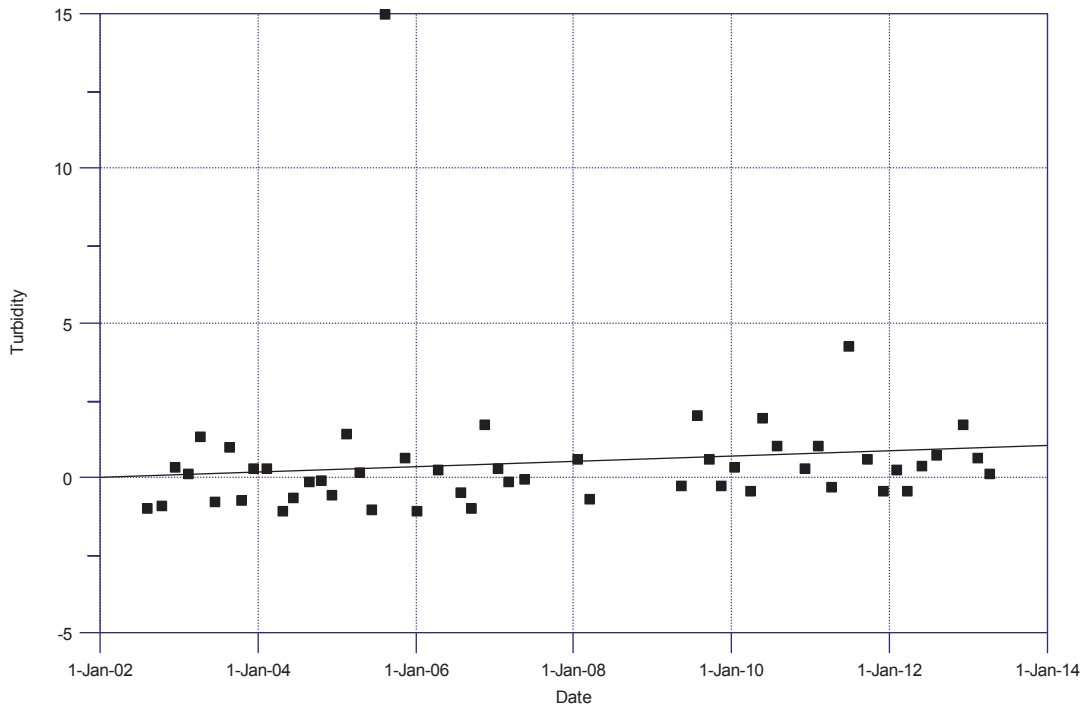

Figure A1.5 Long-term trend in flow-adjusted dissolved reactive phosphorus concentrations between 2002 and 2013. Statistics are outlined in Table 5.1.1.

