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Executive summary

Section 35 of the Resource Management Act requires local authorities to undertake monitoring of the region's environment, including land, air, and fresh and marine water quality. The freshwater physicochemical component of the State of Environment Monitoring (SEM) programme for Taranaki was initiated by the Taranaki Regional Council in the 1995-96 monitoring year and subsequently has been continued in each year. Data from this programme was used as the basis for the first five-year SEM report published in 2003 and for trending purposes over the ten year period, 1995 to 2005 and the thirteen year period 1995 to 2008 as presented in the third SEM report published in 2009.

In the year under review, surveys continued to be performed regularly in the second week of every month from July 2013 to June 2014, under a narrower range of flow conditions than typical, ranging through several moderate freshes, to low late summer-autumn flows. This year was characterised by significantly higher median flows sampled by the programme in all rivers and streams. Each sampling run measured up to 22 physical and chemical water quality parameters at eleven sites representing seven selected ring plain catchments and one eastern hill-country catchment.

The twelve months of water quality data are presented for each of the sites together with a statistical summary for both the year and accumulated data to date. Results are discussed on a site-by-site basis, and more briefly, on a comparative parameters' basis. Data from the three Taranaki sites included in the NIWA national network monitoring programme are also presented and discussed.

Variability in site water quality occurred in response to flow conditions and with season. Generally there was some spatial deterioration in most aspects of water quality in a downstream direction. This was illustrated by poorer water clarity (increased turbidity), increased bacteriological counts and nutrient levels, and wider water temperature and pH ranges at downstream sites. This was usually coincident with increases in substrate algal cover during summer-autumn low flow conditions, a feature of Taranaki ring plain streams (and surface waters elsewhere in New Zealand); a response to elevated nutrient runoff, and warmer more open conditions in lower reaches of developed and farmland catchments. Higher turbidity and suspended solids levels (and therefore poorer visual clarity) characterised the eastern hill country Mangaehu and Waitara Rivers site in these 'rivers' lower reaches.

Over the 2013-2014 monitoring year, in general terms, water quality was comparatively similar to slightly worse in clarity, and to a lesser degree in suspended solids concentrations but deteriorated in median faecal coliform and enterococci bacteria numbers. Narrower temperature ranges, mainly due to lower maximum water temperatures, but similar median water temperatures, were measured in the 2013-2014 period compared with ranges and medians measured during the first eighteen years of the SEM programme. Median dissolved reactive phosphorus levels were elevated at two sites and total phosphorus levels were elevated at five sites. The site in the lower Waingongoro River downstream of the recent diversion of the Eltham WWTP discharge (by pipeline) out of the catchment showed minimal significant improvement in the recent year, coincident with a deterioration in three median nutrient concentrations and median faecal coliform bacteria at the upstream Eltham Road site. Median nitrate and total nitrogen species levels were lower at up to two sites, while median ammonia nitrogen levels were higher at seven sites and lower at two sites.

The report also provides an assessment of each site's statistical water quality in terms of appropriate guidelines and standards for various usages based upon a summary of the record for the complete 1995-2014 period.

This report on the results of the 2013-2014 monitoring period also includes recommendations for the 2014-2015 period and the results of internal and external laboratory quality control exercises, which, with relatively few exceptions, resulted in good inter and intra-laboratory precision.

With the availability of a suitable period (minimum of ten years) of robust data and access to appropriate statistical software, temporal trend analyses were performed for state of the environment reporting purposes and reported elsewhere during 2006. Regular updates of these temporal trends subsequently have been prepared at appropriate intervals and reported separately, and data for the period 1995 to 2014 are summarised and presented for all eleven sites briefly in the current Annual Report.

Long term (19-year) physicochemical trends have shown some significant deterioration in aspects of water quality (particularly nutrients) in many of the middle and lower catchments (e.g. the Mangaoraka Stream at Corbett Road, Punehu Stream at SH 45, and Waiwhakaiho River at SH3). There has been a significant long term improvement in total nitrogen at six of the eleven sites monitored. Long term trends for faecal coliforms and enterococci bacteria showed four statistically significant changes over the 19-year period (mainly deterioration located at lower catchment sites). Significant deteriorations in black disc clarity were recorded at three sites, two of which reflected historical erosion events in the headwaters. The most improvement in long term water quality has been illustrated in the Waingongoro River at SH 45 with significantly improving trends in DRP, total phosphorus, nitrate, and total nitrogen. This improvement has been coincident with land-irrigation of a major industrial (meatworks) discharge and the diversion of Eltham's WWTP discharge out of the river in recent years. Most long term deterioration in aspects of water quality have been found in the lower reaches of the Mangaoraka Stream where six parameters have significantly deteriorated (both phosphorus species, both bacteriological species, black disc, and BOD_5) and no parameters have shown significant long term improvement.

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1. Introduction

The Resource Management Act 1991 ('the RMA') established new requirements for local authorities to undertake environmental monitoring. Section 35 of the RMA requires local authorities to monitor, among other things, the state of the environment of their region or district, to the extent that is appropriate to enable them to effectively carry out their functions under the Act.

To this effect, the Taranaki Regional Council ('the Council') established a state of the environment monitoring ('SEM') programme for the region. This programme is outlined in the Council's 'State of the Environment Monitoring Procedures Document', which was prepared in 1997. The monitoring programme is based on the significant resource management issues that were identified in the Council's Regional Policy Statement for Taranaki (1994). The relevant issues are presented in Appendix II.

The SEM programme is comprised of a number of individual monitoring activities, many of which are undertaken and managed on an annual basis (from 1 July to 30 June). For these annual monitoring activities, summary reports are produced following the end of each monitoring year. Where possible, individual consent monitoring programmes have been integrated with the SEM programme to save duplication of effort and minimise costs. The purpose of annual SEM reports is to summarise monitoring activity results for the year and provide a brief interpretation of these results.

Annual SEM reports act as 'building blocks' towards the preparation of the regional state of the environment report every five years. The Council's first, or baseline, state of the environment report was prepared in 1996 (TRC, 1996b), summarising the region's progress in improving environmental quality in Taranaki over the past two decades. The second report (for the period 1995-2000) was published in 2003 (TRC, 2003). Data spanning the ten year period 1995 to 2005 have been used in the preparation of a trend report (TRC, 2006). The third State of the Environment report (for the period 1995 to 2007) was published (TRC, 2009a) and included trend reporting and the fourth report (for the 1995 to 2013 period) is currently in preparation. The provision of appropriate computer software statistical procedures now allows regular reporting on trends in the environmental quality over time, in relation to Council's ongoing monitoring activities, now that there has been an accumulation of a comprehensive dataset of sufficient duration to permit a meaningful analysis of trends (i.e. minimum of 10 years).

This report summarises the results for the sites surveyed in the freshwater physicochemical SEM programme over the 2013-2014 monitoring year, the nineteenth year of the programme. Previous years' results have been presented in the TRC Technical Reports listed in the References section.

A network of nine freshwater sites was established in mid-1995 for physicochemical monitoring on a long-term basis to provide information on trends in the state of Taranaki's regional surface water quality and this network was maintained with the addition (for various purposes) of one site during the 1998-99 period and another site in the 2003-2004 period.

The Taranaki Regional Council's SEM programme also includes a freshwater biological component encompassing the same eleven sites plus forty-six additional sites, which is reported separately (see TRC, 2013a).

The physicochemical programme has been designed to provide a general picture of water quality for eight different catchments in the region affected by a range of different land uses and industries, and recognising cumulative impacts. This monitoring is undertaken in addition to consent compliance monitoring and will enable the Council to report on trends in water quality over time for the Taranaki region. The monitoring programme covers eight of the sixty-nine catchments in the Taranaki region and 39% of the total area of the region (Figures 1 and 2). Given that a number of the largest catchments in the region are included in the network, it provides a relatively representative indication of the state of surface water in the region.

The sites were specifically selected to be representative of major/significant waterways and positioned in the upper, middle, and lower reaches of catchments. Both ringplain and eastern hill country catchments were represented with a mixture of land uses including waterways under industrial discharge pressures.

The existing programme also meshes with the national programme, which has been operated by the National Institute of Water and Atmospheric Research (NIWA) since January 1989. This National Water Quality Network (NWQN) was designed to monitor changes in water quality by sampling physical and chemical parameters monthly at 77 river sites around New Zealand (Smith, et al, 1989). The programme includes three sites in Taranaki (Figure 1); one upper/mid catchment site (Manganui River at State Highway 3, incorporating some farm land area) and two lower catchment sites (Waitara River at Bertrand Road and Waingongoro River at State Highway 45).

Using data collected in the NWQN since 1989, NIWA scientists have analysed trends over time for a number of parameters at the Taranaki sites and have rated them relative to other New Zealand rivers (McBride, 1996, TRC, 2003 and TRC, 2009). Water quality has been relatively stable at the Waitara River site compared with national trends and, not surprisingly, water quality remains high at the upper/mid catchment Manganui River site. A deterioration in aspects of water quality has occurred at the site in the lower reaches of the Waingongoro River over time. Trends in nutrient levels (nitrates and phosphorus) have been identified at both lower catchment sites. There has been a reduction in ammonia-N levels at the Waitara River site (between 1989 and 2007) over the longer period. Levels of all nutrient species increased at the Waingongoro River site (between 1989 and 2007), although phosphorus levels have stabilised since 1995, most likely due to a reduced loading from a major point source discharge in the mid reaches of the Waingongoro River catchment.

The design of the TRC SEM programme was deliberately chosen to follow the design of the NIWA national programme although the actual sampling days in each monthly survey do not coincide for the two programmes. However, the two programmes are complementary and each is designed for robust trend detection purposes using similar methodologies.

Physicochemical water quality monitoring is performed to obtain an understanding of the physical and chemical characteristics of water by means of statistical sampling (Ward & McBride, 1986). It requires repetitive measurements of such characteristics through time. The complex variations of those characteristics in the natural, and more especially the modified environment, makes it difficult to obtain accurate understandings, and therefore the monitoring systems employed must be designed to supply the required information at the necessary sensitivity, accuracy and precision (Ward & McBride, 1986).

2. Sites

The Council has chosen sites which are within the existing hydrological flow monitoring network where possible. Hydrological information is vital to the interpretation of physicochemical data. Generally, sites have been positioned strategically within representative catchments in the region, with industrial and/or intensive farming land uses, and including both the higher and lower quality waterways of the region (Figures 1 and 2).

The sites selected and maintained for the monitoring of physicochemical water quality by Taranaki Regional Council are listed in Table 1, with comments relating to selection criteria following the table.

Table 1 Sample sites for TRC network programme

Stream	Location	Site code
Maketawa Stream	at Tarata Road	MKW000300
Mangaoraka Stream	at Corbett Road	MRK000420
Waiwhakaiho River	at SH3	WKH000500
Stony River	at Mangatete Road	STY000300
Punehu Stream	at Wiremu Road	PNH000200
Punehu Stream	at SH45	PNH000900
Waingongoro River	at Eltham Road	WGG000500
Waingongoro River	at SH45	WGG000900
Patea River	at Barclay Road	PAT000200
Patea River	at Skinner Road	PAT000360
Mangaehu River	at Raupuha Road	MGH000950

All sites are described in detail and referenced with location maps, photographs, GPS and map references on the internal electronic TRC site index card system which is integrated into the existing LABSYS water quality computer and Taradise GIS databases.

A brief description of all sites in the Taranaki Regional Council and NIWA programmes follows.

Site Maketawa Stream at Tarata Road

The site in the lower reaches of a developed farmland catchment is representative of a sub-catchment of the Manganui and Waitara Rivers catchments, with valued trout and native fish habitat. The stream drains into the Manganui River below the principal abstractions for the Motukawa HEP scheme. This site requires flow gauging on each sampling occasion for rating purposes.

Site Mangaoraka Stream at Corbett Road

This site is representative of a northern Taranaki ringplain stream, (but with its source outside the National Park), draining an agricultural catchment. The site is also a hydrological recording station. It is located toward the lower catchment and is the principal tributary of the lower Waiongana Stream. The Mangaoraka Stream is a trout fishery of local importance.

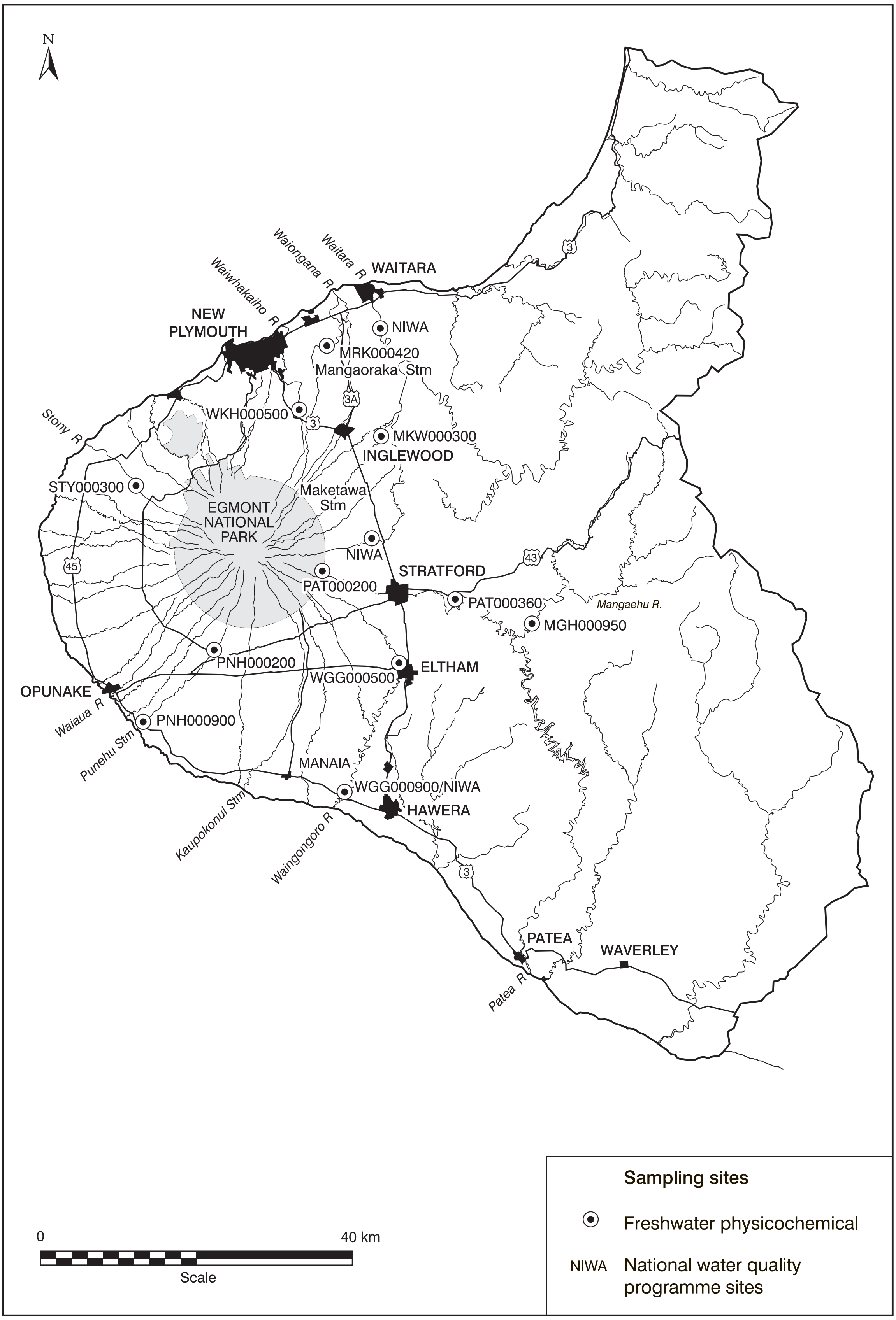

Figure 1 Freshwater physicochemical SEM sampling sites

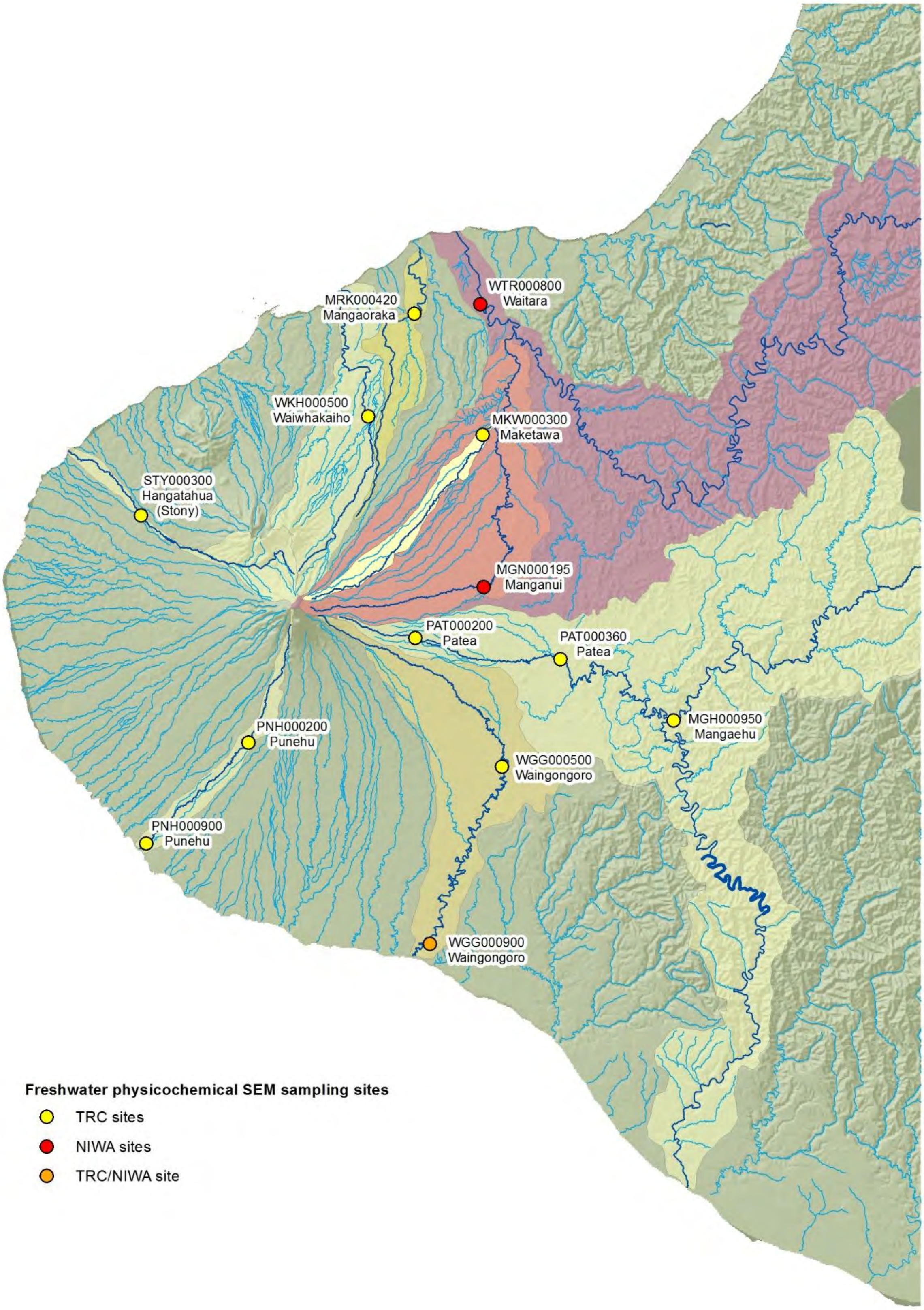

Figure 2 Freshwater physicochemical SEM sampling sites aerial map

Site Waiwhakaiho River at SH3

This site is an existing hydrological recording station and was included in the Taranaki ring plain survey (TRC 1984). It is representative of the mid catchment of a National Park-sourced river draining developed farmland and is immediately upstream of the major diversion site for the New Plymouth water supply and the Mangorei HEP scheme. This site has also been integrated into compliance monitoring programmes related to the diversion consent. The lower river is markedly influenced by HEP generation releases and industrial impacts and is further monitored by way of a site specific monitoring programme. Occasional natural headwater erosion events may affect water quality from time to time (including iron-oxide release from tributary streams).

Site Hangatahua (Stony) River at Mangatete Road

This river is protected in its natural state by way of a Local Conservation Order. This site is as close to the National Park Boundary (within 7 km) as realistically possible, given the need for regular access. The site was used during the ring plain survey (TRC, 1984). This river is notoriously difficult to rate (hydrologically) and regular flow gauging is necessary although, more recently, a hydrological recording station has been established. The river has also been affected by significant natural erosion events in the headwaters from time-to-time. Several of these events have occurred since the SEM programme commenced particularly in the latter part of 2006, during mid 2008 and mid 2009, and early 2014.

Sites Punehu Stream at Wiremu Road (1) and at SH45 (2)

This stream is representative of a south-western Taranaki catchment subjected primarily to intensive agricultural land use with water quality potentially affected by diffuse source run-off and point source discharges from dairy shed treatment pond systems in the lower reaches of the catchment and Mangatawa Stream sub-catchment in particular. No industrial discharges in the catchment are known to occur. Both sites were included in the Taranaki ring plain survey and the lower site near the coast remained a NIWA hydrological recording station as a representative basin until 2011 when the station was shutdown. The upstream site (located approximately 2 km from the National Park boundary) is representative of relatively unimpacted stream water quality although this reach is in open farmland, and requires regular flow rating. Flow gaugings at this site are therefore necessary on each sampling occasion and flow gaugings were implemented at the lower reach site in 2011.