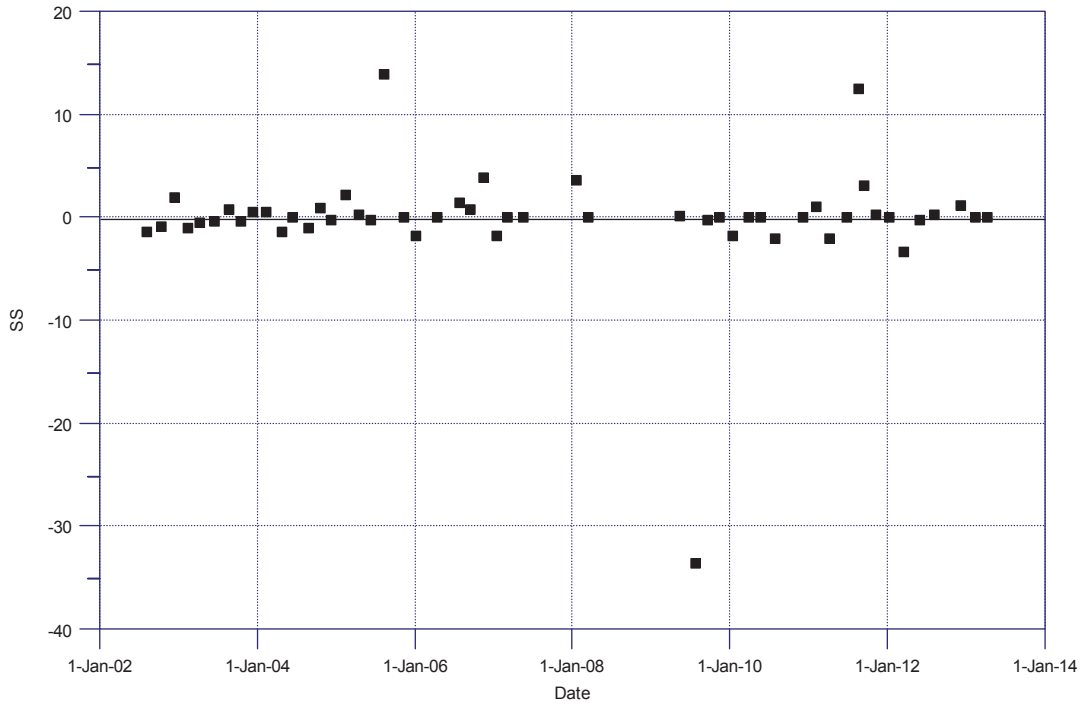

Figure A1.6 Long-term trend in flow-adjusted dissolved reactive phosphorus concentrations between 2002 and 2013. Statistics are outlined in Table 5.1.1.

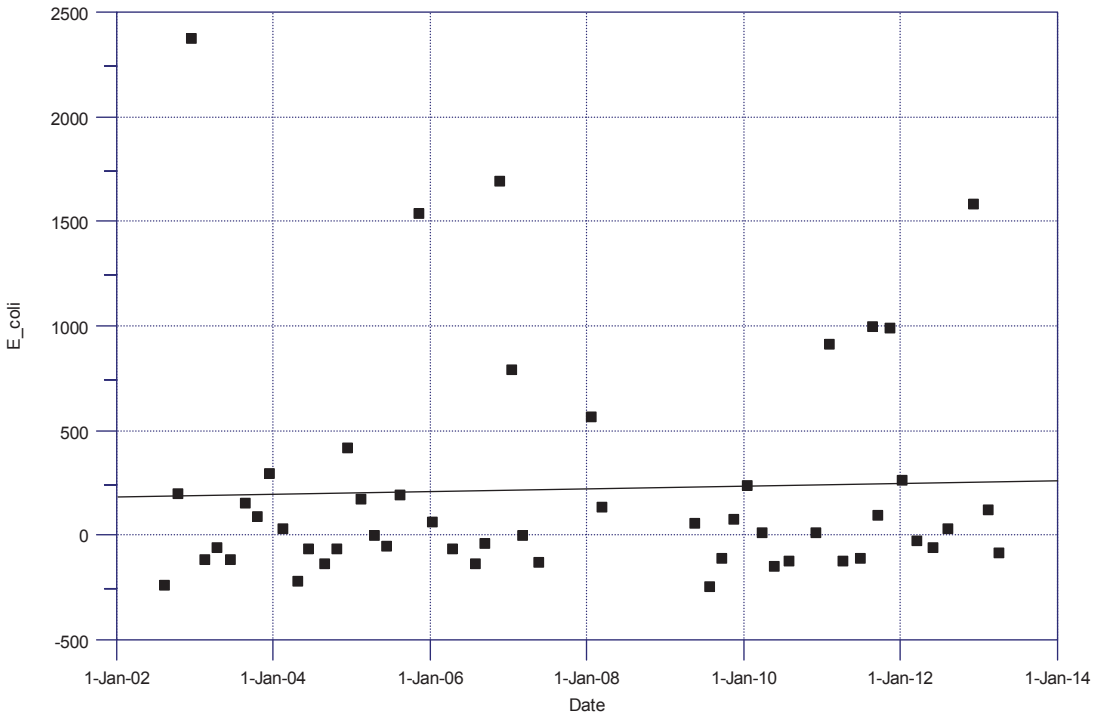

Figure A1.7 Long-term trend in flow-adjusted dissolved reactive phosphorus concentrations between 2002 and 2013. Statistics are outlined in Table 5.1.1.