Sites Waingongoro River at Eltham Road (1) and at SH45 (2)

Both sites were Taranaki ring plain survey sites and are existing hydrological recording stations. Site 1 is representative of agricultural impacts in the upper catchment and provides a control site for monitoring the impacts of major industrial/municipal discharges which occur in the vicinity of Eltham. The site is therefore also included in a consent compliance monitoring programme.

Site 2 is representative of the combined impacts of industrial/municipal and agricultural point source discharges plus diffuse run-off, in the lower reaches of a principal Taranaki trout fishery river and the longest river confined to the ring plain. One of the major industrial (meatworks) point-source discharges to the mid reaches of the river has been partially re-directed to land irrigation during summer-autumn low flow periods since January 2001 and the Eltham WWTP discharge was diverted out of the catchment (by pipeline to the Hawera WWTP) from July, 2010.

This site is also currently part of the NIWA (NZ rivers) survey network and NIWA data will continue to be utilised as well as data collected by the Council since July 1998.

Sites Patea River catchment: Patea River at Barclay Road, Skinner Road, and Mangaehu River at Raupuha Road bridge

The Barclay Road site is representative of the upper catchment adjacent to the National Park above agricultural impacts and requires flow ratings to be established. The Skinner Road site, which is integrated with consent compliance monitoring programmes, was a ring plain survey site, and is representative of developed farmland drainage and is downstream of Stratford (urban run-off, closed landfill and up-graded (in 2009) oxidation pond discharges and the combined cycle power station discharge). It is also an established hydrological recorder station. The Mangaehu River site, in the lower reaches of one of the largest hill country catchments, represents the principal eastern hill country tributary flowing into the Patea River and has an established hydrological recorder station.

Site Waitara River at Bertrand Road

This site is currently part of the NIWA (NZ rivers) survey network and is an existing hydrological recording station. It was also a Taranaki ring plain survey site, and is representative of the lower reaches of the largest Taranaki catchment (draining both ring plain and eastern hill country catchments) but upstream of any tidal influence. NIWA data is utilised for this site.

Site Manganui River at SH3

This site was a Taranaki ring plain survey site and is currently one of the three Taranaki sites in the NIWA (NZ rivers) survey network in conjunction with the existing hydrological recording station. The site is representative of the upper/mid reaches (approximately 7 km from the National Park boundary) of a high quality river receiving limited agricultural run-off. NIWA data is utilised for this site.

3. Sampling procedure and analytical parameters

Sampling has been performed monthly on the second Wednesday of each calendar month, to allow for typical variations in relation to fluctuating flows and seasonal trends. This is consistent with the scientifically established sampling frequency that is required for long-term trend analysis. It has been performed by trained Council Technical Officers under the supervision of the designated Scientific Officer and according to standard TRC field methodology outlined in an appropriate manual (TRC 2004a) which was last revised in 2012.

Analyses have been performed in the TRC IANZ-registered chemistry laboratory using standard methods. The parameters analysed and site of measurements are listed in Table 2.

Table 2 SEM physicochemical parameters and site of measurement

Parameter	Unit	Location
Time	NZST	On site
Temperature	˚C	On site
Flow	m^3/s	On site recorder or rated SG or gauging
Dissolved oxygen	g/m^3	On site
BOD_5 (total)	g/m^3	Laboratory
pH	-	Laboratory
Conductivity @ 20°C	mS/m	Laboratory
Black disc clarity	m	On site
Turbidity	NTU	Laboratory
Absorbance @ 770, 440, 340 nm	/cm	Laboratory (membrane filtration)
Ammonia-N	g/m^3N	Laboratory
Nitrate-N	g/m^3N	Laboratory
Total-N	g/m^3N	Laboratory
Dissolved reactive phosphorus	g/m^3P	Laboratory
Total phosphorus	g/m^3P	Laboratory
Alkalinity	g/m^3CaCO_3	Laboratory
Suspended solids	g/m^3	Laboratory
Faecal coliform and *E. coli* bacteria (mTech)	nos/100 ml	Laboratory
Enterococci bacteria	nos/100 ml	Laboratory

The precision of the laboratory analyses has been checked regularly by the collection of split samples from one randomly chosen site on selected sampling runs (generally every 3 months). These samples were unidentified for laboratory purposes and included with the other samples in the normal manner for laboratory analysis. Comparative results have been stored in the appropriate database and a separate internal report prepared for quality control purposes (see Appendix III).

Stream flow gaugings have been performed at the five sites where no permanent hydrological stations exist and/or the rating is unstable, in conjunction with each monthly sampling survey run.

All samples were logged into the TRC computer database following receipt by the laboratory with subsequent analytical results and audited flow data stored in this database.

4. Water quality results

Water quality data accumulated for the period July 2013 to June 2014 are presented for each of the eleven sites. Statistical summaries of this data and the cumulative data for nine sites (July 1995 to June 2014), one site in the lower Waingongoro River (July 1998 to June 2014), and one site in the lower Maketawa Stream (July 2003 to June 2014) are also presented on a site-by-site basis, together with a general discussion of water quality at each site. A comparison of water quality through the region is provided following the individual sites' discussions (Section 4.2).

4.1 Sites' water quality

Maketawa Stream at Tarata Road (site: MKW000300)

Analytical data from the monthly samples are presented in Table 3.

Table 3 Analytical results from monthly samples: Maketawa Stream at Tariki Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m^3 $CaCO_3$)	Black disc (m)	BOD_5 (g/m^3)	Cond @ 20 C (mS/m)	DO (g/m^3)	DO Sat (%)	DRP (g/m^3P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
10 Jul 2013	0805	0.034	0.008	0.000	20	0.35	1.4	6.3	11.7	99	0.029	7900	9700
14 Aug 2013	0800	0.031	0.006	0.000	22	0.80	0.8	7.3	11.2	99	0.025	520	250
10 Sep 2013	0800	0.014	0.003	0.000	32	2.26	0.6	9.2	11.8	101	0.017	230	21
10 Oct 2013	0710	0.052	0.011	0.001	16	1.56	0.6	6.1	11.4	100	0.020	800	120
13 Nov 2013	0705	0.013	0.003	0.000	29	3.64	0.8	8.8	10.8	100	0.028	150	29
11 Dec 2013	0700	0.016	0.004	0.000	30	3.12	<0.5	8.7	10.1	99	0.030	490	40
08 Jan 2014	0700	0.036	0.007	0.000	24	1.81	0.6	7.5	10.2	101	0.030	2000	930
12 Feb 2014	0700	0.015	0.003	0.000	31	3.01	0.6	8.6	9.7	100	0.028	270	800
12 Mar 2014	0705	0.010	0.003	0.000	34	2.46	<0.5	9.1	10.0	99	0.040	290	730
09 Apr 2014	0800	0.023	0.006	0.000	32	1.55	1.0	9.0	9.9	98	0.038	3700	7000
14 May 2014	0800	0.008	0.003	0.000	29	2.99	<0.5	9.0	10.9	100	0.034	460	270
11 Jun 2014	0800	0.067	0.015	0.001	15	0.44	0.9	5.8	10.8	100	0.030	830	400

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m^3/s)	NH_4 (g/m^3N)	NO_2 (g/m^3N)	NO_3 (g/m^3N)	pH	SS (g/m^3)	Temp (C)	TKN (g/m^3N)	TN (g/m^3N)	TP (g/m^3P)	Turb (NTU)
10 Jul 2013	0805	8000	3.950	0.036	0.004	0.386	7.5	14	7.9	0.47	0.86	0.144	7.2
14 Aug 2013	0800	520	2.991	0.019	0.003	0.307	7.5	5	9.2	0.13	0.44	0.052	2.5
10 Sep 2013	0800	230	1.608	0.009	<0.001	0.240	7.6	<2	8.0	0.04	0.28	0.030	0.9
10 Oct 2013	0710	800	3.160	0.010	0.002	0.268	7.4	3	8.4	0.11	0.38	0.035	1.2
13 Nov 2013	0705	150	1.561	0.014	0.001	0.209	7.5	<2	11.7	0.03	0.24	0.029	0.6
11 Dec 2013	0700	500	2.608	0.009	0.003	0.497	7.7	<2	13.8	0.11	0.61	0.029	0.8
08 Jan 2014	0700	2000	4.002	0.017	0.003	0.457	7.5	<2	13.8	0.11	0.57	0.044	1.2
12 Feb 2014	0700	280	1.066	0.010	<0.001	0.019	7.6	<2	15.5	0.11	0.13	0.038	0.6
12 Mar 2014	0705	290	0.838	0.008	<0.001	0.019	7.6	<2	14.7	0.11	0.13	0.048	0.5
09 Apr 2014	0800	3800	1.700	0.005	0.001	0.039	7.8	4	14.1	0.05	0.09	0.056	1.2
14 May 2014	0800	460	2.275	0.008	0.002	0.468	7.6	<2	10.7	0.02	0.49	0.035	1.1
11 Jun 2014	0800	830	4.834	0.058	0.005	0.385	7.3	6	10.6	0.29	0.68	0.083	2.6

The statistical summary of this data is presented in Table 4.

Table 4 Statistical summary of data from July 2013 to June 2014: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.008	0.067	0.020	12	0.018
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.015	0.005	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity total	g/m^3 $CaCO_3$	15	34	29	12	7
BLACK DISC	Black disc transparency	m	0.35	3.64	2.04	12	1.1
BOD_5	Biochemical oxygen demand 5 day	g/m^3	< 0.5	1.4	0.6	12	0.3
CONDY	Conductivity @ 20°C	mS/m	5.8	9.2	8.6	12	1.3
DO	Dissolved oxygen	g/m^3	9.7	11.8	10.8	12	0.7
PERSAT	Dissolved oxygen saturation	%	98	101	100	12	1
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.017	0.040	0.030	12	0.007
ECOL	E. coli bacteria	nos/100 ml	150	7900	505	12	2265
ENT	Enterococci bacteria	nos/100 ml	21	9700	335	12	3179
FC	Faecal coliform bacteria	nos/100 ml	150	8000	510	12	2299
FLOW	Flow	m^3/s	0.838	4.830	2.440	12	1.27
NH_4	Ammoniacal nitrogen	g/m^{3}N	0.005	0.058	0.010	12	0.015
NO_2	Nitrite nitrogen	g/m^{3}N	< 0.001	0.005	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m^{3}N	0.02	0.50	0.29	12	0.175
pH	pH		7.3	7.8	7.6	12	0.1
SS	Suspended solids	g/m^3	< 2	14	< 2	12	3
TEMP	Temperature	°C	7.9	15.5	11.2	12	2.8
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.02	0.47	0.11	12	0.13
TN	Total nitrogen	g/m^{3}N	0.09	0.86	0.41	12	0.24
TP	Total phosphorus	g/m^{3}P	0.029	0.144	0.041	12	0.033
TURB	Turbidity	NTU	0.5	7.2	1.2	12	1.9

A statistical summary of the eleven years' data collected since 1 July 2003 is presented in Table 5.

Table 5 Statistical summary of data from July 2003 to June 2014: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.002	0.141	0.018	132	0.023
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.031	0.004	132	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	132	0
ALKT	Alkalinity total	g/m^3 $CaCO_3$	7	34	28	132	6
BLACK DISC	Black disc transparency	m	0.21	5.23	2.60	132	1.15
BOD_5	Biochemical oxygen demand 5 day	g/m^3	< 0.5	2.3	<0.5	132	0.3
CONDY	Conductivity @ 20°C	mS/m	3.2	12.6	8.5	132	1.2
DO	Dissolved oxygen	g/m^3	9.0	12.5	10.6	132	0.8
PERSAT	Dissolved oxygen saturation	%	90	102	98	132	2
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.004	0.040	0.022	132	0.007
ECOL	E. coli bacteria	nos/100 ml	50	26000	305	132	2777
ENT	Enterococci bacteria	nos/100 ml	6	9700	150	132	1380
FC	Faecal coliform bacteria	nos/100 ml	50	26000	315	132	2787
FLOW	Flow	m^3/s	0.838	17.200	1.958	132	2.67
NH_4	Ammoniacal nitrogen	g/m^{3}N	0.003	0.093	0.009	132	0.016
NO_2	Nitrite nitrogen	g/m^{3}N	< 0.001	0.009	0.002	132	0.002
NO_3	Nitrate nitrogen	g/m^{3}N	< 0.01	0.92	0.25	132	0.208
pH	pH		6.8	7.9	7.6	132	0.2
SS	Suspended solids	g/m^3	< 2	55	< 1	132	7
TEMP	Temperature	°C	4.8	17.6	11.5	132	3
TKN	Total kjeldahl nitrogen	g/m^{3}N	< 0.01	0.52	0.07	132	0.11
TN	Total nitrogen	g/m^{3}N	0.05	0.96	0.39	132	0.23
TP	Total phosphorus	g/m^{3}P	0.018	0.180	0.034	132	0.026
TURB	Turbidity	NTU	0.5	14	0.85	132	1.9

Discussion

2013-2014 period

Good aesthetic water quality was indicated by a median black disc clarity of 2.04 metres, in the lower reaches of this ring-plain stream near to its confluence with the Manganui River. The maximum clarity (black disc value of 3.64 m) was recorded in late spring under relatively low flow conditions (1.56 m^3/s). No significant floods, but several small freshes, were sampled during the year, with relatively small elevations in turbidity (to 7.2 NTU) and in suspended solids concentration (14 g/m^3) under fresh flow conditions (3.95 m^3/sec) sampled in mid winter 2013. Poorer water quality conditions apparent at the time of this fresh flow were recorded with increases in bacterial number (8000 faecal coliforms/100ml), BOD_5 (1.4 g/m^3), and some nutrients (e.g. TP [0.144 g/m^3]) recorded when black disc visibility decreased to 0.35 m.

pH was relatively stable (7.3 to 7.8), although it would be expected that pH would have reached a higher maximum later in the day than at the usual times of sampling (i.e. prior to 0805 NZST), particularly during summer low flow conditions.

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 98% saturation) and low BOD_5 levels (median: 0.6 g/m^3). Bacteriological quality was poor, but typical of the lower reaches of developed ring plain catchments, subject to agricultural impacts, with median faecal coliform and enterococci numbers of 510 and 335 (per 100 mls) respectively. Water temperature varied over a moderate range of 7.6°C with a maximum late summer (early morning) river temperature of 15.5°C recorded in February 2014.

Brief comparison with the previous 2003-2013 (ten year) period

Generally, stream water quality at this site during the 2013-2014 period was slightly poorer in appearance/clarity (lower median black disc clarity [by 0.58 m], higher median turbidity [by 0.4 NTU], but no difference in median suspended solids level). Bacterial water quality was markedly poorer, with an increase in median faecal coliform number of 205 per 100 mls and an increase in median enterococci number of 185 per 100 mls. Median water temperature was very similar, while the maximum water temperature (15.5°C) was 2.1°C lower than the previous maximum recorded. Other physicochemical aspects of water quality were very similar for the two periods. Relatively narrow ranges for parameters such as suspended solids, turbidity, pH and total phosphorus reflected the lack of significant flood events sampled during the 2013-2014 period. Median flow sampled during 2013-2014 was higher (by 516 l/sec) than the median of flows sampled over the previous ten-year period due in part to the several fresh flow conditions sampled during the latest period despite the lowest flow event (0.838 m^3/sec) sampled to date, in March 2014. Median pH values were identical and the maximum pH value was within 0.1 unit of that of the past ten-year record. All nutrient species had higher median values (by 5 to 63%) during the monitoring year in comparison with the medians of the previous ten year record.

Mangaoraka Stream at Corbett Road (site: MRK000420)

Analytical data from the monthly samples are presented in Table 6 and the stream flow record is illustrated in Figure 3.

Table 6 Analytical results from monthly samples: Mangaoraka Stream at Corbett Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ CaCO₃)	Black disc (m)	BOD_5 (g/m^3)	Cond @ 20 C (mS/m)	DO (g/m^3)	DO Sat (%)	DRP (g/m^3P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
10 Jul 2013	0835	0.030	0.007	0.000	29	0.25	3.1	11.2	11.2	97	0.016	2400	1200
14 Aug 2013	0830	0.024	0.005	0.000	46	0.96	0.9	15.3	10.8	99	0.010	1400	5700
10 Sep 2013	0835	0.019	0.004	0.000	42	2.43	0.6	15.0	11.3	102	0.005	1000	200
10 Oct 2013	0745	0.027	0.006	0.000	40	1.91	0.6	14.2	10.8	99	0.009	2300	700
13 Nov 2013	0750	0.027	0.007	0.001	46	2.38	0.6	15.4	11.0	102	0.009	740	150
11 Dec 2013	0730	0.022	0.005	0.000	34	1.73	0.5	12.4	10.1	101	0.018	930	440
08 Jan 2014	0730	0.037	0.007	0.000	32	1.19	1.1	11.6	9.8	99	0.019	6300	3500
12 Feb 2014	0730	0.026	0.005	0.000	75	2.52	1.0	21.3	8.9	93	0.004	1700	1500
12 Mar 2014	0745	0.022	0.005	0.000	108	2.34	0.7	27.6	8.9	89	0.008	970	460
09 Apr 2014	0830	0.028	0.006	0.000	108	2.51	1.2	28.7	8.7	88	0.007	4100	4200
14 May 2014	0835	0.018	0.005	0.000	37	1.40	1.4	13.8	10.4	100	0.032	2100	20000
11 Jun 2014	0835	0.037	0.008	0.000	29	0.32	3.0	11.7	10.4	98	0.021	3500	4800
Date	**Time (NZST)**	**FC (Nos/ 100ml)**	**Flow (m^3/s)**	**NH_4 (g/m^3N)**	**NO_2 (g/m^3N)**	**NO_3 (g/m^3N)**	**pH**	**SS (g/m^3)**	**Temp (C)**	**TKN (g/m^3N)**	**TN (g/m^3N)**	**TP (g/m^3P)**	**Turb (NTU)**
10 Jul 2013	0835	2400	3.493	0.117	0.008	0.912	7.5	49	9.6	1.10	2.02	0.252	20
14 Aug 2013	0830	1400	1.332	0.017	0.003	0.837	7.7	4	10.9	0.03	0.87	0.033	2.2
10 Sep 2013	0835	1000	1.042	0.012	0.003	0.827	7.6	<2	10.6	0.13	0.96	0.018	1.3
10 Oct 2013	0745	2300	1.457	0.014	0.005	1.035	7.5	<2	10.6	0.14	1.18	0.028	1.5
13 Nov 2013	0750	740	0.855	0.009	0.003	0.707	7.7	<2	12.4	0.07	0.78	0.018	1.2
11 Dec 2013	0730	930	2.594	0.012	0.003	0.857	7.6	4	15.3	0.22	1.08	0.032	1.7
08 Jan 2014	0730	6400	3.115	0.076	0.014	0.806	7.5	5	15.4	0.55	1.37	0.047	2.2
12 Feb 2014	0730	1700	0.376	0.010	0.002	0.328	7.7	<2	17.4	0.30	0.63	0.018	1.3
12 Mar 2014	0745	970	0.184	0.013	0.007	0.573	7.8	<2	15.9	0.21	0.79	0.020	1.0
09 Apr 2014	0830	4100	0.171	0.010	0.005	0.405	7.9	<2	15.4	0.27	0.68	0.022	1.2
14 May 2014	0835	2100	1.724	0.082	0.004	0.746	7.5	4	12.4	0.25	1.00	0.054	2.3
11 Jun 2014	0835	3600	4.706	0.100	0.014	0.936	7.4	27	12.2	0.96	1.91	0.177	8.5

The statistical summary of this data is presented in Table 7.

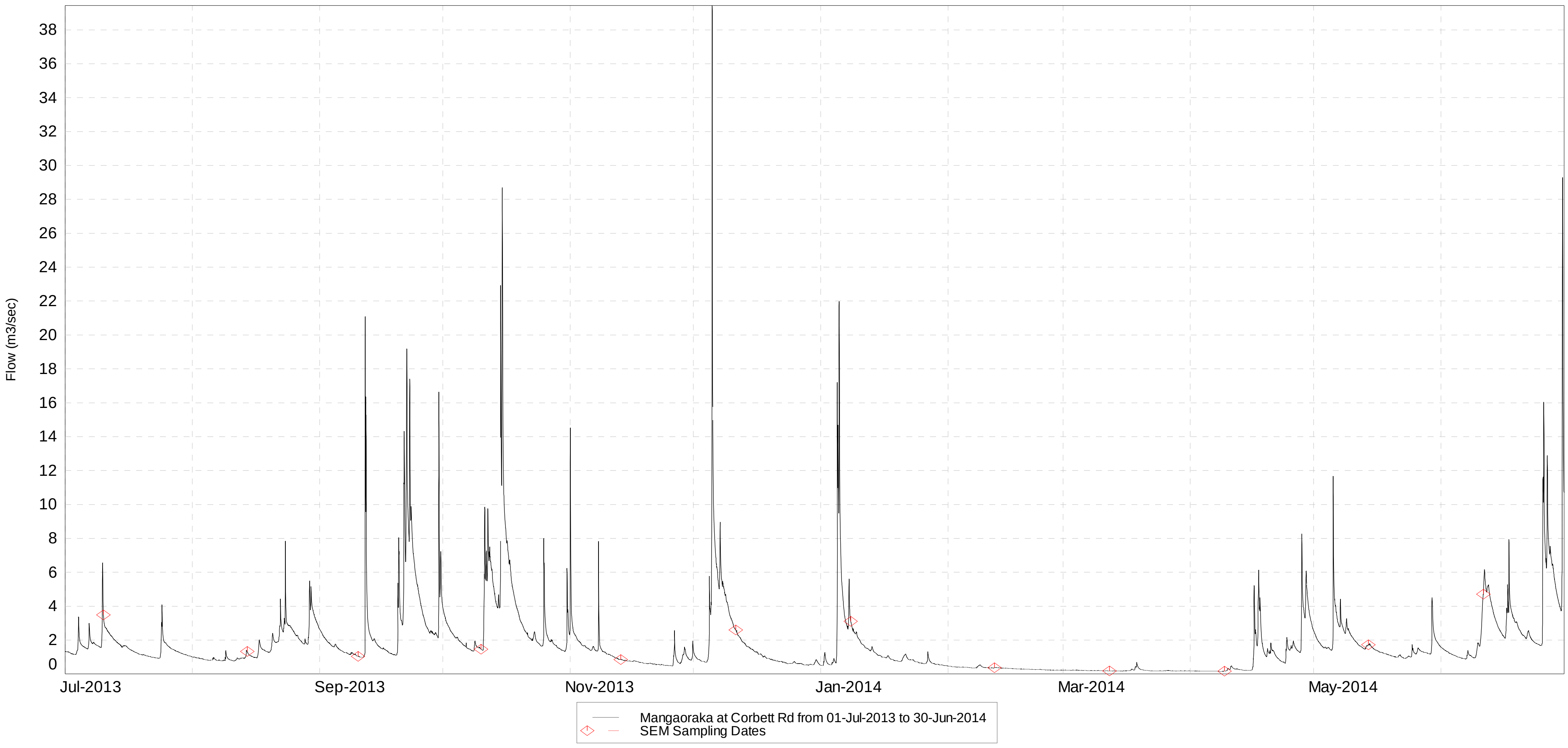

Figure 3 Flow record for the Mangaoraka Stream at Corbett Road

Table 7 Statistical summary of data from July 2012 to June 2013: Mangaoraka Stream at Corbett Road

Parameter		Units	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.018	0.037	0.026	12	0.006
A440F	Absorbance @ 440nm filtered	/cm	0.004	0.008	0.006	12	0.001
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity total	g/m^3 CaCO^3	29	108	41	12	29
BLACKDISC	Black disc transparency	m	0.25	2.52	1.82	12	0.83
BOD_5	Biochemical oxygen demand 5 day	g/m^3	0.5	3.1	1.0	12	0.9
CONDY	Conductivity @ 20°C	mS/m@20C	11.2	28.7	14.6	12	6.1
DO	Dissolved oxygen	g/m^3	8.7	11.3	10.4	12	0.9
PERSAT	Dissolved oxygen saturation	%	88	102	99	12	5
DRP	Dissolved reactive phosphorus	g/m^3 P	0.004	0.032	0.010	12	0.008
ECOL	E. coli bacteria	/100ml	740	6300	1900	12	1642
ENT	Enterococci bacteria	/100ml	150	20000	1350	12	5535
FC	Faecal coliform bacteria	/100ml	740	6400	1900	12	1671
FLOW	Flow	m^3/s	0.171	4.706	1.394	12	1.438
NH_4	Ammoniacal nitrogen	g/m^3 N	0.009	0.117	0.014	12	0.041
NO_2	Nitrite nitrogen	g/m^3 N	0.002	0.014	0.004	12	0.004
NO_3	Nitrate nitrogen	g/m^3 N	0.33	1.04	0.82	12	0.213
PH	pH	pH	7.4	7.9	7.6	12	0.1
SS	Suspended solids	g/m^3	<2	49	3	12	14
TEMP	Temperature	˚C	9.6	17.4	12.4	12	2.6
TKN	Total kjeldahl nitrogen	g/m^3 N	0.03	1.10	0.24	12	0.34
TN	Total nitrogen	g/m^3 N	0.63	2.02	0.98	12	0.45
TP	Total phosphorus	g/m^3 P	0.018	0.252	0.030	12	0.075
TURB	Turbidity	NTU	1.0	20	2.0	12	6

A statistical summary of the nineteen years' data collected since 1 July 1995 is presented in Table 8.

Table 8 Statistical summary of data from July 1995 to June 2014: Mangaoraka Stream at Corbett Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.014	0.074	0.025	228	0.012
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.019	0.005	228	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	228	0.001
ALKT	Alkalinity total	g/m^3 $CaCO_3$	14	108	40	228	18
BLACK DISC	Black disc transparency	m	0.055	4.73	1.86	228	0.92
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	14	0.6	228	1.5
CONDY	Conductivity @ 20°C	mS/m	5.6	28.7	14.4	228	3.9
DO	Dissolved oxygen	g/m^3	7.8	11.8	0.01	227	0.8
PERSAT	Dissolved oxygen saturation	%	83	107	96	227	4
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.003	0.074	0.009	228	0.009
ECOL	E. coli bacteria	nos/100 ml	120	60000	780	204	7294
ENT	Enterococci bacteria	nos/100 ml	31	180000	365	228	14064
FC	Faecal coliform bacteria	nos/100 ml	120	60000	775	228	7939
FLOW	Flow	m^3/s	0.160	34.100	1.182	228	3.113
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.308	0.021	228	0.049
NO_2	Nitrite nitrogen	g/m^{3}N	<0.001	0.039	0.005	228	0.006
NO_3	Nitrate nitrogen	g/m^{3}N	0.05	1.73	0.84	228	0.305
pH	pH		6.9	8.1	7.6	228	0.2
SS	Suspended solids	g/m^3	<2	310	2	228	27
TEMP	Temperature	°C	5.8	20.5	13.0	228	2.9
TKN	Total kjeldahl nitrogen	g/m^{3}N	<0.01	4.46	0.20	228	0.46
TN	Total nitrogen	g/m^{3}N	0.282	5.18	1.10	228	0.53
TP	Total phosphorus	g/m^{3}P	0.007	0.860	0.022	228	0.095
TURB	Turbidity	NTU	0.8	100	1.6	227	8.9

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

Discussion

2013-2014 period

Black disc clarity and turbidity results continued to indicate a reasonable standard of aesthetic water quality for the lower reaches of a developed, agricultural catchment although it is noted that turbidity levels were slightly higher (minimum: 1.0 NTU; median: 2.0 NTU) than might be expected given the concentration of suspended solids (minimum: <2 g/m^3; median: 3 g/m^3). This is due to the very fine, colloidal nature of suspended material in the stream at this site partly due to the headwaters being situated below the National Park. The moderate maximum black disc value of 2.52 m coincided with late summer, low flow conditions (following no fresh events in the previous month), while the poorest turbidity conditions (20 NTU and 0.25 m black disc) were recorded during a fresh in mid winter 2013 when a suspended sediment concentration of 49 g/m^3, BOD_5 of 3.1 g/m^3, and faecal coliform number of 2400 per 100 mls were measured. Most parameters indicated poorest water quality during this fresh, particularly elevated turbidity and total phosphorus levels, although higher bacteria numbers were recorded on three other occasions.

The relative absence of freshes during mid-summer to autumn contributed to the slightly elevated pH values (7.7 to 7.9) and these levels were similar to those recorded previously through late summer-autumn months. It should be noted all levels were recorded prior to mid-morning and were not representative of higher pH levels that might be expected later in the day when algal photosynthetic activity would be likely to raise pH more significantly.

Generally, high dissolved oxygen concentrations, high percentage saturation, and low BOD_5 levels (< 1.5 g/m^3) were indicative of relatively good physicochemical water quality, but the extremely high median bacterial numbers (1,350 enterococci and 1900 faecal coliforms per 100 ml), were much higher than typical of the lower reaches of a stream draining an intensively developed catchment, although the Mangaoraka Stream is essentially a lowland catchment as its headwaters do not extend as far towards the upper slopes of Mt Taranaki as most ring plain rivers and streams. [Investigative work in the lower catchment has identified stock access to streams as a probable primary contributor to these elevated numbers although the cumulative impacts of consented dairy pond discharges also contribute, particularly under lower flow conditions]. Water temperatures varied over a moderate range of 7.8°C with a maximum (mid-morning) temperature of 17.4°C in February 2014 during a period of very low flow conditions. Dissolved oxygen saturation did not fall below 88% during the period, with this minimum recorded under a period of lengthy, very low flow conditions (Figure 3).

Brief comparison with the previous 1995-2013 period

Aesthetic stream water quality at this site during the 2013-2014 period was very similar [median black disc clarities within 0.04 m and similar median suspended solids level and median turbidities within 0.4 NTU]. Bacterial water quality deteriorated as reflected in increases in median faecal coliform number of 1555 per 100 mls and median enterococci number which increased by 1000 per 100 mls. Median water temperature was 0.6˚C lower in the 2013-2014 period while the maximum water temperature (17.4°C) was 3.1°C lower than the previous maximum recorded. Median conductivity was very similar and probably reflected the absence of very high flow conditions sampled during the latest period. This was coincident with the median flow sampled during 2013-2014 (1.39 m^3 /sec) which was higher (by 224 l/sec) than the median of flows sampled over the previous eighteen-year period. Moderate ranges for parameters such as suspended solids, turbidity, pH, and BOD_5 reflected the smaller freshes sampled on occasions during the 2013-2014 period (Figure 3), rather than high floods (or rising flows) occasionally sampled in the past. Median pH values were identical and maximum pH was 0.2 unit lower than the past record. Most nitrogen nutrient species had slightly lower median values during the monitoring year in comparison with the previous eighteen-year record while phosphorus nutrient species had slightly higher median values over the 2013-2014 period.

Waiwhakaiho River at SH 3 (site: WKH000500)

Analytical data from the monthly samples are presented in Table 9 and the river flow record is illustrated in Figure 4.

Table 9 Analytical results from monthly samples: Waiwhakaiho River at SH3

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m^3 $CaCO_3$)	Black disc (m)	BOD_5 (g/m^3)	Cond @ 20 C (mS/m)	DO (g/m^3)	DO Sat (%)	DRP (g/m^3P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
10 Jul 2013	0905	0.047	0.012	0.001	19	1.35	0.5	6.2	11.8	100	0.016	660	260
14 Aug 2013	0855	0.030	0.006	0.000	25	1.48	0.5	8.0	11.3	100	0.014	240	320
10 Sep 2013	0905	0.012	0.003	0.000	46	3.22	<0.5	12.2	12.3	107	0.024	340	150
10 Oct 2013	0810	0.026	0.006	0.000	37	2.95	<0.5	9.8	11.7	104	0.022	400	360
13 Nov 2013	0815	0.010	0.002	0.000	56	3.46	<0.5	14.3	11.8	107	0.035	290	120
11 Dec 2013	0800	0.016	0.004	0.000	44	2.81	<0.5	11.3	10.8	105	0.026	300	220
08 Jan 2014	0800	0.046	0.010	0.000	31	1.64	0.6	8.1	10.5	103	0.021	1000	150
12 Feb 2014	0800	0.010	0.002	0.000	66	3.65	0.6	15.5	10.2	105	0.041	200	230
12 Mar 2014	0820	0.005	0.002	0.000	73	3.21	<0.5	16.5	10.6	100	0.057	190	230
09 Apr 2014	0900	0.012	0.003	0.000	76	2.37	0.6	17.4	10.3	103	0.052	830	800
14 May 2014	0900	0.007	0.003	0.000	51	2.32	0.5	13.1	11.1	101	0.033	280	160
11 Jun 2014	0900	0.050	0.011	0.001	20	0.91	0.7	5.9	10.9	100	0.016	700	480

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m^3/s)	NH_4 (g/m^3N)	NO_2 (g/m^3N)	NO_3 (g/m^3N)	pH	SS (g/m^3)	Temp (C)	TKN (g/m^3N)	TN (g/m^3N)	TP (g/m^3P)	Turb (NTU)
10 Jul 2013	0905	700	11.546	0.018	0.003	0.177	7.6	3	7.5	0.08	0.26	0.034	1.4
14 Aug 2013	0855	240	9.140	0.026	0.001	0.139	7.7	<2	8.7	0.02	0.16	0.029	1.1
10 Sep 2013	0905	340	3.709	0.009	0.001	0.049	7.8	<2	8.6	0.06	0.11	0.032	0.8
10 Oct 2013	0810	400	5.421	0.003	0.002	0.098	7.7	<2	8.9	0.07	0.17	0.033	0.8
13 Nov 2013	0815	290	2.481	<0.003	<0.001	0.039	8.0	<2	10.8	0.04	0.08	0.036	1.2
11 Dec 2013	0800	310	4.618	0.012	0.004	0.196	8.0	<2	13.4	0.07	0.27	0.026	0.7
08 Jan 2014	0800	1000	8.349	0.020	0.003	0.217	7.7	<2	13.5	0.08	0.30	0.028	0.8
12 Feb 2014	0800	200	2.385	0.009	<0.001	0.019	8.0	<2	15.3	0.07	0.09	0.049	0.8
12 Mar 2014	0820	200	1.705	0.006	<0.001	0.009	8.2	5	13.7	0.06	0.07	0.062	0.5
09 Apr 2014	0900	900	2.305	<0.003	<0.001	0.009	8.2	<2	14.0	0.09	0.10	0.059	0.8
14 May 2014	0900	280	3.815	0.008	0.002	0.218	7.8	<2	10.3	0.04	0.26	0.033	0.8
11 Jun 2014	0900	700	18.491	0.039	0.003	0.217	7.4	3	10.5	0.20	0.42	0.045	1.5

The statistical summary of this data is presented in Table 10.

Table 10 Statistical summary of data from July 2013 to June 2014

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.005	0.050	0.014	12	0.017
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.012	0.004	12	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	19	76	45	12	20
BDISC	Black disc transparency	m	0.91	3.65	2.59	12	0.92
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	0.7	0.5	12	0.1
CONDY	Conductivity @ 20'C	mS/m	5.9	17.4	11.8	12	4
DO	Dissolved Oxygen	g/m^3	10.2	12.3	11.0	12	0.7
PERSAT	Dissolved Oxygen Saturation %	%	100	107	103	12	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.014	0.057	0.028	12	0.014
ECOL	E.coli bacteria	nos/100 ml	190	1000	320	12	273
ENT	Enterococci bacteria	nos/100 ml	120	800	230	12	191
FC	Faecal Coliforms	nos/100 ml	200	1000	325	12	284
FLOW	Flow	m^3/s	1.705	18.491	4.216	12	4.97
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.039	0.009	12	0.011
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.004	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.22	0.012	12	0.088
PH	pH		7.4	8.2	7.8	12	0.2
SS	Suspended solids	g/m^3	<2	5	<2	12	1
TEMP	Temperature	°C	7.5	15.3	10.6	12	2.6
TKN	Total Kjeldahl nitrogen	g/m^3N	0.02	0.20	0.07	12	0.04
TN	Total nitrogen	g/m^3N	0.07	0.42	0.16	12	0.11
TP	Total phosphorus	g/m^3P	0.026	0.062	0.034	12	0.012
TURB	Turbidity	NTU	0.5	1.5	0.8	12	0.3

A statistical summary of the nineteen years' data collected since 1 July 1995 is presented in Table 11.

Table 11 Statistical summary of data from July 1995 to June 2014: Waiwhakaiho River at SH3

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.005	0.095	0.015	228	0.018
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.022	0.004	228	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.007	0.000	228	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	8	76	49	228	17
BDISC	Black disc transparency	m	0.130	8.05	3.06	228	1.43
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	4.3	<0.5	228	0.5
CONDY	Conductivity @ 20'C	mS/m	3.4	17.4	12.2	228	3.3
DO	Dissolved Oxygen	g/m^3	9.1	12.8	10.8	228	0.7
PERSAT	Dissolved Oxygen Saturation %	%	91	108	100	228	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.108	0.024	228	0.011
ECOL	E.coli bacteria	nos/100 ml	23	56000	200	204	4393
ENT	Enterococci bacteria	nos/100 ml	1	28000	94	228	2013
FC	Faecal Coliforms	nos/100 ml	23	83000	210	228	6891
FLOW	Flow	m^3/s	1.705	83.440	3.741	228	9.188
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.148	0.008	228	0.021
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.010	0.002	228	0.001
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.47	0.11	228	0.104
PH	pH		6.8	8.5	7.9	228	0.3
SS	Suspended solids	g/m^3	<2	89	<2	228	10
TEMP	Temperature	°C	4.8	18.3	11.0	228	2.8
TKN	Total Kjeldahl nitrogen	g/m^3N	0.01	1.95	0.07	228	0.21
TN	Total nitrogen	g/m^3N	0.020	2.10	0.20	228	0.24
TP	Total phosphorus	g/m^3P	0.014	0.437	0.034	228	0.046
TURB	Turbidity	NTU	0.4	26	0.7	227	2.74

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

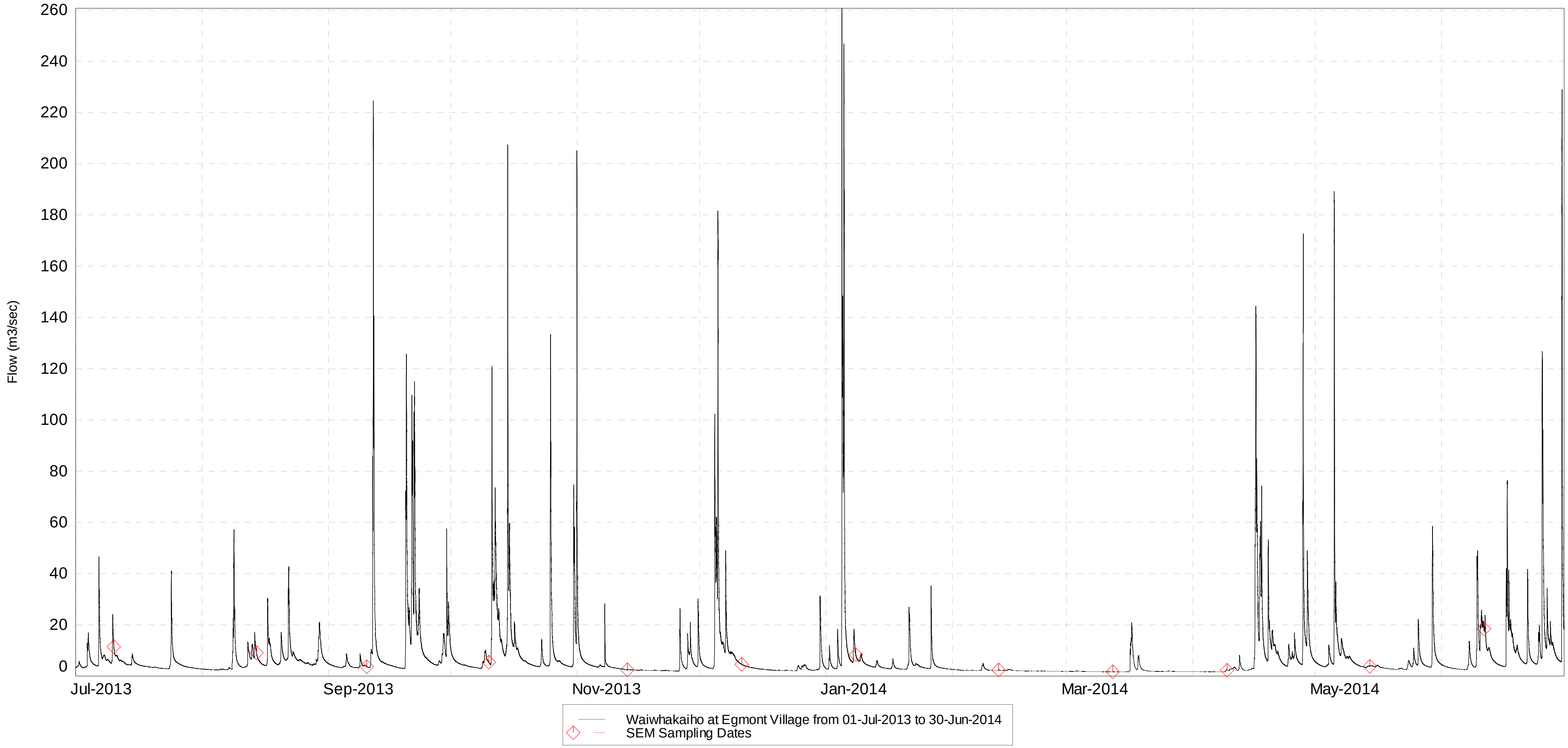

Figure 4 Flow record for the Waiwhakaiho River at SH3 Egmont Village

Discussion

2013-2014 period

Photo 2 Kokowai Stream iron-oxide seepage, 7 November 2013

Photo 1 Upper Waiwhakaiho River at Peters Road, 7 November 2013

In early November 2013, severe orange discolouration of the river occurred when an iron-oxide laden seepage discharge from the Kokowai Stream (Photo 1) entered the main river within the National Park. Discolouration extended downstream (Photo 2) beyond the mid reaches but the river cleared within a few days of this event. Iron-oxide staining of the river bed boulders remained noticeable for several weeks. (Note: Similar events had occurred in the past (e.g. 1975) but none had been recorded since the inception of the SEM programme in mid-1995).

During the 2013-2014 period, black disc clarity and turbidity results indicated relatively good water quality in terms of appearance, particularly for the mid reaches of a developed ringplain agricultural catchment. This was emphasised by median black disc and turbidity values of 2.59 m and 0.8 NTU respectively. The maximum black disc value (3.65 metres) was recorded in late summer under low flow conditions (2.39 m^3/sec) (Figure 4), with the worst conditions (black disc clarity of 0.91 m) on the falling stage of a small fresh flow (18 m^3/sec) in June 2014 when the turbidity increased slightly (1.5 NTU) but there was minimal increase in suspended solids concentration (3 g/m^3). Generally, poorer water quality was recorded at the time of this fresh flow when slightly elevated faecal coliform bacterial numbers (700 number/100 ml) and colour (absorbance @ 340 mm), together with decreased clarity and conductivity, were recorded.

A maximum pH value of 8.2 was recorded under low flow conditions in late summer with values above 7.9 units during low flow conditions. pH values could be expected to have risen further later in the day, as all sampling at this site was undertaken no later than 0905 hrs.

Very good water quality was indicated by high dissolved oxygen concentrations (median saturation of 103%) and low BOD_5 levels (median of 0.5 g/m^3). Bacteriological quality was moderate, with median faecal coliform and enterococci numbers (325 and 230 per 100 mls respectively) typically reflecting agricultural catchment influences and partly reflecting the infrequency of freshes during, or immediately prior to, sampling surveys during 2013-2014.

River water temperatures recorded a moderate range of 7.8°C during the period with a maximum mid-morning water temperature of 15.3°C recorded in February 2014 during a lengthy period of low flow conditions.

Brief comparison with the previous 1995-2013 period

River water quality measured by the 2013-2014 survey in many aspects was generally slightly poorer than that recorded over the previous eighteen-year period. Median black disc clarity was worse (by 0.52 m) with median turbidity higher by 0.1 NTU, but median suspended solids levels were identical between periods. Bacteriological water quality was poorer in terms of median faecal coliform number (by 125 per 100 mls) and for median enterococci number (by 142 per 100mls). A much narrower range of water temperatures (by 5.7˚C) was recorded in the most recent twelve-month period. Median water temperature was 0.4°C lower in the most recent period and the maximum temperature was 3.0°C lower than that recorded during the previous eighteen years.

Median sampled flow over the 2013-2014 period was higher (by 486 l/sec) than for the flows sampled in the previous eighteen-year period coincident with a few fresh events despite the low flows between mid-summer and autumn sampled during the latest period. This was reflected in the lower median conductivity level found for the 2013-2014 period. The lowest flow sampled (by 13 l/sec) over the nineteen year period was recorded in March 2014.

Median concentrations for some nitrogen nutrient species were slightly higher in the 2013-2014 period while there was a small increases in the median dissolved reactive phosphorus in this period.

No significant differences were recorded in terms of the medians of BOD_5 and percentage dissolved oxygen between the two periods although the latter rose by 3% over the most recent period.

Stony River at Mangatete Road (site: STY000300)

Analytical data from the monthly samples are presented in Table 12.

Table 12 Analytical results from monthly samples: Stony River at Mangatete Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ CaCO₃)	Black disc (m)	BOD₅ (g/m³)	Cond @ 20 C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
10 Jul 2013	1010	0.018	0.004	0.000	25	3.18	<0.5	6.8	12.1	101	0.011	14	6
14 Aug 2013	1000	0.014	0.003	0.000	25	2.59	<0.5	7.5	11.4	101	0.010	11	17
10 Sep 2013	1000	0.007	0.001	0.000	37	5.71	<0.5	9.8	11.6	102	0.012	<2	<2
10 Oct 2013	0930	0.011	0.002	0.000	33	2.99	<0.5	8.2	11.2	102	0.015	13	1
13 Nov 2013	0935	0.004	0.001	0.000	46	7.80	<0.5	11.6	10.7	102	0.021	5	4
11 Dec 2013	0915	0.011	0.002	0.000	34	2.90	<0.5	8.5	10.7	102	0.022	16	16
08 Jan 2014	0900	0.012	0.002	0.000	33	3.25	<0.5	7.9	10.4	102	0.010	15	4
12 Feb 2014	0900	0.004	0.000	0.000	50	0.25	<0.5	12.0	10.4	103	0.016	31	32
12 Mar 2014	0925	0.002	0.001	0.000	57	1.65	<0.5	13.0	10.8	103	0.018	1	15
09 Apr 2014	1010	0.005	0.001	0.000	55	1.02	<0.5	12.6	10.1	101	0.020	50	150
14 May 2014	1000	0.000	0.002	0.000	37	3.16	<0.5	9.3	11.3	101	0.017	110	64
11 Jun 2014	1010	0.050	0.011	0.001	14	0.81	<0.5	4.3	11.1	100	0.010	48	21

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m³/s)	NH₄ (g/m³N)	NO₂ (g/m³N)	NO₃ (g/m³N)	pH	SS (g/m³)	Temp (C)	TKN (g/m³N)	TN (g/m³N)	TP (g/m³P)	Turb (NTU)
10 Jul 2013	1010	14	6.034	<0.003	<0.001	0.019	7.7	<2	7.3	0.03	<0.05	0.017	0.7
14 Aug 2013	1000	11	5.484	0.006	<0.001	<0.01	7.8	<2	8.5	0.04	<0.05	0.016	0.8
10 Sep 2013	1000	<2	3.390	<0.003	<0.001	<0.01	7.9	<2	8.9	0.03	0.04	0.016	0.6
10 Oct 2013	0930	13	4.639	<0.003	<0.001	0.019	7.7	<2	9.6	0.03	0.05	0.024	0.9
13 Nov 2013	0935	5	2.737	<0.003	<0.001	0.009	7.9	<2	13.2	0.04	<0.05	0.021	0.4
11 Dec 2013	0915	16	3.787	<0.003	<0.001	0.019	7.9	3	12.7	0.07	0.09	0.025	1.3
08 Jan 2014	0900	15	4.524	0.012	<0.001	0.009	7.8	<2	13.3	0.01	0.02	0.016	0.6
12 Feb 2014	0900	31	2.609	<0.003	<0.001	0.009	8.0	26	13.6	0.05	0.06	0.064	18
12 Mar 2014	0925	1	2.017	0.003	<0.001	0.009	8.2	<2	12.6	0.05	0.06	0.028	1.3
09 Apr 2014	1010	50	2.454	<0.003	<0.001	0.009	8.1	5	13.9	0.03	0.04	0.027	1.7
14 May 2014	1000	110	3.761	<0.003	<0.001	0.029	7.8	<2	9.7	0.02	<0.05	0.017	0.8
11 Jun 2014	1010	48	12.526	0.003	<0.001	0.009	7.3	6	9.7	0.05	0.06	0.032	2.5

The statistical summary of this data is presented in Table 13.

Table 13 Statistical summary of data from July 2013 to July 2014 Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.000	0.050	0.009	12	0.013
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.011	0.002	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	14	57	36	12	13
BDISC	Black disc transparency	m	0.25	7.80	2.94	12	2.11
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	<0.5	<0.5	12	0
CONDY	Conductivity @ 20˚C	mS/m	4.3	13.0	8.9	12	2.6
DO	Dissolved oxygen	g/m^3	10.1	12.1	11.0	12	0.6
PERSAT	Dissolved oxygen saturation %	%	100	103	102	12	1
DRP	Dissolved reactive phosphorus	g/m^3P	0.010	0.022	0.016	12	0.005
ECOL	E.coli bacteria	nos/100 ml	1	110	14	12	31
ENT	Enterococci bacteria	nos/100 ml	1	150	16	12	42
FC	Faecal coliforms	nos/100 ml	1	110	14	12	31
FLOW	Flow	m^3/s	2.017	12.526	3.774	12	2.814
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.012	<0.003	12	0.003
NO_2	Nitrite nitrogen	g/m^3N	<0.001	<0.001	<0.001	12	0
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.03	<0.01	12	0.007
pH	pH		7.3	8.2	7.8	12	0.2
SS	Suspended solids	g/m^3	<2	26	<2	12	7
TEMP	Temperature	°C	7.3	13.9	11.2	12	2.3
TKN	Total kjeldahl nitrogen	g/m^3N	0.01	0.07	0.04	12	0.02
TN	Total nitrogen	g/m^3N	0.02	0.09	0.05	12	0.02
TP	Total phosphorus	g/m^3P	0.016	0.064	0.022	12	0.013
TURB	Turbidity	NTU	0.4	18	0.9	12	4.93

A statistical summary of the nineteen years' data collected since 1 July 1995, is presented in Table 14.

Table 14 Statistical summary of data from July 1995 to June 2014: Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.000	0.077	0.009	228	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.028	0.002	228	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.007	0.000	228	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	5	57	38	228	12
BDISC	Black disc transparency	m	0.010	13.12	3.32	228	2.76
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.6	<0.5	228	0.1
CONDY	Conductivity @ 20˚C	mS/m	2.8	13.3	9.7	228	2.4
DO	Dissolved oxygen	g/m^3	9.4	12.2	10.7	228	0.6
PERSAT	Dissolved oxygen saturation %	%	87	104	99	230	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.210	0.018	228	0.014
ECOL	E.coli bacteria	nos/100 ml	<1	950	8	204	88
ENT	Enterococci bacteria	nos/100 ml	<1	460	5	228	48
FC	Faecal coliforms	nos/100 ml	<1	1000	8	228	87
FLOW	Flow	m^3/s	1.988	55.504	3.592	228	7.215
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.020	<0.003	228	0.003
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.004	<0.001	228	0
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.11	0.02	228	0.017
pH	pH		7.0	8.2	7.8	228	0.2
SS	Suspended solids	g/m^3	<2	2500	2	228	320
TEMP	Temperature	°C	5.7	16.6	10.8	228	2.5
TKN	Total kjeldahl nitrogen	g/m^3N	<0.01	1.78	0.04	228	0.17
TN	Total nitrogen	g/m^3N	0.020	1.82	0.06	228	0.17
TP	Total phosphorus	g/m^3P	0.008	3.380	0.024	228	0.312
TURB	Turbidity	NTU	0.2	700	0.8	227	68.82

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

Discussion

2013-2014

Black disc clarity and turbidity results, which more often in the past have indicated generally good river water quality in terms of appearance for the mid-reaches of a Taranaki ring plain river, have also showed significant deterioration in aesthetic quality from time to time as a result of severe erosion in the headwaters of this river during winter and spring floods in 1998-1999 and again following an intensive, prolonged wet period in February 2004. Some improvement occurred in 2004-2005 and continued through most of the 2005-2006 period but conditions deteriorated markedly following the very wet spring conditions in 2006, near mid winter 2008, and in mid winter 2009. No significant headwater erosion events were identified over the 2009-2010 period, but headwater erosion was recorded in late May - early June 2011. Further erosion events in the headwaters were recorded during a dry period in February 2014 (see Photo 3), when the minimum black disc value (0.25) and elevated turbidity (18 NTU) and suspended solids (26 g/m^3) values were recorded despite the low flow conditions (2.61 m^3/sec). Wet weather and fresh flow conditions in June 2014 were reflected in a black disc clarity of 0.81 m and turbidity value of 2.5 NTU with a small elevation in suspended solids concentration (6 g/m^3) and small increases in total phosphorus (0.032 g/m^3) and faecal coliform bacterial levels (48 nos/100 mls) but not to the extent found in other ringplain streams following such freshes. The maximum black disc clarity of 7.80 m was measured in late spring under low flow conditions coincident with the very low suspended solids and turbidity (0.4 NTU) levels.

Photo 3 Stony River headwater erosion, February 2014

Maximum mid-morning pH (8.2) under autumn low flow conditions and the median pH (7.8) were equivalent with past years' results. Dissolved oxygen concentrations were consistently high with a minimum saturation of 100% and BOD_5 levels were below the detectable limit on all occasions; a further indication of high water quality when not influenced by severe erosion events.

Bacteriological water quality was very high with median faecal coliform and enterococci numbers (14 and 16 per 100 mls respectively) indicative of minimal impact of upstream developed farmland at this site near mid-catchment, although there was an unexplained elevation in counts in early April under low flow conditions.

River water temperatures varied over a moderate range of 6.6°C during the period, with a maximum mid-morning temperature of 13.9°C recorded in early autumn (April 2014) under low flow conditions.

Nutrient levels were generally very low in terms of median ammoniacal nitrogen, nitrate-N, and dissolved reactive phosphorus concentrations (all ≤0.02 g/m^3). Total nitrogen and total phosphorus concentrations were relatively low throughout the year, with the exception of elevations in TP and TN during the headwater erosion and June 2014 fresh events coincident with increased suspended solids concentrations.

Brief comparison with the previous 1995-2013 period

Water quality measured during the 2013-2014 survey period, in comparison with the previous eighteen years' survey results, was worse aesthetically in terms of median black disc clarity (which was lower by 0.62 m), median turbidity (higher by 0.2 NTU), although the median suspended solids level was equivalent with the historical median.

Median bacteriological water quality was slightly poorer in the latest period, although both periods had very high quality with both median faecal coliform counts below 20 per 100 mls.

Water temperature range was narrower (by 4.3°C) due mainly to a lower maximum temperature during 2013-2014, with the median slightly higher (0.4°C warmer) in the 2013-2014 period to that in the earlier eighteen-year period. All median nutrient species were lower or relatively similar to the previous longer period medians.

Median sampled flow during the 2013-2014 period was slightly higher (by 0.19 m^3/sec) than the median of flows sampled over the previous eighteen-year period, with few freshes and no flood events (in excess of 13 m^3/sec) and a relatively lengthy low flow period sampled in 2013-2014. This was reflected in the slightly lower median conductivity (by 0.8 mS/m @ 20˚C) over the 2013-2014 period.

Punehu Stream at Wiremu Road (site: PNH000200)

Analytical data are presented in Table 15 from the monthly samples.

Table 15 Analytical results from the monthly samples: Punehu Stream at Wiremu Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m^3 $CaCO_3$)	Black disc (m)	BOD_5 (g/m^3)	Cond @ 20 C (mS/m)	DO (g/m^3)	DO Sat (%)	DRP (g/m^3P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
10 Jul 2013	1050	0.062	0.014	0.001	13	0.66	<0.5	8.8	11.6	100	0.015	77	38
14 Aug 2013	1030	0.030	0.007	0.000	16	0.72	<0.5	10.0	11.1	100	0.017	20	11
10 Sep 2013	1045	0.026	0.006	0.000	20	1.60	0.5	9.9	11.1	102	0.018	12	<2
10 Oct 2013	1000	0.049	0.011	0.000	13	2.03	<0.5	8.2	11.1	101	0.014	140	11
13 Nov 2013	1020	0.028	0.006	0.001	22	2.78	<0.5	9.3	10.5	101	0.023	25	5
11 Dec 2013	0950	0.043	0.009	0.001	23	1.58	<0.5	8.8	10.3	102	0.030	130	12
08 Jan 2014	0935	0.040	0.008	0.000	22	1.79	<0.5	9.1	9.8	102	0.020	250	48
12 Feb 2014	0940	0.030	0.005	0.000	23	2.29	<0.5	8.6	10.0	103	0.027	84	27
12 Mar 2014	1000	0.017	0.004	0.000	26	2.32	<0.5	8.7	10.3	104	0.053	96	66
09 Apr 2014	1050	0.077	0.016	0.001	8	0.58	1.2	8.9	10.1	100	0.016	1000	330
14 May 2014	1035	0.027	0.007	0.000	22	1.35	<0.5	9.5	11.0	101	0.026	200	46
11 Jun 2014	1040	0.136	0.029	0.001	8	0.32	1.2	5.6	10.9	100	0.016	930	400

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m^3/s)	NH_4 (g/m^3N)	NO_2 (g/m^3N)	NO_3 (g/m^3N)	pH	SS (g/m^3)	Temp (C)	TKN (g/m^3N)	TN (g/m^3N)	TP (g/m^3P)	Turb (NTU)
10 Jul 2013	1050	77	1.012	0.024	0.002	0.138	7.4	7	7.5	0.14	0.28	0.038	3.6
14 Aug 2013	1030	26	0.582	0.020	0.001	0.099	7.5	3	9.0	0.06	0.16	0.033	3.1
10 Sep 2013	1045	12	0.496	0.019	<0.001	0.059	7.5	2	10.0	0.10	0.16	0.033	3.0
10 Oct 2013	1000	140	0.804	0.009	0.001	0.029	7.4	3	9.3	0.13	0.16	0.032	1.8
13 Nov 2013	1020	25	0.379	<0.003	0.001	0.019	7.5	<2	12.7	0.03	<0.05	0.026	2.0
11 Dec 2013	0950	140	0.498	0.011	0.002	0.038	7.6	<2	13.9	0.12	0.16	0.040	1.8
08 Jan 2014	0935	250	0.513	0.013	0.001	0.039	7.6	<2	15.4	0.11	0.15	0.020	2.1
12 Feb 2014	0940	110	0.362	0.005	<0.001	0.009	7.7	<2	15.0	0.04	0.05	0.035	1.6
12 Mar 2014	1000	96	0.203	0.008	<0.001	0.009	7.9	<2	14.5	0.09	0.10	0.060	1.2
09 Apr 2014	1050	1000	1.374	0.044	0.003	0.077	7.4	12	13.5	0.36	0.44	0.065	3.4
14 May 2014	1035	200	0.612	0.025	0.001	0.079	7.5	2	9.8	0.09	0.17	0.029	3.8
11 Jun 2014	1040	930	4.381	0.058	0.002	0.108	7.1	25	9.8	0.55	0.66	0.105	7.6

The statistical summary of this data is presented in Table 16.

Table 16 Statistical summary of data from July 2013 to June 2014 Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.017	0.136	0.35	12	0.033
A440F	Absorbance @ 440nm filtered	/cm	0.004	0.029	0.008	12	0.007
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	8	26	21	12	6
BDISC	Black disc transparency	m	0.32	2.78	1.59	12	0.79
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.2	<0.5	12	0.3
CONDY	Conductivity @ 20˚C	mS/m	5.6	10.0	8.8	12	1.1
DO	Dissolved oxygen	g/m^3	9.8	11.6	10.7	12	0.6
PERSAT	Dissolved oxygen saturation %	%	100	104	101	12	1
DRP	Dissolved reactive phosphorus	g/m^3P	0.014	0.053	0.019	12	0.011
ECOL	E.coli bacteria	nos/100 ml	12	1000	113	12	343
ENT	Enterococci bacteria	nos/100 ml	<2	400	32	12	134
FC	Faecal coliforms	nos/100 ml	12	1000	125	12	341
FLOW	Flow	m^3/s	0.203	4.381	0.548	12	1.13
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.058	0.016	12	0.016
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.003	0.001	12	0.001
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.14	0.05	12	0.042
pH	pH		7.1	7.9	7.5	12	0.2
SS	Suspended solids	g/m^3	<2	25	2	12	7
TEMP	Temperature	°C	7.5	15.4	11.4	12	2.7
TKN	Total kjeldahl nitrogen	g/m^3N	0.03	0.55	0.10	12	0.15
TN	Total nitrogen	g/m^3N	<0.05	0.66	0.16	12	0.18
TP	Total phosphorus	g/m^3P	0.020	0.105	0.034	12	0.023
TURB	Turbidity	NTU	1.2	7.6	2.6	12	1.7

A statistical summary of the nineteen years' data collected since 1 July 1995, is presented in Table 17.

Table 17 Statistical summary of data from July 1995 to July 2014: Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.017	0.144	0.033	228	0.024
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.032	0.007	228	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.005	0.000	228	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	6	27	22	228	5
BDISC	Black disc transparency	m	0.080	4.53	1.84	228	0.88
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	3.0	<0.5	228	0.3
CONDY	Conductivity @ 20˚C	mS/m	4.0	10.9	8.6	228	1.2
DO	Dissolved oxygen	g/m^3	8.9	12.5	10.4	227	0.8
PERSAT	Dissolved oxygen saturation %	%	87	106	100	227	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.007	0.389	0.022	228	0.026
ECOL	E.coli bacteria	nos/100 ml	3	6100	115	204	842
ENT	Enterococci bacteria	nos/100 ml	<1	1200	36	228	158
FC	Faecal coliforms	nos/100 ml	3	6100	120	228	856
FLOW	Flow	m^3/s	0.180	12.380	0.437	228	1.145
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.078	0.006	228	0.01
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.014	0.001	228	0.001
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.18	0.03	228	0.041
pH	pH		6.9	8.3	7.7	228	0.2
SS	Suspended solids	g/m^3	<2	160	2	228	13
TEMP	Temperature	°C	5.0	19.2	11.8	228	3.3
TKN	Total kjeldahl nitrogen	g/m^3N	0.010	0.85	0.09	228	0.13
TN	Total nitrogen	g/m^3N	<0.05	0.87	0.15	228	0.14
TP	Total phosphorus	g/m^3P	0.015	0.413	0.034	228	0.04
TURB	Turbidity	NTU	0.5	29	1.7	227	3.23

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

Discussion

2013-2014

Although black disc clarity and turbidity results were indicative of relatively good water quality in terms of aesthetic appearance, these values continued to be lower than might be anticipated for the upper reaches of a ring plain stream, i.e. medians of 1.59 m (black disc) and 2.6 NTU (turbidity). This was related to the open nature of the reaches of both the stream and the upstream tributary draining developed farmland catchment immediately downstream of the National Park through the 2 km reach upstream of this site. This area had also been subject to stock access in the past (see photos in TRC 2000 and 2011) although in recent years the banks have been fenced and planted in the immediate vicinity of the site.

Minimum black disc clarity (0.32 m) was recorded during a fresh in June 2014 following several freshes in the preceding two weeks and coincidental with an increase in suspended solids concentration (25 g/m^3) and increase in turbidity (7.6 NTU). A marked increase in total phosphorus concentration and faecal coliform bacteria number were also recorded. Similar faecal coliform numbers (1000 per 100 mls) were recorded two months earlier in the period under a smaller fresh flow condition. A maximum black disc value of 2.78 m was measured under moderately low flow conditions in November 2013.

The maximum pH (7.9) was recorded (in mid morning) on one occasion during early autumn, under very low flow conditions (203 l/sec)..

Dissolved oxygen concentrations were consistently high (100 to 104% saturation for the period) and BOD_5 levels were very low and less than 0.5 g/m^3 on the majority of occasions; further indications of generally high water quality.

A moderate median faecal coliform bacterial count for the upper reaches of a ring plain stream (125 per 100 mls) indicated some impacts of upstream farmland run-off (and possible stock access) on stream water quality at this site, and represented deterioration below the National Park boundary in this aspect of water quality. Surface runoff from surrounding farmland has been a common feature in the past in this reach of the stream and three freshes were sampled during the 2013-2014 period, similar to many previous periods, resulting in a typical median for the latest period.

Water temperatures varied over a relatively wide range (7.9°C) for the upper reaches of a ring plain stream, reflecting the bouldery, open nature of the reach below the National Park. A maximum mid morning water temperature of 15.4°C was recorded in January 2014, relatively high for the upper reaches of a ring plain stream at this time of the day (0935 hrs).

Brief comparison with the previous 1995-2013 period

Stream water quality measured during the 2013-2014 period, was relatively poorer in terms of median turbidity and median black disc clarity (which decreased by 0.26 m) than the overall record. Median suspended solids concentration remained low and in the recent year was equivalent with the median of the previous eighteen-year period. Median dissolved oxygen percentage saturation levels were very similar (within 1%) for both periods.

Bacteriological water quality was very similar for the two periods in terms of median faecal coliform number (within 5 per 100 ml) and median numbers of enterococci (within 4 per 100 ml), reflecting typical numbers of freshes sampled in 2013-2014. Most nitrogen species' median concentrations tended to be slightly higher in the recent year, while median DRP decreased.

The water temperature range was narrower (by 6.3°C) compared with surveys prior to the latest twelve-month period; with the median flow sampled being higher (by 115 l/sec) in the 2013-2014 period. The narrower temperature range was caused by markedly lower maximum temperature in particular (by 3.8˚ C) in 2013-2014 than the previous maximum recorded.

Median pH values were within 0.2 unit during the two sampling periods but the maximum pH was 0.4 unit lower than the maximum recorded in the previous eighteen-year period.

Punehu Stream at SH45 (site: PNH000900)

Analytical data are presented in Table 18 from the monthly samples. The flow data in Table 18 presents actual flows at the site at the time of sampling, as the previous flow recording station in this stream is no longer operated by NIWA.

Table 18 Analytical results from monthly samples: Punehu Stream at SH45

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ $CaCO_3$)	Black disc (m)	BOD_5 (g/m³)	Cond @ 20 C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
10 Jul 2013	1115	0.053	0.015	0.003	22	0.25	1.9	17.2	11.6	99	0.035	770	430
14 Aug 2013	1100	0.030	0.006	0.000	28	1.18	1.1	19.9	11.1	100	0.046	740	210
10 Sep 2013	1115	0.029	0.006	0.001	33	1.83	<0.5	20.3	10.9	99	0.050	350	130
10 Oct 2013	1030	0.053	0.011	0.001	25	1.48	1.2	15.0	11.3	100	0.032	1000	260
13 Nov 2013	1050	0.030	0.006	0.000	36	2.47	0.6	20.3	10.6	100	0.051	220	100
11 Dec 2013	1015	0.037	0.008	0.001	37	1.58	1.2	20.6	10.2	101	0.073	400	320
08 Jan 2014	1005	0.039	0.007	0.000	36	1.78	1.1	18.2	9.8	101	0.088	770	610
12 Feb 2014	1005	0.039	0.007	0.000	38	1.90	1.1	15.0	9.8	101	0.052	210	820
12 Mar 2014	1030	0.036	0.008	0.001	41	2.11	0.6	15.4	10.0	103	0.069	320	4000
09 Apr 2014	1125	0.096	0.020	0.001	12	0.31	2.9	11.3	10.1	99	0.034	4700	8300
14 May 2014	1100	0.035	0.009	0.000	32	0.80	1.8	18.0	10.8	100	0.078	3100	2800
11 Jun 2014	1100	0.108	0.024	0.001	14	0.19	3.2	10.3	11.0	100	0.031	2600	4300

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m³/s)	NH_4 (g/m³N)	NO_2 (g/m³N)	NO_3 (g/m³N)	pH	SS (g/m³)	Temp (C)	TKN (g/m³N)	TN (g/m³N)	TP (g/m³P)	Turb (NTU)
10 Jul 2013	1115	770	2.456	0.059	0.013	2.137	7.5	22	8.8	0.48	2.63	0.150	15
14 Aug 2013	1100	740	1.278	0.075	0.024	2.146	7.6	4	10.6	0.38	2.55	0.080	2.8
10 Sep 2013	1115	350	1.190	0.125	0.033	2.107	7.6	4	11.1	0.64	2.78	0.104	2.8
10 Oct 2013	1030	1000	1.653	0.070	0.022	1.018	7.5	3	9.9	0.58	1.62	0.062	2.0
13 Nov 2013	1050	220	0.898	0.039	0.023	1.697	7.6	<2	13.3	0.22	1.94	0.072	1.4
11 Dec 2013	1015	400	1.400	0.057	0.039	2.101	7.7	2	15.3	0.32	2.46	0.100	2.0
08 Jan 2014	1005	800	1.059	0.057	0.024	1.256	7.6	<2	16.3	0.38	1.66	0.116	1.7
12 Feb 2014	1005	220	0.492	0.009	0.003	0.427	7.7	<2	16.6	0.26	0.69	0.070	1.6
12 Mar 2014	1030	330	0.306	0.023	0.004	0.426	7.9	<2	17.1	0.18	0.61	0.088	1.6
09 Apr 2014	1125	5000	2.121	0.110	0.008	0.412	7.4	25	14.1	0.78	1.20	0.167	8.0
14 May 2014	1100	3200	1.191	0.097	0.024	1.376	7.6	5	11.8	0.46	1.86	0.118	4.3
11 Jun 2014	1100	2600	8.340	0.113	0.008	1.202	7.2	69	10.9	1.22	2.43	0.310	21

The statistical summary of this data is presented in Table 19.

Table 19 Statistical summary of data from July 2013 to June 2014 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.029	0.108	0.038	12	0.026
A440F	Absorbance @ 440nm Filtered	/cm	0.006	0.024	0.008	12	0.006
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.003	0.001	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	12	41	32	12	9
BDISC	Black disc transparency	m	0.19	2.47	1.53	12	0.77
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	3.2	1.2	12	0.9
CONDY	Conductivity @ 20'C	mS/m	10.3	20.6	17.6	12	3.5
DO	Dissolved Oxygen	g/m^3	9.8	11.6	10.7	12	0.6
PERSAT	Dissolved Oxygen Saturation %	%	99	103	100	12	1
DRP	Dissolved reactive phosphorus	g/m^3P	0.031	0.088	0.050	12	0.019
ECOL	E.coli bacteria	nos/100 ml	210	4700	755	12	1429
ENT	Enterococci bacteria	nos/100 ml	100	8300	520	12	2546
FC	Faecal Coliforms	nos/100 ml	220	5000	755	12	1505
FLOW	Flow	m^3/s	0.306	8.340	1.2	12	2.127
NH_4	Ammoniacal nitrogen	g/m^3N	0.009	0.125	0.064	12	0.036
NO_2	Nitrite nitrogen	g/m^3N	0.003	0.039	0.022	12	0.011
NO_3	Nitrate nitrogen	g/m^3N	0.41	2.15	1.32	12	0.69
PH	pH		7.2	7.9	7.6	12	0.2
SS	Suspended solids	g/m^3	<2	69	4	12	20
TEMP	Temperature	°C	8.8	17.1	12.6	12	2.9
TKN	Total Kjeldahl nitrogen	g/m^3N	0.18	1.22	0.42	12	0.29
TN	Total nitrogen	g/m^3N	0.61	2.78	1.90	12	0.74
TP	Total phosphorus	g/m^3P	0.062	0.310	0.102	12	0.068
TURB	Turbidity	NTU	1.4	21	2.0	12	6

A statistical summary of the nineteen years' data collected since 1 July 1995, is presented in Table 20.

Table 20 Statistical summary of data from July 1995 to June 2014 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.015	0.115	0.039	228	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.027	0.008	228	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.006	0.000	228	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	10	46	34	228	7
BDISC	Black disc transparency	m	0.055	3.57	1.54	228	0.69
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	8.1	1.0	228	0.9
CONDY	Conductivity @ 20'C	mS/m	5.8	21.8	16.0	228	2.4
DO	Dissolved Oxygen	g/m^3	8.6	12.8	10.4	228	0.8
PERSAT	Dissolved Oxygen Saturation %	%	90	114	99	228	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.013	0.212	0.044	228	0.027
ECOL	E.coli bacteria	nos/100 ml	48	20000	480	202	2230
ENT	Enterococci bacteria	nos/100 ml	15	9300	320	227	1168
FC	Faecal Coliforms	nos/100 ml	51	20000	515	228	2570
FLOW	Flow	m^3/s	0.242	12.300	0.803	228	1.581
NH_4	Ammoniacal nitrogen	g/m^3N	0.004	0.376	0.041	228	0.061
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.110	0.014	228	0.015
NO_3	Nitrate nitrogen	g/m^3N	0.07	3.13	0.92	228	0.636
PH	pH		7.1	8.6	7.7	228	0.2
SS	Suspended solids	g/m^3	<2	220	3	228	21
TEMP	Temperature	°C	5.0	21.0	13.3	228	3.5
TKN	Total Kjeldahl nitrogen	g/m^3N	0.040	1.99	0.32	228	0.27
TN	Total nitrogen	g/m^3N	0.260	3.96	1.36	228	0.75
TP	Total phosphorus	g/m^3P	0.026	0.531	0.080	228	0.062
TURB	Turbidity	NTU	0.9	50	1.8	227	5.1

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

Discussion

2013-2014 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.53 m, this clarity being typical of the lower reaches of developed ringplain catchments. A median suspended solids concentration of 4 g/m^3 and turbidity of 2.0 NTU were also more typical of the lower reaches of a ring plain catchment. Minimum clarity (black disc of 0.19 m, turbidity of 21 NTU, and suspended solids concentration of 69 g/m^3) were recorded during a fresh (of 8.34 m^3/sec) in June 2014. Deterioration in other water quality parameters under these conditions was shown by elevations in bacterial numbers, total phosphorus concentration, and an increase in BOD_5 concentration.

pH peaked at 7.9 (in early autumn) under very low flow conditions, but this was recorded in mid morning and would be expected to have reached a higher level later in the day. This was 0.7 unit lower than the maximum recorded previously at a similar time of the day.

Although dissolved oxygen concentrations remained consistently high (minimum of 99% saturation), BOD_5 concentrations occasionally indicated low levels of organic enrichment (ie $\geq$1 g/m^3).

The very high median bacteriological numbers (520 enterococci and 755 faecal coliforms per 100 mls) were further indicative of the impacts of developed farmland run-off and point source discharges on the water quality of the lower reaches of a ring plain catchment. The wide range of faecal coliform numbers (220 to 5,000 per 100 mls) found during spring to autumn lower flow conditions were indicative of point source discharges of pond system treated dairy sheds' wastes and/or stock access (see TRC, 2011). Relatively high median nutrient levels were consistent with such impacts.

Water temperature varied over a moderate range of 8.3˚C with a maximum summer (late morning) temperature of 17.1 C recorded in March 2014 and the lowest temperature (8.8 C) recorded in July 2013; the former 3.9 C below the previous maximum temperature and the latter 3.8˚C above the previous minimal temperature.

Brief comparison of upper and lower Punehu Stream sites during the 2013-2014 period

Downstream deterioration in certain aspects of water quality in the lower stream reaches was emphasised by a very significant increase in median bacteriological numbers (630 faecal coliforms per 100 mls and 488 enterococci per 100 mls), and median nutrient concentrations (particularly nitrogen species), with nitrate, total nitrogen, and total phosphorus increasing by factors of about 25, 12, and 3 times respectively. These downstream spatial trends may be compared with median 18-year historical data which indicate bacterial increases of 390 per 100 mls (faecal coliforms) and 264 per 100 mls (enterococci) and increases in nitrate, total nitrogen, and total phosphorus of 30, 7, and 2 times respectively. Relatively similar median turbidity levels and suspended solids concentrations were found, with a very small decrease in median black disc clarity (4% reduction) between sites compared with the historical median turbidity increase of only 0.1 NTU and decrease in median black disc clarity of 0.31 m. Some of these changes are more apparent when mass loadings are calculated, taking into account the increased flow at the lower site (e.g.

median flow increased by 42% in the lower reaches of the stream). The downstream water temperature range increased by only 0.4 C while the median increased by 1.2 C. The median pH increased by only 0.1 unit in the lower reaches.

The differences between upper and lower stream clarity (black disc), turbidity, pH and temperature ranges may have been greater but for the impact of the open, developed farmland on the reach between the National Park and the upper site at Wiremu Road.

Brief comparison with the previous 1995-2013 period

Very similar aesthetic water quality was indicated with minimal difference in median turbidity recorded during the more recent twelve-month survey period, very minor decrease in median black disc clarity of 0.01 m, and a minimal increase in median suspended solids concentration (of 1 g/m^3).

In the more recent survey period a significant deterioration was recorded in median faecal coliform bacterial number (of 245 per 100 mls) and in median enterococci bacteria number (by 220 per 100 mls). Marked deterioration in median nutrient species concentrations were recorded for ammoniacal nitrogen, nitrate N, and total nitrogen which increased by about 68%, 47%, and 44 % of the long term medians respectively, with slightly lower increases of 16% in dissolved reactive phosphorus and 18% for total phosphorus.

Median dissolved oxygen saturation levels were within 1% and median BOD_5 levels increased by 0.3 g/m^3 in the most recent period.

There was minimal difference in median pH for the 2013-2014 period although the maximum pH was 0.7 unit lower in comparison with the previous eighteen-year period.

Water temperature range was much narrower (by 7.7 C); this decrease due to both higher minimum and lower maximum water temperatures (both by at least 3.8˚C) over the recent survey period, with the 2013-2014 median water temperature 0.8˚C lower than the median eighteen year temperature.

Median sampled flow over the 2013-2014 period was well above the median sampled (by 424 l/sec) flow for the previous eighteen-year period, despite a very low flow period in late summer 2014.

Waingongoro River at Eltham Road (site: WGG000500)

Analytical data are presented in Table 21 from the monthly sampling programme. The river flow recorded at this site for the twelve-month period is presented in Figure 5.

Table 21 Analytical results from monthly samples: Waingongoro River at Eltham Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m^3 $CaCO_3$)	Black disc (m)	BOD_5 (g/m^3)	Cond @ 20 C (mS/m)	DO (g/m^3)	DO Sat (%)	DRP (g/m^3P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
10 Jul 2013	1240	0.025	0.006	0.000	26	0.55	1.4	10.2	11.6	100	0.028	2900	900
14 Aug 2013	1200	0.020	0.004	0.000	24	1.04	1.1	10.1	11.0	101	0.020	120	120
10 Sep 2013	1255	0.014	0.003	0.000	31	0.81	0.7	11.8	11.3	105	0.018	3000	130
10 Oct 2013	1135	0.034	0.008	0.001	23	1.43	0.8	9.0	11.2	103	0.023	610	280
13 Nov 2013	1210	0.015	0.004	0.000	30	1.50	0.5	11.6	10.8	106	0.023	20	13
11 Dec 2013	1135	0.015	0.003	0.000	30	1.09	0.6	11.0	10.4	104	0.032	170	50
08 Jan 2014	1115	0.018	0.003	0.000	29	2.05	0.6	10.0	10.0	102	0.041	260	100
12 Feb 2014	1135	0.022	0.005	0.000	31	2.65	0.7	10.2	10.8	111	0.030	190	99
12 Mar 2014	1200	0.020	0.005	0.000	42	1.66	0.7	12.3	10.7	111	0.033	670	310
09 Apr 2014	1240	0.061	0.014	0.001	21	0.47	3.7	8.4	10.0	99	0.041	6000	7700
14 May 2014	1305	0.013	0.004	0.000	30	1.45	1.1	11.1	11.3	105	0.036	280	110
11 Jun 2014	1215	0.052	0.012	0.001	20	0.52	1.6	6.9	10.8	100	0.030	1300	360

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m^3/s)	NH_4 (g/m^3N)	NO_2 (g/m^3N)	NO_3 (g/m^3N)	pH	SS (g/m^3)	Temp (C)	TKN (g/m^3N)	TN (g/m^3N)	TP (g/m^3P)	Turb (NTU)
10 Jul 2013	1240	3600	2.890	0.065	0.009	1.321	7.7	12	8.4	0.32	1.65	0.096	4.3
14 Aug 2013	1200	120	3.315	0.048	0.009	1.161	7.7	7	10.0	0.36	1.53	0.069	2.6
10 Sep 2013	1255	3000	1.669	0.009	0.006	1.504	7.9	3	10.9	0.15	1.66	0.043	1.6
10 Oct 2013	1135	610	3.004	0.063	0.010	1.08	7.6	3	10.0	0.44	1.53	0.056	1.7
13 Nov 2013	1210	20	1.482	0.028	0.007	1.413	7.8	2	14.4	0.12	1.54	0.038	1.2
11 Dec 2013	1135	180	2.500	0.013	0.006	1.534	7.8	4	14.3	0.04	1.58	0.062	1.5
08 Jan 2014	1115	280	1.665	0.021	0.007	1.093	7.7	<2	15.1	0.18	1.28	0.048	1.1
12 Feb 2014	1135	190	0.810	0.017	0.006	0.674	8.2	<2	15.4	0.14	0.82	0.048	1.1
12 Mar 2014	1200	680	0.340	0.013	0.004	0.626	7.9	<2	16.6	0.14	0.77	0.051	1.1
09 Apr 2014	1240	6100	2.723	0.080	0.011	0.549	7.6	14	13.5	0.70	1.26	0.132	4.4
14 May 2014	1305	300	1.886	0.010	0.011	1.369	7.8	3	11.0	0.19	1.57	0.054	2.0
11 Jun 2014	1215	1400	5.014	0.112	0.011	0.619	7.4	10	10.4	0.59	1.22	0.109	3.8

The statistical summary of this data is presented in Table 22.

Table 22 Statistical summary of data from July 2013 to June 2014: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.013	0.061	0.020	12	0.016
A440F	Absorbance @ 440nm Filtered	/cm	0.003	0.014	0.004	12	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	20	42	30	12	6
BDISC	Black disc transparency	m	0.47	2.65	1.26	12	0.66
BOD_5	Biochemical oxygen demand 5day	g/m³	0.5	3.7	0.8	12	0.9
CONDY	Conductivity @ 20'C	mS/m	6.9	12.3	10.2	12	1.5
DO	Dissolved Oxygen	g/m³	10.0	11.6	10.8	12	0.5
PERSAT	Dissolved Oxygen Saturation %	%	99	111	104	12	4
DRP	Dissolved reactive phosphorus	g/m³P	0.018	0.041	0.030	12	0.008
ECOL	E.coli bacteria	nos/100 ml	20	6000	445	12	1811
ENT	Enterococci bacteria	nos/100 ml	13	7700	125	12	2171
FC	Faecal Coliforms	nos/100 ml	20	6100	455	12	1897
FLOW	Flow	m³/s	0.340	5.014	2.193	12	1.249
NH_4	Ammoniacal nitrogen	g/m³N	0.009	0.112	0.024	12	0.034
NO_2	Nitrite nitrogen	g/m³N	0.004	0.011	0.008	12	0.002
NO_3	Nitrate nitrogen	g/m³N	0.55	1.53	1.13	12	0.371
PH	pH		7.4	8.2	7.8	12	0.2
SS	Suspended solids	g/m³	<2	14	3	12	4
TEMP	Temperature	°C	8.4	16.6	12.2	12	2.7
TKN	Total Kjeldahl nitrogen	g/m³N	0.04	0.70	0.18	12	0.21
TN	Total nitrogen	g/m³N	0.77	1.66	1.53	12	0.31
TP	Total phosphorus	g/m³P	0.038	0.132	0.055	12	0.029
TURB	Turbidity	NTU	1.1	4.4	1.6	12	1.3

A statistical summary of the nineteen years' data collected since 1 July 1995, is presented in Table 23.

Table 23 Statistical summary of data from July 1995 to June 2014: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.009	0.100	0.021	228	0.013
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.024	0.005	228	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.003	0.000	228	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	11	49	30	228	7
BDISC	Black disc transparency	m	0.10	4.39	1.68	228	0.83
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	7.3	0.7	228	0.9
CONDY	Conductivity @ 20'C	mS/m	4.6	14.7	11.2	228	1.6
DO	Dissolved Oxygen	g/m³	9.2	13.0	10.6	229	0.7
PERSAT	Dissolved Oxygen Saturation %	%	92	121	102	229	5
DRP	Dissolved reactive phosphorus	g/m³P	0.003	0.146	0.019	228	0.014
ECOL	E.coli bacteria	nos/100 ml	6	59000	170	204	4287
ENT	Enterococci bacteria	nos/100 ml	3	7700	100	228	944
FC	Faecal Coliforms	nos/100 ml	6	100000	190	228	7802
FLOW	Flow	m³/s	0.326	28.797	1.654	228	3.386
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	1.720	0.018	228	0.118
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.033	0.007	228	0.005
NO_3	Nitrate nitrogen	g/m³N	0.14	2.31	1.11	228	0.474
PH	pH		7.1	8.6	7.8	228	0.3
SS	Suspended solids	g/m³	<2	180	3	228	18
TEMP	Temperature	°C	5.6	20.8	12.4	228	3.2
TKN	Total Kjeldahl nitrogen	g/m³N	<0.01	2.41	0.20	228	0.3
TN	Total nitrogen	g/m³N	0.27	3.22	1.44	228	0.51
TP	Total phosphorus	g/m³P	0.013	0.829	0.038	228	0.079
TURB	Turbidity	NTU	0.7	36	1.5	227	3.98

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

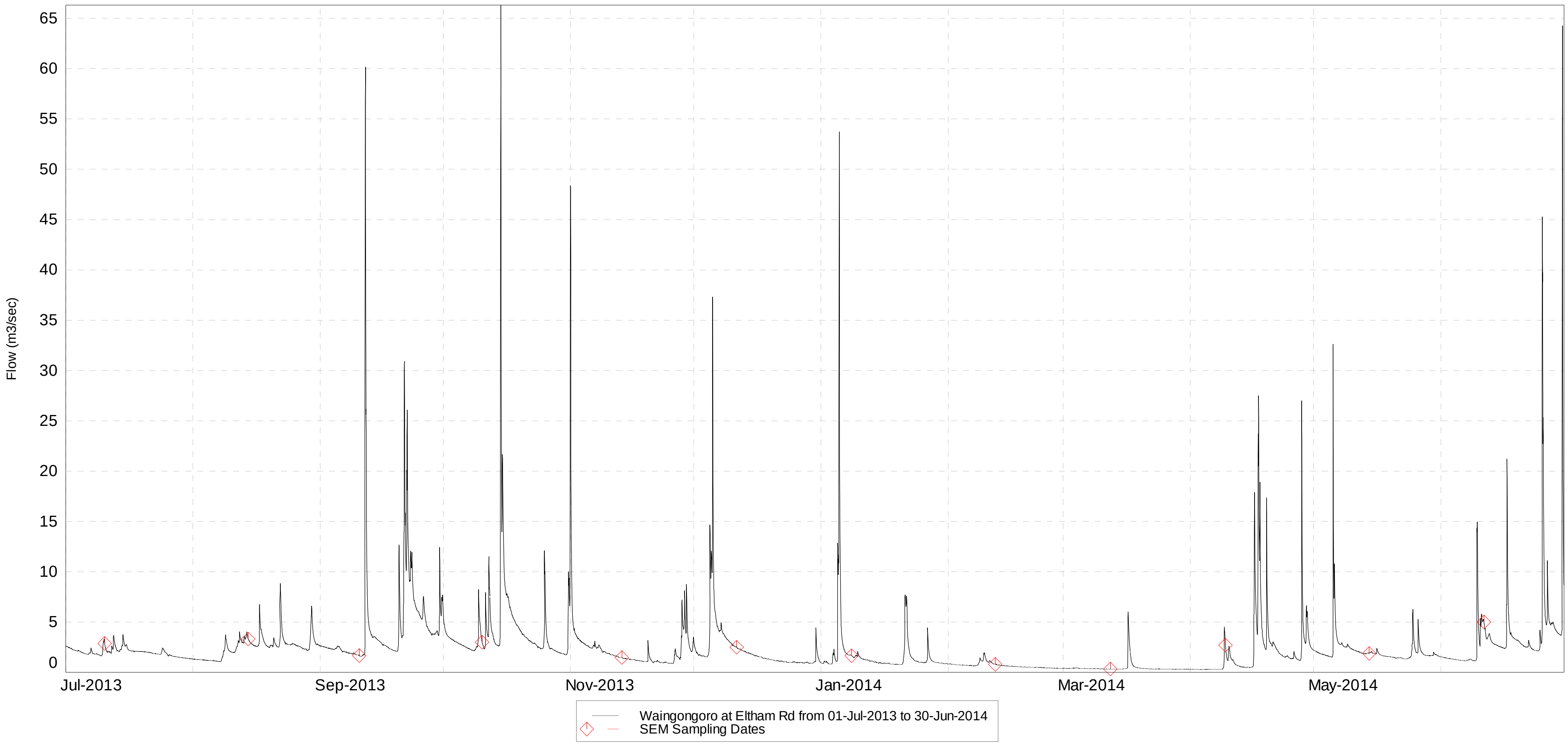

Figure 5 Flow record for the Waingongoro River at Eltham Road

Discussion

2013-2014

Moderate aesthetic water quality (more similar to lower reaches' aesthetic quality) was indicated by a median black disc clarity of 1.26 m and median turbidity of 1.6 NTU, in the mid-reaches of the longest ring-plain river in Taranaki but recognising that this site (altitude: 200 m asl) is 23 km from the National Park boundary. The maximum clarity (black disc of 2.65 m), 1.74 m lower than the historical maximum, was recorded in late summer during low flow conditions (0.81 m^3/s), while worst black disc clarities (0.47 and 0.52 m) occurred during small freshes coincident with turbidities of 4.4 and 3.8NTU and suspended solids concentrations of 14 and 10 g/m^3 sampled in April and June 2014 (Figure 5). Generally, poorer water quality conditions monitored during freshes (elevated bacterial numbers, some elevated nutrients, discolouration, and decreased clarity) were apparent on at least three occasions during the 2013-2014 period with the April, 2014 event following a lengthy period of low flow conditions.

pH reached a maximum of 8.2 in late summer coincident with supersaturation (111%) of dissolved oxygen, although it would be expected that pH would have risen further later in the day, particularly in mid to late summer, than the value measured at the time of sampling (near midday).

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 99% saturation recorded in autumn) and low BOD_5 levels (median: 0.8 g/m^3). Bacteriological quality was poorer than typical of the mid reaches of developed ring plain catchments, subject to agricultural impacts, with median faecal coliform and enterococci numbers of 455 and 125 (per 100 mls) respectively. Water temperature varied over a moderate range of 8.2 C with a maximum summer (late morning) river temperature of 16.6 C recorded in March 2014 under very low flow conditions (Figure 5); only 14 l/sec above the minimum flow sampled over the previous 18 year period.

Brief comparison with previous 1995-2013 period

The latest twelve-month period sampled a narrower range of flow conditions including the second lowest flow (0.34 m^3/s) sampled to date, while median sampled flow was higher (by 570 l/sec) than the median of flows sampled in the previous eighteen-year period. Aesthetic river water quality was poorer in terms of median black disc clarity (which decreased by 0.46 m), median suspended solids level (no change), and median turbidity level (which increased by 0.1 NTU) during the 2013-2014 period, coincident with a slightly higher proportion of fresh flows sampled.

In general, marked deterioration in faecal coliform bacteriological water quality was recorded in the 2013-2014 period with a higher median number (by 275 per 100 mls) and some deterioration in median enterococci number (by 25 per 100 mls). Some increases were indicated in median nutrient species' concentrations over the 2013-2014 period particularly ammoniacal nitrogen, dissolved phosphorus, and total phosphorus which rose 33%, 67%, and 49% respectively.

The range in water temperature was much narrower (by 7.0 C) over the 2013-2014 period mainly due to a cooler (by 4.2˚C) maximum water temperature although the median water temperature was only 0.2˚C lower in the 2013-2014 period.

Median pH values were identical but the maximum pH previously recorded (over 18 years) was 0.4 unit higher than that measured in the 2013-2014 period.

Waingongoro River at SH45 (site: WGG000900)

Analytical data are presented in Table 24 from the monthly sampling programme. The river flow recorded at this site for the twelve-month period at this SH45 site is presented in Figure 6.

Table 24 Analytical results from monthly samples: Waingongoro River at SH45

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ $CaCO_3$)	Black disc (m)	BOD_5 (g/m³)	Cond @ 20 C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
10 Jul 2013	1205	0.026	0.005	0.001	34	0.54	2.5	16.4	11.7	100	0.058	4200	250
14 Aug 2013	1130	0.029	0.007	0.001	32	0.82	2.5	16.4	10.9	100	0.051	220	46
10 Sep 2013	1210	0.026	0.006	0.001	38	0.68	1.6	17.1	11.1	103	0.041	110	16
10 Oct 2013	1100	0.035	0.008	0.001	32	0.65	2.7	13.9	11.0	102	0.046	4500	250
13 Nov 2013	1130	0.027	0.006	0.001	38	1.02	1.2	16.3	10.6	105	0.039	1600	82
11 Dec 2013	1105	0.023	0.005	0.000	37	1.11	1.0	14.6	10.1	103	0.053	260	110
08 Jan 2014	1040	0.030	0.006	0.000	38	1.61	0.9	14.2	9.9	103	0.065	240	160
12 Feb 2014	1050	0.032	0.006	0.000	43	1.71	1.1	15.3	10.4	108	0.047	68	91
12 Mar 2014	1125	0.031	0.007	0.001	54	2.11	1.1	18.6	10.1	106	0.069	130	100
09 Apr 2014	1205	0.058	0.013	0.001	57	0.79	3.0	23.2	9.6	97	0.108	2000	3700
14 May 2014	1220	0.015	0.005	0.000	37	1.78	1.0	14.6	11.2	103	0.036	540	610
11 Jun 2014	1140	0.049	0.011	0.001	29	0.40	3.6	11.0	10.6	98	0.069	830	1300

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m³/s)	NH_4 (g/m³N)	NO_2 (g/m³N)	NO_3 (g/m³N)	pH	SS (g/m³)	Temp (C)	TKN (g/m³N)	TN (g/m³N)	TP (g/m³P)	Turb (NTU)
10 Jul 2013	1205	4200	8.320	0.040	0.031	2.249	7.7	16	8.9	0.38	2.66	0.138	5.0
14 Aug 2013	1130	220	8.244	0.041	0.026	2.034	7.6	12	11.0	0.44	2.50	0.119	4.3
10 Sep 2013	1210	110	5.488	0.031	0.022	2.238	7.8	9	12.0	0.58	2.84	0.098	3.5
10 Oct 2013	1100	4500	9.755	0.108	0.029	1.411	7.6	12	11.3	0.96	2.40	0.128	4.7
13 Nov 2013	1130	1700	5.322	0.073	0.010	1.850	7.8	4	15.6	0.28	2.14	0.072	2.3
11 Dec 2013	1105	260	7.680	0.026	0.013	1.807	7.8	7	16.3	0.44	2.26	0.080	2.6
08 Jan 2014	1040	260	4.359	0.041	0.011	1.449	7.7	4	16.5	0.32	1.78	0.091	1.7
12 Feb 2014	1050	68	2.434	0.012	0.007	1.063	8.0	2	16.8	0.37	1.44	0.073	1.5
12 Mar 2014	1125	130	1.324	0.047	0.015	1.125	8.0	2	18.3	0.38	1.52	0.100	1.2
09 Apr 2014	1205	2000	1.988	0.127	0.026	1.334	7.9	6	15.7	0.86	2.22	0.184	3.0
14 May 2014	1220	540	4.971	0.018	0.006	1.464	7.8	4	11.3	0.27	1.74	0.054	2.3
11 Jun 2014	1140	830	10.961	0.167	0.043	1.067	7.4	18	11.6	0.79	1.90	0.181	5.6

The statistical summary of this data is presented in Table 25.

Table 25 Statistical summary of data from July 2013 to June 2014: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.015	0.058	0.030	12	0.011
A440F	Absorbance @ 440nm Filtered	/cm	0.005	0.013	0.006	12	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.001	12	0
ALKT	Alkalinity Total	g/m3 CaCO3	29	57	38	12	9
BDISC	Black disc transparency	m	0.40	2.11	0.92	12	0.56
BOD_5	Biochemical oxygen demand 5day	g/m3	0.9	3.6	1.4	12	0.9
CONDY	Conductivity @ 20'C	mS/m	11.0	23.2	15.8	12	3
DO	Dissolved Oxygen	g/m3	9.6	11.7	10.6	12	0.6
PERSAT	Dissolved Oxygen Saturation %	%	97	108	103	12	3
DRP	Dissolved reactive phosphorus	g/m3P	0.036	0.108	0.052	12	0.02
ECOL	E.coli bacteria	nos/100 ml	68	4500	400	12	1585
ENT	Enterococci bacteria	nos/100 ml	16	3700	135	12	1052
FC	Faecal Coliforms	nos/100 ml	68	4500	400	12	1586
FLOW	Flow	m3/s	1.324	10.961	5.405	12	3.119
NH_4	Ammoniacal nitrogen	g/m3N	0.012	0.167	0.041	12	0.048
NO_2	Nitrite nitrogen	g/m3N	0.006	0.043	0.018	12	0.011
NO_3	Nitrate nitrogen	g/m3N	1.06	2.25	1.46	12	0.433
PH	pH		7.4	8.0	7.8	12	0.2
SS	Suspended solids	g/m3	2	18	6	12	5
TEMP	Temperature	°C	8.9	18.3	13.8	12	3
TKN	Total Kjeldahl nitrogen	g/m3N	0.27	0.96	0.41	12	0.24
TN	Total nitrogen	g/m3N	1.44	2.84	2.18	12	0.45
TP	Total phosphorus	g/m3P	0.054	0.184	0.099	12	0.042
TURB	Turbidity	NTU	1.2	5.6	2.8	12	1.5

This was the sixteenth year of state of the environment data collection by the Taranaki Regional Council for this site, and these data are provided in Table 26 for reference or comparative purposes.

Table 26 Statistical summary of data from July 1998 to June 2014: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.078	0.032	192	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.019	0.007	192	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	192	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	21	62	39	192	9
BDISC	Black disc transparency	m	0.12	4.34	1.18	192	0.59
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	6.7	1.0	192	0.9
CONDY	Conductivity @ 20˚C	mS/m	9.8	23.2	16.4	192	2.2
DO	Dissolved oxygen	g/m^3	8.4	12.9	10.5	192	0.8
PERSAT	Dissolved oxygen saturation %	%	89	141	101	192	6
DRP	Dissolved reactive phosphorus	g/m^3P	0.015	0.223	0.057	192	0.035
ECOL	E.coli bacteria	nos/100 ml	3	41000	220	191	3411
ENT	Enterococci bacteria	nos/100 ml	6	4200	150	192	549
FC	Faecal coliforms	nos/100 ml	3	41000	220	192	3403
FLOW	Flow	m^3/s	0.997	50.341	4.818	192	6.906
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.305	0.034	192	0.042
NO_2	Nitrite nitrogen	g/m^3N	0.003	0.132	0.021	192	0.018
NO_3	Nitrate nitrogen	g/m^3N	0.74	2.98	1.87	192	0.52
pH	pH		7.3	9.1	7.8	192	0.3
SS	Suspended solids	g/m^3	< 2	120	5	192	16
TEMP	Temperature	°C	5.4	22.0	13.7	192	3.7
TKN	Total kjeldahl nitrogen	g/m^3N	0.02	1.51	0.40	192	0.25
TN	Total nitrogen	g/m^3N	0.97	3.59	2.40	192	0.57
TP	Total phosphorus	g/m^3P	0.042	0.325	0.100	192	0.051
TURB	Turbidity	NTU	1.2	36	2.3	191	4.2

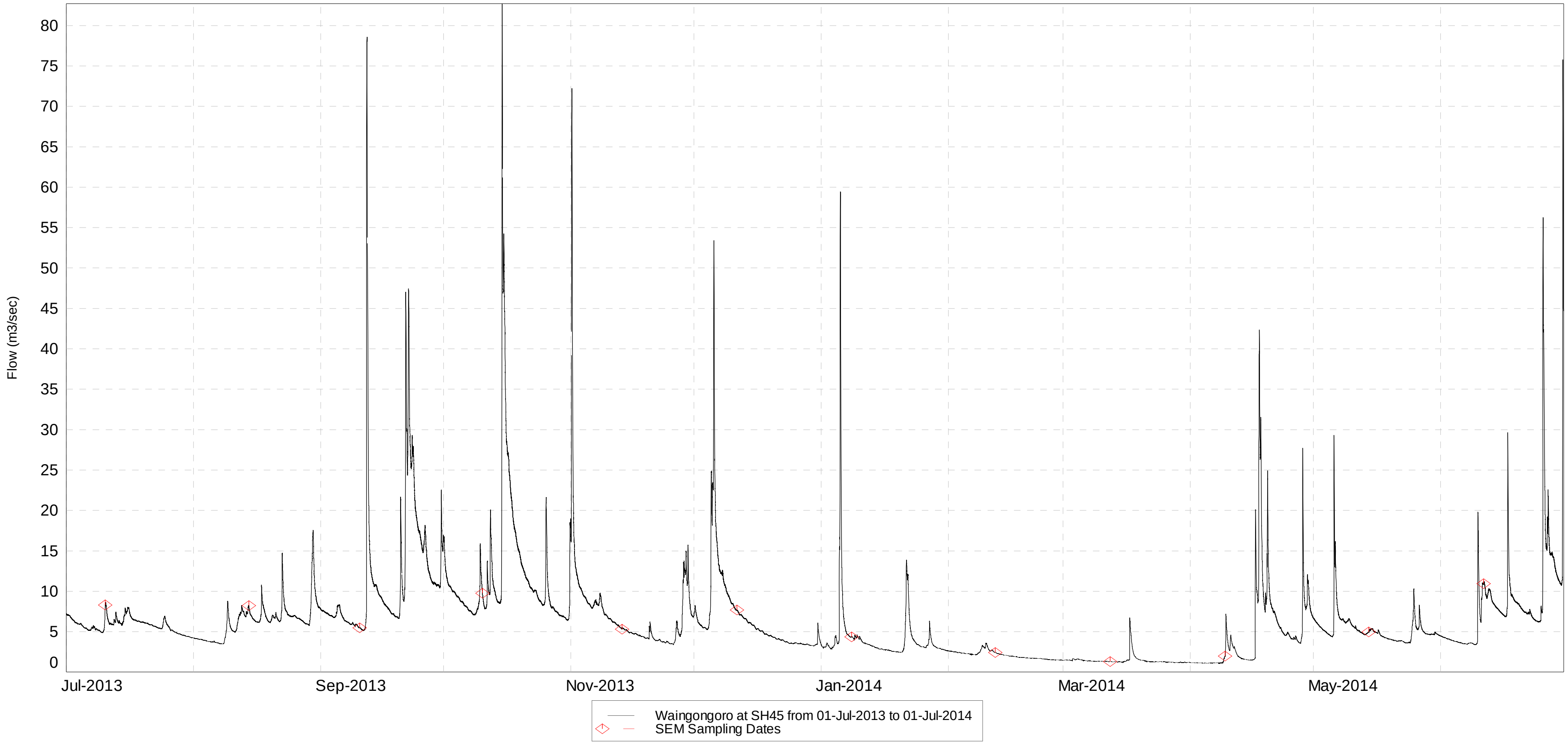

Figure 6 Flow record for the Waingongoro River at SH45

Discussion

2013-2014 period

Relatively poor aesthetic water quality was indicated by a median black disc clarity of 0.92 m and median turbidity of 2.8 NTU, in the lower reaches of the longest ring-plain confined river or stream in Taranaki. The moderately low maximum clarity (black disc value of 2.11 m) was recorded in early autumn during very low flow conditions (1.32m^3/s). The lowest black disc clarities of 0.40 m and 0.54 m, highest turbidities of 5.6 NTU and 5.0 NTU, and suspended solids concentrations of 18 g/m^3 and 16 g/m^3 were sampled during small freshes in June 2014 and July 2013 respectively. Poorest water quality conditions were apparent at times of fresh flows (Figure 6) when elevated bacterial numbers, nutrients, and/or discolouration, and decreased clarity were typical.

pH reached 8.0 in late summer-early autumn under very low flow conditions coincidental with highest dissolved oxygen saturation level (106 to 108%), although it would be expected that pH would have risen further during summer/autumn later in the day (i.e. after 1125 NZST), than at the earlier sampling times.

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 97% saturation) and moderately low BOD_5 levels (median: 1.4 g/m^3). Bacteriological quality was poor for this site with numbers higher than typical for of the lower reaches of developed ring plain catchments, subject to agricultural impacts; with median faecal coliform and enterococci numbers of 400 and 135 (per 100 mls) respectively. These numbers reflected, to some degree, the proximity of preceding river freshes on several sampling survey occasions during the period. Median nutrient levels were relatively high and typical of the lower reaches of ring plain rivers receiving agricultural and industrial point-source discharges. Water temperatures varied over a moderate range of 9.4 C with a maximum autumn (late morning) river temperature of 18.3 C recorded in March 2014.

Brief comparison of upper and lower Waingongoro River sites during the 2013-2014 period

Downstream deterioration in aspects of water quality in the lower reaches of the river was emphasised by more turbid conditions (lower median black disc clarity by 0.34 m (27% decrease), increased median turbidity level (by 1.2 NTU), and a small increase in median suspended solids concentration of 3 g/m^3). Bacteriological quality, in terms of the median faecal coliform count, remained poor although there was a small improvement (of 55 per 100 mls) at the lower river site whereas the median enterococci count deteriorated by 10 per 100 mls (compared with historical median deteriorations of 40 per 100 ml for faecal coliforms and 50 per 100 mls for enterococci). The lower river site's pH range was narrower (but only by 0.2 unit) but the median pH levels were identical at both sites. Maximum pH recorded was 0.2 unit lower at the downstream site, which was atypical of downstream trends in ringplain streams.

Median BOD_5 was higher by 0.6 g/m^3 at the SH45 site where all median nutrient species' concentrations also showed significant increases (by up to 80%) compared with upstream concentrations). Historical median data indicate from 68% to 200% increases in nutrient species concentrations in a downstream direction.

Water temperature range was wider (by 1.2 C) at the lower site with median water temperature 1.6 C warmer at this site in the lower reach of the river in comparison with the mid reach site. Historical median temperatures have increased downstream by 1.3˚C and ranges by 1.4˚C. Median flow increased by 146% at the lower reach site in the 2013-2014 period compared with 191% over the previous 16-year period.

Brief comparison with the previous 1998-2013 period

The most recent twelve-month period sampled a much narrower range of flow conditions but the median sampled flow was higher by 647 l/sec than that sampled over the previous fifteen-year period. This was due in part to several freshes, despite the late summer-autumn low flow period, sampled in the 2013-2014 year.

Water clarity was slightly poorer with the medians for suspended solids higher by 1 g/m^3, turbidity higher by 0.5 NTU, and black disc clarity lower by 0.28 m in the 2013-2014 period.

Median faecal coliform bacterial number showed a marked deterioration of 180 per 100 ml but enterococci improved slightly by 15 per 100 ml. While pH median values were identical, a much narrower range (by 1.2 units) was recorded in the recent twelve-month period due to the absence of very elevated summer pH values which had been recorded at times in the previous fifteen-year period. Dissolved oxygen saturation median values were within 2%. Both median phosphorus species nutrient levels were relatively similar in the recent one year period and two of the median nitrogen nutrient species' levels were slightly lower in the recent year. The exception was the median ammonia nitrogen which increased by 28% over the 2013-2014 year.

The range in water temperatures was much narrower (by 7.2 C) due to a higher minimum temperature (by 3.5˚C) and lower maximum temperature (by 3.7˚C) while the median was only 0.1 C higher in the 2013-2014 sampling period than that recorded over the previous fifteen-year period.

Patea River at Barclay Road (site: PAT000200)

Analytical data are presented in Table 27 from the monthly sampling programme.

Table 27 Analytical results from monthly samples: Patea River at Barclay Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ $CaCO_3$)	Black disc (m)	BOD_5 (g/m³)	Cond @ 20 C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
10 Jul 2013	1310	0.050	0.011	0.001	11	1.76	<0.5	4.2	11.7	99	0.014	11	3
14 Aug 2013	1230	0.023	0.005	0.000	9	3.66	<0.5	5.7	11.1	99	0.009	4	3
10 Sep 2013	1325	0.013	0.003	0.000	23	4.99	<0.5	6.8	11.5	100	0.019	50	84
10 Oct 2013	1205	0.036	0.007	0.001	10	3.68	<0.5	4.4	11.1	100	0.010	7	4
13 Nov 2013	1240	0.014	0.004	0.001	24	6.96	<0.5	6.5	11.1	103	0.026	72	1
11 Dec 2013	1200	0.016	0.004	0.000	21	5.20	<0.5	5.8	10.5	102	0.027	15	7
08 Jan 2014	1150	0.021	0.004	0.000	19	6.19	<0.5	5.3	10.3	102	0.015	21	1
12 Feb 2014	1210	0.017	0.003	0.000	22	5.02	<0.5	6.0	10.5	103	0.023	8	<1
12 Mar 2014	1230	0.009	0.003	0.000	30	5.59	<0.5	7.6	10.7	102	0.036	11	23
09 Apr 2014	1330	0.056	0.012	0.001	9	1.57	0.6	4.6	10.2	100	0.013	96	56
14 May 2014	1340	0.013	0.004	0.001	23	4.77	<0.5	6.0	11.2	101	0.032	48	3
11 Jun 2014	1310	0.070	0.014	0.001	7	1.46	<0.5	3.1	10.8	100	0.008	92	3

Date		FC (Nos/ 100ml)	Flow (m³/s)	NH_4 (g/m³N)	NO_2 (g/m³N)	NO_3 (g/m³N)	pH	SS (g/m³)	Temp (C)	TKN (g/m³N)	TN (g/m³N)	TP (g/m³P)	Turb (NTU)
10 Jul 2013	1310	11	0.483	<0.003	0.001	0.019	7.4	<2	5.7	0.03	<0.05	0.020	1.0
14 Aug 2013	1230	4	0.550	0.034	<0.001	0.03	7.2	<2	7.1	0.03	0.06	0.015	0.7
10 Sep 2013	1325	50	0.199	0.017	<0.001	0.019	7.6	<2	6.8	0.06	0.08	0.026	0.8
10 Oct 2013	1205	7	0.491	<0.003	<0.001	0.009	7.3	<2	7.3	0.07	0.08	0.018	0.6
13 Nov 2013	1240	74	0.164	0.008	<0.001	0.019	7.5	<2	10.2	0.03	<0.05	0.025	0.5
11 Dec 2013	1200	15	0.208	0.004	<0.001	0.019	7.6	<2	11.5	0.08	0.10	0.026	0.6
08 Jan 2014	1150	21	0.243	0.008	<0.001	0.009	7.4	<2	11.8	0.03	0.04	0.015	0.4
12 Feb 2014	1210	8	0.214	<0.003	<0.001	0.009	7.6	<2	11.6	0.07	0.08	0.036	0.5
12 Mar 2014	1230	11	0.111	0.005	<0.001	0.019	7.8	<2	10.5	0.06	0.08	0.039	0.5
09 Apr 2014	1330	97	0.647	0.004	0.001	0.009	7.5	<2	11.3	0.17	0.18	0.026	1.2
14 May 2014	1340	48	0.240	<0.003	<0.001	0.019	7.5	<2	8.3	0.02	0.04	0.032	0.7
11 Jun 2014	1310	92	1.427	0.007	<0.001	0.019	7.1	<2	9.0	0.09	0.11	0.019	0.8

The statistical summary of this data is presented in Table 28.

Table 28 Statistical summary of data from July 2013 to June 2014: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.070	0.019	12	0.02
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.014	0.004	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	7	30	20	12	8
BDISC	Black disc transparency	m	1.46	6.96	4.88	12	1.84
BOD_5	Biochemical oxygen demand 5day	g/m³	< 0.5	0.6	< 0.5	12	0
CONDY	Conductivity @ 20˚C	mS/m	3.1	7.6	5.8	12	1.3
DO	Dissolved oxygen	g/m³	10.2	11.7	11.0	12	0.5
PERSAT	Dissolved oxygen saturation %	%	99	103	100	12	1
DRP	Dissolved reactive phosphorus	g/m³P	0.008	0.036	0.018	12	0.009
ECOL	E.coli bacteria	nos/100 ml	4	96	18	12	34
ENT	Enterococci bacteria	nos/100 ml	< 1	84	3	12	27
FC	Faecal coliforms	nos/100 ml	4	97	18	12	35
FLOW	Flow	m³/s	0.111	1.427	0.242	12	0.363
NH_4	Ammoniacal nitrogen	g/m³N	< 0.003	0.034	0.004	12	0.009
NO_2	Nitrite nitrogen	g/m³N	< 0.001	0.001	< 0.001	12	0
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.03	0.02	12	0.006
pH	pH		7.1	7.8	7.5	12	0.2
SS	Suspended solids	g/m³	< 2	< 2	< 2	12	0
TEMP	Temperature	°C	5.7	11.8	9.6	12	2.2
TKN	Total kjeldahl nitrogen	g/m³N	0.02	0.17	0.06	12	0.04
TN	Total nitrogen	g/m³N	< 0.05	0.18	0.08	12	0.04
TP	Total phosphorus	g/m³P	0.015	0.039	0.026	12	0.008
TURB	Turbidity	NTU	0.4	1.2	0.6	12	0.23

A statistical summary of the nineteen years' data collected since 1 July 1995, is presented in Table 29.

Table 29 Statistical summary of data from July 1995 to June 2014: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.006	0.112	0.016	228	0.022
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.024	0.004	228	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	228	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	3.0	31	21	227	7
BDISC	Black disc transparency	m	0.09	9.10	4.38	227	1.81
BOD_5	Biochemical oxygen demand 5day	g/m³	< 0.5	3.7	< 0.5	228	0.3
CONDY	Conductivity @ 20˚C	mS/m	2.5	8.2	6.1	228	1.4
DO	Dissolved oxygen	g/m³	9.1	12.4	10.6	228	0.7
PERSAT	Dissolved oxygen saturation %	%	90	103	98	228	2
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.042	0.018	228	0.008
ECOL	E.coli bacteria	nos/100 ml	< 1	10000	20	204	763
ENT	Enterococci bacteria	nos/100 ml	< 1	2200	9	228	177
FC	Faecal coliforms	nos/100 ml	< 1	10000	20	228	724
FLOW	Flow	m³/s	0.084	18.000	0.216	228	1.57
NH_4	Ammoniacal nitrogen	g/m³N	< 0.003	0.057	< 0.003	228	0.006
NO_2	Nitrite nitrogen	g/m³N	< 0.001	0.003	0.001	228	0
NO_3	Nitrate nitrogen	g/m³N	< 0.01	0.14	0.02	228	0.017
pH	pH		6.5	8.0	7.5	228	0.2
SS	Suspended solids	g/m³	< 2	160	< 2	228	12
TEMP	Temperature	°C	3.7	14.7	9.2	228	2.5
TKN	Total kjeldahl nitrogen	g/m³N	< 0.01	2.70	0.05	228	0.21
TN	Total nitrogen	g/m³N	< 0.05	2.72	0.08	228	0.21
TP	Total phosphorus	g/m³P	< 0.01	0.281	0.024	228	0.023
TURB	Turbidity	NTU	0.3	31	0.5	227	2.26

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

Discussion

2013-2014 period

Aesthetic water quality was very high, as emphasised by median black disc and turbidity values of 4.88 m and 0.6 NTU respectively, and a maximum black disc clarity of 6.96 m measured under spring low flow conditions (164 l/sec). The lowest black disc clarity (1.46 m) was recorded in June 2014, coincident with a moderate fresh (1.427 m^3/s) in the river, with increases in colour and bacteria, but no measurable increases in BOD_5, turbidity, or suspended solids recorded.

Maximum pH (7.8) at this shaded site was measured in early autumn under very low flow conditions. pH range however was relatively narrow under all flow conditions (varying by only 0.7 unit) over the period.

Dissolved oxygen concentrations were consistently high with a minimum saturation of 99% recorded. The high water quality was also emphasised by very low BOD_5 levels (below 0.5 g/m^3 for the majority of the period) and generally low nutrient concentrations under normal flow conditions. Dissolved reactive phosphorus levels were typical of National Park sourced rivers.

Bacterial water quality was high (median faecal coliform and enterococci numbers of 18 and 3 per 100 mls respectively). There was minimal evidence of the slightly elevated counts found in past years in summer-autumn during periods of stable flow conditions, which may have been due to stock access upstream of the site noted previously in this short reach of the river below the National Park boundary.

River water temperatures varied over a moderate range (6.1 C) at this relatively shaded site during the period. A maximum mid-day temperature of 11.8 C was recorded under recession flow conditions in January 2014.

Brief comparison with the previous 1995-2013 period

A much narrower range but a higher median of river flows was sampled during the 2013-2014 period, with a few small and one larger freshes sampled, in comparison with the previous eighteen-year period. Median flow for the 2013-2014 sampling occasions was 28 l/sec higher than the median of sampled flows over the previous eighteen-year period. Aesthetic river water quality was very similar in terms of median turbidity although median black disc clarity was higher (by 0.51 m) during the 2013-2014 period. Median suspended solids concentrations were very low for both periods.

Median nutrient species levels were comparatively similar between the two periods, although there were small increases in median ammoniacal nitrogen and total phosphorus over the latest twelve-month sampling period.

Median faecal coliform bacterial number decreased (by 2 per 100 mls) and median enterococci number decreased (by 6 per 100 mls) over the recent sampling period. Median pH values were identical for the two periods while the maximum pH value was only 0.2 unit lower in the 2013-2014 period.

Median water temperature over the past twelve-month period was only 0.4 C higher than the median for the previous eighteen-year period but the maximum temperature was 2.9 C lower in the latest period than previously recorded. A narrower range of temperatures (by 4.9 C) was recorded in the 2013-2014 period due mainly to a lower maximum temperature (by 2.9 C) in this period.

Patea River at Skinner Road (site: PAT000360)

Analytical data are presented in Table 30 from the monthly sampling programme and the flow illustrated in Figure 7.

Table 30 Analytical results from monthly samples: Patea River at Skinner Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m^3 $CaCO_3$)	Black disc (m)	BOD_5 (g/m^3)	Cond @ 20 C (mS/m)	DO (g/m^3)	DO Sat (%)	DRP (g/m^3P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
10 Jul 2013	1410	0.031	0.007	0.001	23	0.34	2.3	8.0	11.5	99	0.033	2400	1100
14 Aug 2013	1330	0.023	0.005	0.000	22	0.91	1.5	9.1	10.8	100	0.028	480	150
10 Sep 2013	1415	0.019	0.004	0.000	28	2.28	0.9	10.2	11.3	104	0.023	100	35
10 Oct 2013	1300	0.035	0.008	0.001	21	1.55	1.0	7.8	11.2	104	0.027	1100	260
13 Nov 2013	1320	0.017	0.004	0.000	27	2.75	0.5	9.9	10.9	109	0.035	63	20
11 Dec 2013	1255	0.018	0.004	0.000	28	1.98	0.7	9.4	10.3	104	0.037	290	72
08 Jan 2014	1235	0.021	0.004	0.000	29	2.31	0.6	9.0	9.9	104	0.039	380	110
12 Feb 2014	1315	0.029	0.006	0.000	30	1.74	1.4	9.7	11.1	119	0.056	110	93
12 Mar 2014	1330	0.024	0.006	0.000	38	1.81	1.1	12.7	11.3	119	0.097	130	230
09 Apr 2014	1355	0.064	0.016	0.001	28	0.35	5.6	10.2	9.9	100	0.090	5200	11000
14 May 2014	1415	0.014	0.005	0.001	28	1.61	1.4	9.7	11.1	104	0.053	1400	650
11 Jun 2014	1330	0.047	0.010	0.001	20	0.45	2.3	7.1	10.7	100	0.032	1500	670

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m^3/s)	NH_4 (g/m^3N)	NO_2 (g/m^3N)	NO_3 (g/m^3N)	pH	SS (g/m^3)	Temp (C)	TKN (g/m^3N)	TN (g/m^3N)	TP (g/m^3P)	Turb (NTU)
10 Jul 2013	1410	2400	4.941	0.113	0.015	0.885	7.5	13	8.2	0.56	1.46	0.136	8.1
14 Aug 2013	1330	480	7.630	0.108	0.014	1.026	7.5	6	10.1	0.23	1.27	0.060	2.4
10 Sep 2013	1415	100	2.321	0.049	0.012	0.978	7.6	<2	10.6	0.11	1.10	0.044	1.7
10 Oct 2013	1300	1100	4.544	0.084	0.012	0.748	7.5	<2	10.2	0.22	0.98	0.053	1.6
13 Nov 2013	1320	63	2.424	0.044	0.013	0.907	7.9	<2	14.9	0.09	1.01	0.045	1.3
11 Dec 2013	1255	300	4.918	0.058	0.015	1.005	7.7	<2	14.5	0.24	1.26	0.053	1.5
08 Jan 2014	1235	380	4.918	0.092	0.014	0.866	7.6	2	16.1	0.24	1.12	0.057	1.4
12 Feb 2014	1315	110	1.302	0.017	0.019	0.731	8.6	2	17.3	0.27	1.02	0.088	1.5
12 Mar 2014	1330	140	0.662	0.022	0.020	0.960	8.5	<2	16.9	0.30	1.28	0.129	1.4
09 Apr 2014	1355	5200	2.859	0.135	0.018	0.642	7.7	14	14.0	0.78	1.44	0.203	5.0
14 May 2014	1415	1400	4.018	0.067	0.018	1.022	7.8	3	11.6	0.20	1.24	0.066	2.0
11 Jun 2014	1330	1500	10.589	0.146	0.015	0.685	7.3	8	11.1	0.59	1.29	0.107	4.6

The statistical summary of this data is presented in Table 31.

Table 31 Statistical summary of data from July 2013 to June 2014: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.014	0.064	0.024	12	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.004	0.016	0.006	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	20	38	28	12	5
BDISC	Black disc transparency	m	0.34	2.75	1.68	12	0.82
BOD_5	Biochemical oxygen demand 5day	g/m^3	0.5	5.6	1.2	12	1.4
CONDY	Conductivity @ 20˚C	mS/m	7.1	12.7	9.6	12	1.4
DO	Dissolved oxygen	g/m^3	9.9	11.5	11.0	12	0.5
PERSAT	Dissolved oxygen saturation %	%	99	119	104	12	7
DRP	Dissolved reactive phosphorus	g/m^3P	0.023	0.097	0.036	12	0.024
ECOL	E.coli bacteria	nos/100 ml	63	5200	430	12	1486
ENT	Enterococci bacteria	nos/100 ml	20	11000	190	12	3104
FC	Faecal coliforms	nos/100 ml	63	5200	430	12	1485
FLOW	Flow	m^3/s	0.662	10.589	4.281	12	2.758
NH_4	Ammoniacal nitrogen	g/m^3N	0.017	0.146	0.076	12	0.042
NO_2	Nitrite nitrogen	g/m^3N	0.012	0.020	0.015	12	0.003
NO_3	Nitrate nitrogen	g/m^3N	0.64	1.03	0.90	12	0.137
pH	pH		7.3	8.6	7.6	12	0.4
SS	Suspended solids	g/m^3	< 2	14	2	12	4
TEMP	Temperature	°C	8.2	17.3	12.8	12	3
TKN	Total kjeldahl nitrogen	g/m^3N	0.09	0.78	0.24	12	0.21
TN	Total nitrogen	g/m^3N	0.98	1.46	1.25	12	0.16
TP	Total phosphorus	g/m^3P	0.044	0.203	0.063	12	0.049
TURB	Turbidity	NTU	1.3	8.1	1.6	12	2.1

A statistical summary of the nineteen years' data collected since 1 July 1995 is presented in Table 32.

Table 32 Statistical summary of data from July 1995 to June 2014: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.095	0.023	228	0.015
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.023	0.005	228	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	228	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	10	57	27	228	6
BDISC	Black disc transparency	m	0.05	4.68	1.82	228	0.86
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	16.0	0.9	228	1.5
CONDY	Conductivity @ 20˚C	mS/m	5.0	14.3	9.9	228	1.5
DO	Dissolved oxygen	g/m^3	8.9	12.9	10.6	228	0.7
PERSAT	Dissolved oxygen saturation %	%	87	121	102	228	6
DRP	Dissolved reactive phosphorus	g/m^3P	0.010	0.160	0.038	228	0.031
ECOL	E.coli bacteria	nos/100 ml	2	25000	200	204	3304
ENT	Enterococci bacteria	nos/100 ml	4	19000	115	228	1689
FC	Faecal coliforms	nos/100 ml	2	63000	230	228	5279
FLOW	Flow	m^3/s	0.650	77.530	3.012	228	7.774
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.329	0.054	228	0.052
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.051	0.016	228	0.008
NO_3	Nitrate nitrogen	g/m^3N	0.21	1.54	0.92	228	0.215
pH	pH		7.0	8.8	7.8	228	0.4
SS	Suspended solids	g/m^3	< 2	360	2	228	29
TEMP	Temperature	°C	5.3	21.8	12.8	228	3.4
TKN	Total kjeldahl nitrogen	g/m^3N	0.010	4.07	0.24	228	0.37
TN	Total nitrogen	g/m^3N	0.740	4.50	1.22	228	0.34
TP	Total phosphorus	g/m^3P	0.022	1.390	0.066	228	0.114
TURB	Turbidity	NTU	0.2	80	1.5	227	7.2

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I

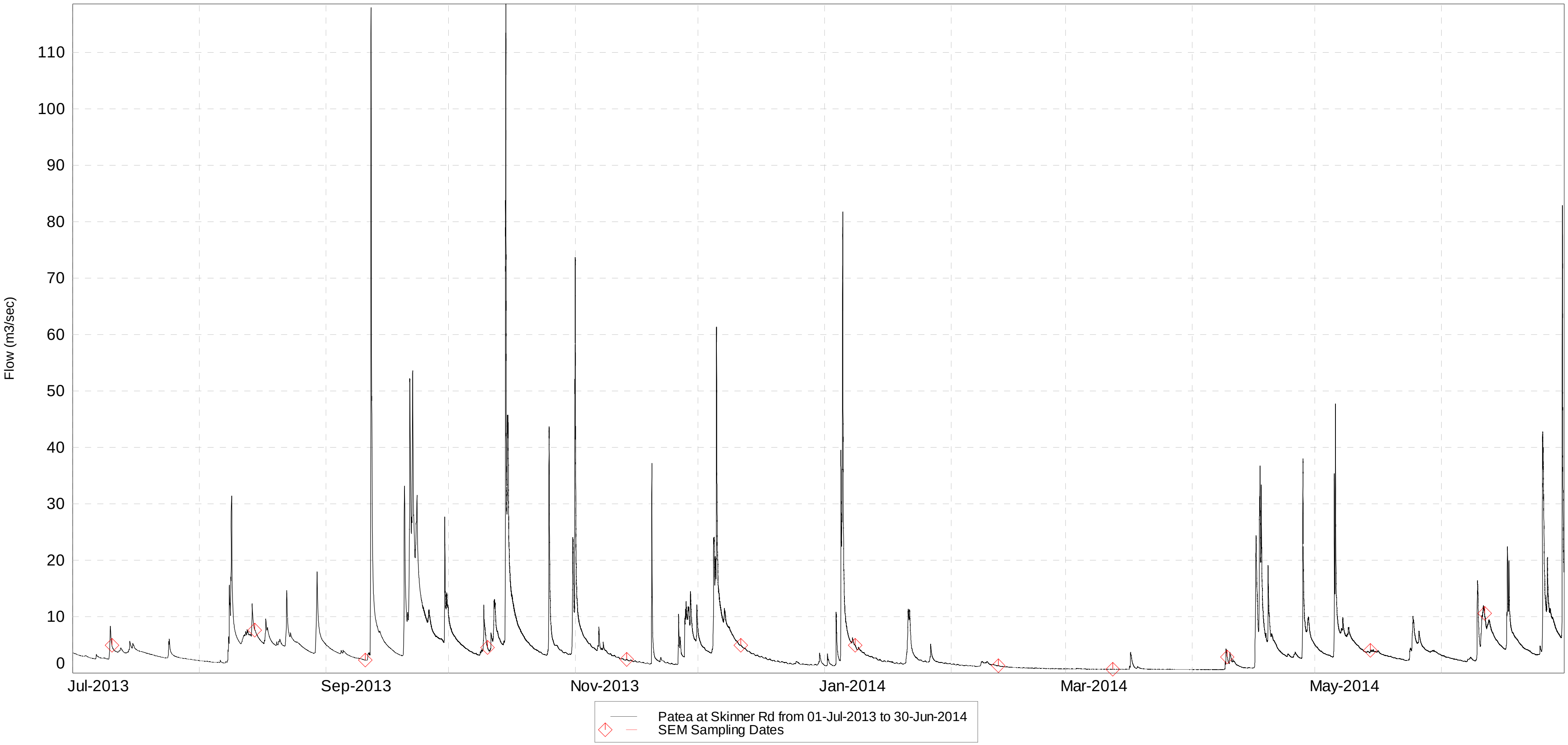

Figure 7 Flow record for the Patea River at Skinner Road

Discussion

2013-2014 period

Moderate median black disc clarity (1.68 metres) and median turbidity (1.6 NTU) were slightly lower than typical of the mid reaches of a ring plain river draining a developed catchment and receiving various point source discharges. However, this clarity and a low median suspended solids concentration (2 g/m^3), were indicative of moderate aesthetic water quality at this site. Minimal clarities (black disc of 0.34 m to 0.45 m and turbidities of 4.6 NTU to 8.1 NTU) and a small increase in suspended solids concentrations (8 g/m^3 to 14 g/m^3) were recorded during fresh events sampled in July 2013, April and June 2014 (Figure 7). Deterioration in other water quality parameters during these events was also illustrated by a high faecal coliform bacterial numbers, and elevated BOD_5 and total phosphorus concentrations.

Early afternoon pH levels reached a maximum of 8.6 units in late summer coincidental with dissolved oxygen saturation peaking at 119%. Dissolved oxygen levels were consistently high (99% or higher saturation) with supersaturation recorded particularly during late summer to autumn low flow conditions coincident with more extensive algal cover and elevated pH levels (> 8.4 units). BOD_5 concentrations under normal to low recession flow conditions were generally indicative of moderately low organic contamination (i.e. up to 1.5 g/m^3 on these occasions).

The moderately poor median bacteriological numbers (190 enterococci and 430 faecal coliforms per 100 mls) may be attributed to the high proportion of developed catchment, urban runoff, proximity of the municipal oxidation ponds system discharge to this site, and dairy farm waste disposal in the upper catchment. The relatively narrow range of faecal coliform numbers recorded under lower river flow conditions probably reflected some seasonal variability in the recently upgraded municipal oxidation pond performance due to the relative proximity of this discharge, more than to other point source or non-point source discharges.

Water temperatures varied over a moderate wide range of 9.1°C with a maximum (early afternoon) summer temperature of 17.3 C recorded in February 2014 (coincident with a pH of 8.6 and 119% dissolved oxygen saturation).

Brief comparison of upper and mid Patea River catchment sites during the 2013-2014 period

Some deterioration from the high upstream water quality conditions measured at the Barclay Road site was apparent at the Skinner Road site nearly 19 km (river distance) below the National Park boundary. This was emphasised particularly by elevated median bacterial species' numbers (24 to 60-fold increases) and increases in median nutrient species concentrations (2 to 45 fold) compared with historical (18-year) downstream increase in median bacterial numbers (11 to 12 fold) and nutrient species concentrations (2 to 46 fold). The pH range increased by 0.6 unit at the Skinner Road site with a maximum pH 0.8 unit higher than at the upstream site. A moderate increase in median turbidity levels (1.0 NTU) was measured in mid catchment identical to the historical median increase. Median BOD_5 increased by about 0.7 g/m^3 although maximum BOD_5 was 5.0 g/m^3 higher downstream. A deterioration in black disc clarity (median clarity decreased significantly by 3.20 m and maximum clarity to a larger degree by 4.21 m) was recorded, as a result of increased turbidity from run-off and point source discharges within the developed catchment of the river between the two sites. This may be compared with an 18-year median black disc deterioration of 2.54 m and maximum clarity deterioration of 4.48 m.

Water temperature range increased (by 3.0 C) at the Skinner Road site where median water temperature was higher (by 3.2 C) and maximum water temperature was higher (by 5.5 C) than at the Barclay Road site. In comparison, the historical 18-year median and maximum water temperatures have shown downstream increases of 3.6 C and 7.1 C respectively.

Brief comparison with the previous 1995-2013 period

The median of sampled flows in the recent twelve-month period was 1341 l/sec higher than the median of flows sampled over the 1995-2013 period due partly to several freshes sampled in the 2013-2014 year although the range of river flows sampled was much narrower and included the second lowest flow sampled to date (662 l/sec) in March 2014. Aesthetic water quality was slightly poorer than historical conditions with median black disc clarity lower by 0.15 m although there was no difference in the median suspended solids concentrations and minimal difference in turbidity (0.1 NTU) between periods.

There was a narrower pH range (by 0.5 pH unit) and lower maximum pH (by 0.2 pH unit) during the 2013-2014 period. Median dissolved oxygen percentage saturation was higher by an insignificant 2% in the 2013-2014 period.

Bacterial water quality deteriorated for faecal coliform and enterococci bacteria during the more recent sampling period, with the median faecal coliform number increasing by 200 (per 100 mls) and the enterococci number increasing by 80 (per 100 mls). Seasonal variability in municipal oxidation ponds' system performance and dairy shed wastes disposal would have been expected to have contributed to the differences in bacterial quality between periods.

Water temperature range was much narrower (by 7.4 C) during the more recent sampling period although the median water temperature was identical to the longer term median. The maximum water temperature recorded was 4.5 C lower than previously recorded but the minimum water temperature was higher (by 2.9 C) in the latest twelve-month period.

Median BOD_5 was 0.3 g/m^3 higher in the latest period with most median nutrient species showing decreases (ranging from 3% to 11%) during the more recent twelve-month sampling period. The exception was an increase of about 46% in median ammonia-N and about 3% in median total nitrogen concentrations in 2013-2014.

Mangaehu River at Raupuha Road (site: MGH000950)

Analytical data are presented in Table 33 from the monthly sampling programme. The flow record for the period is illustrated in Figure 8.

Table 33 Analytical results from monthly samples: Mangaehu River at Raupuha Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m^3 $CaCO_3$)	Black disc (m)	BOD_5 (g/m^3)	Cond @ 20 C (mS/m)	DO (g/m^3)	DO Sat (%)	DRP (g/m^{3}P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
10 Jul 2013	1440	0.060	0.012	0.001	28	0.15	1.0	8.6	11.3	96	0.006	1400	770
14 Aug 2013	1400	0.064	0.013	0.001	30	0.25	1.3	9.1	10.8	98	0.013	300	200
10 Sep 2013	1445	0.045	0.009	0.001	40	1.40	<0.5	10.6	11.1	102	0.004	66	12
10 Oct 2013	1330	0.072	0.016	0.001	28	0.27	0.7	7.8	10.4	100	0.006	960	250
13 Nov 2013	1355	0.048	0.010	0.000	41	1.77	<0.5	10.3	10.5	110	0.007	84	5
11 Dec 2013	1330	0.068	0.014	0.001	34	0.86	<0.5	8.5	10.0	104	0.007	380	44
08 Jan 2014	1310	0.060	0.012	0.000	30	0.76	0.5	7.7	9.6	104	0.006	820	290
12 Feb 2014	1400	0.040	0.007	0.000	61	2.06	0.7	14.0	9.3	102	<0.003	69	51
12 Mar 2014	1400	0.028	0.006	0.000	72	2.00	0.7	15.7	9.8	105	<0.003	51	84
09 Apr 2014	1430	0.030	0.006	0.000	70	1.83	0.7	15.6	10.0	105	<0.003	260	190
14 May 2014	1450	0.043	0.010	0.001	36	0.65	0.5	9.5	10.7	100	0.008	490	180
11 Jun 2014	1400	0.056	0.011	0.001	38	0.27	0.9	9.8	10.4	98	0.008	970	730

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m^3/s)	NH_4 (g/m^{3}N)	NO_2 (g/m^{3}N)	NO_3 (g/m^{3}N)	pH	SS (g/m^3)	Temp (C)	TKN (g/m^{3}N)	TN (g/m^{3}N)	TP (g/m^{3}P)	Turb (NTU)
10 Jul 2013	1440	1400	31.938	0.019	0.002	0.158	7.4	150	8.0	0.58	0.74	0.198	44
14 Aug 2013	1400	300	13.427	0.030	0.002	0.148	7.6	25	10.4	0.33	0.48	0.068	14
10 Sep 2013	1445	71	6.140	0.017	0.002	0.138	7.7	2	11.0	0.11	0.25	0.014	2.7
10 Oct 2013	1330	970	13.468	0.008	0.002	0.088	7.5	29	12.3	0.37	0.46	0.084	17
13 Nov 2013	1355	84	5.093	0.008	0.002	0.068	7.9	<2	17.9	0.05	0.12	0.015	2.4
11 Dec 2013	1330	380	8.771	0.009	0.002	0.058	7.8	5	16.9	0.28	0.34	0.027	3.9
08 Jan 2014	1310	830	9.526	0.017	0.002	0.088	7.6	7	18.0	0.14	0.23	0.026	4.5
12 Feb 2014	1400	69	2.536	<0.003	<0.001	0.009	8.1	4	18.9	0.11	0.12	0.010	1.7
12 Mar 2014	1400	51	1.811	0.004	<0.001	0.009	8.2	<2	18.8	0.13	0.14	0.010	1.4
09 Apr 2014	1430	270	2.793	0.004	<0.001	0.009	8.2	<2	17.2	0.13	0.14	0.010	1.8
14 May 2014	1450	490	15.174	0.009	0.001	0.109	7.6	15	11.5	0.13	0.24	0.029	6.5
11 Jun 2014	1400	1000	25.058	0.022	0.002	0.138	7.4	49	11.2	0.33	0.47	0.094	20

The statistical summary of this data is presented in Table 34.

Table 34 Statistical summary of data from July 2013 to June 2014: Mangaehu River at Raupuha Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.028	0.072	0.052	12	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.006	0.016	0.010	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.001	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	28	72	37	12	16
BDISC	Black disc transparency	m	0.15	2.06	0.81	12	0.75
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	1.3	0.7	12	0.3
CONDY	Conductivity @ 20˚C	mS/m	7.7	15.7	9.6	12	2.9
DO	Dissolved oxygen	g/m^3	9.3	11.3	10.4	12	0.6
PERSAT	Dissolved oxygen saturation %	%	96	110	102	12	4
DRP	Dissolved reactive phosphorus	g/m^3P	< 0.003	0.013	0.006	12	0.003
ECOL	E.coli bacteria	nos/100 ml	51	1400	340	12	448
ENT	Enterococci bacteria	nos/100 ml	5	770	185	12	259
FC	Faecal coliforms	nos/100 ml	51	1400	340	12	451
FLOW	Flow	m^3/s	1.811	31.94	9.148	12	9.31
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.030	0.009	12	0.008
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.002	0.002	12	0
NO_3	Nitrate nitrogen	g/m^3N	< 0.01	0.16	0.09	12	0.055
pH	pH		7.4	8.2	7.6	12	0.3
SS	Suspended solids	g/m^3	< 2	150	6	12	42
TEMP	Temperature	°C	8.0	18.9	14.6	12	3.9
TKN	Total kjeldahl nitrogen	g/m^3N	0.05	0.58	0.14	12	0.15
TN	Total nitrogen	g/m^3N	0.12	0.74	0.24	12	0.19
TP	Total phosphorus	g/m^3P	0.010	0.198	0.026	12	0.056
TURB	Turbidity	NTU	1.4	44	4.0	12	13

A statistical summary of the nineteen years' data collected since 1 July 1995 is presented in Table 35.

Table 35 Statistical summary of data from July 1995 to June 2014: Mangaehu River at Raupuha Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.027	0.181	0.054	228	0.018
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.056	0.011	228	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.025	0.000	228	0.002
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	9	79	38	228	13
BDISC	Black disc transparency	m	0.01	4.04	0.84	228	0.76
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	5.6	0.6	228	0.6
CONDY	Conductivity @ 20˚C	mS/m	4.3	16.1	9.8	228	2.3
DO	Dissolved oxygen	g/m^3	7.7	12.9	10.0	228	0.9
PERSAT	Dissolved oxygen saturation %	%	83	118	100	228	6
DRP	Dissolved reactive phosphorus	g/m^3P	< 0.003	0.026	0.006	228	0.004
ECOL	E.coli bacteria	nos/100 ml	6	16000	220	204	1944
ENT	Enterococci bacteria	nos/100 ml	1	6000	68	228	756
FC	Faecal coliforms	nos/100 ml	6	16000	250	228	2066
FLOW	Flow	m^3/s	1.658	111.87	6.830	228	15.836
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.081	0.012	228	0.011
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.016	0.002	228	0.001
NO_3	Nitrate nitrogen	g/m^3N	< 0.01	0.36	0.10	228	0.087
pH	pH		6.9	8.4	7.7	228	0.3
SS	Suspended solids	g/m^3	< 2	1300	4	228	121
TEMP	Temperature	°C	4.3	24.0	13.8	228	4.3
TKN	Total kjeldahl nitrogen	g/m^3N	0.020	1.90	0.17	228	0.26
TN	Total nitrogen	g/m^3N	0.070	2.10	0.30	228	0.29
TP	Total phosphorus	g/m^3P	0.003	0.786	0.020	228	0.101
TURB	Turbidity	NTU	1.4	850	3.5	227	64

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

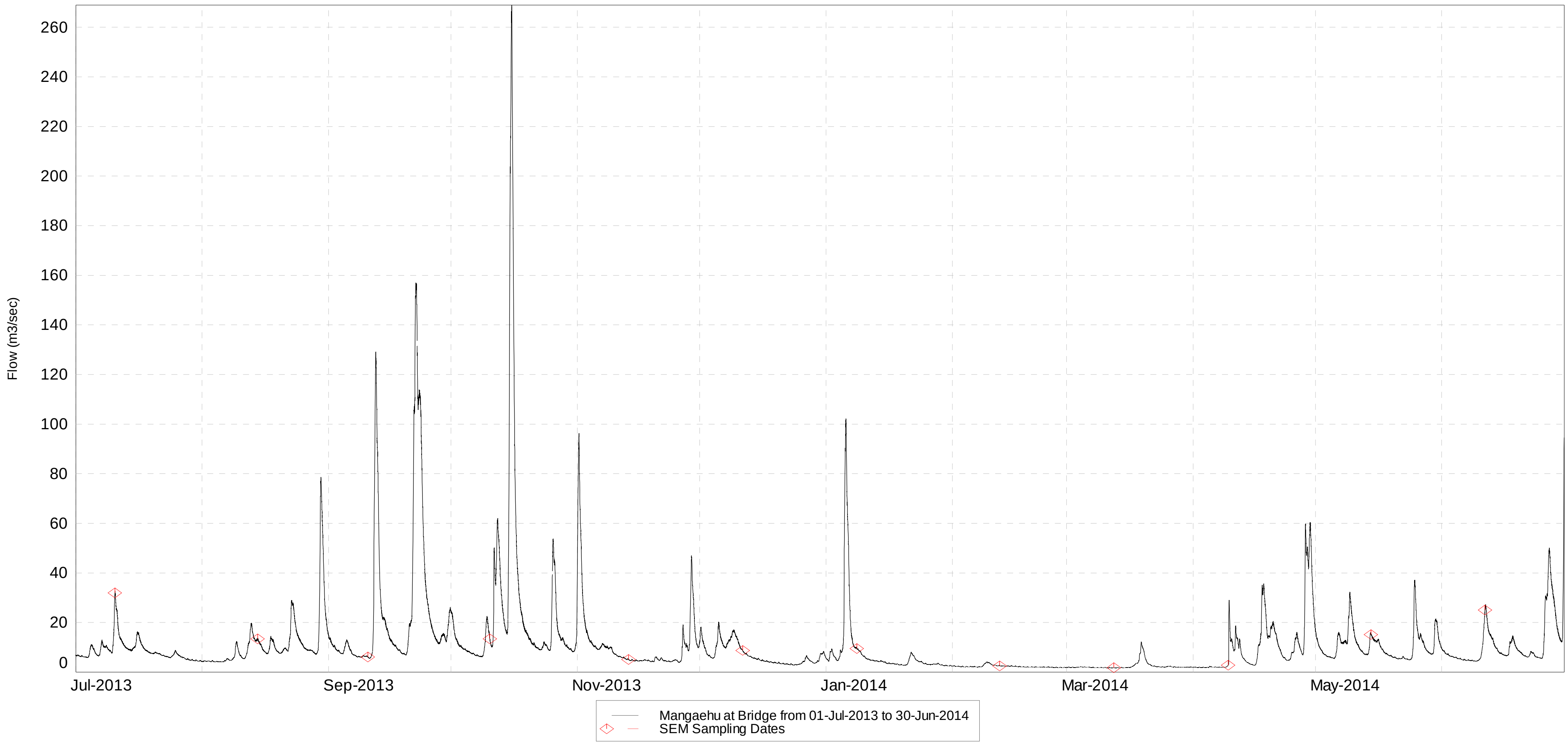

Figure 8 Flow record for the Mangaehu River at Raupuha Road

Discussion

2013-2014 period

The relatively poor visual appearance which characterises the mid and lower reaches of this eastern hill-country catchment river was emphasised by a low median black disc clarity of 0.81 metres with a maximum of 2.06 metres measured under low flow conditions in February 2014, one month after a significant fresh. Clarity was infrequently more than 1.5 metres (on four occasions) due to the presence of very fine, colloidal, suspended particles. The median suspended solids concentration was 6 g/m^3 which was very typical for this river, as several fresh or flood events were sampled during the period. Absorbances (at 340 and 440 nm) were also relatively high (in excess of 0.027/cm and 0.005/cm respectively) at all times, indicative of slight dissolved colour in the river water (e.g. yellow-brown appearance) at this site in the lower reaches of the river. Minimum clarities (0.15 and 0.27 m black disc values) were coincident with turbidity levels of 44 and 20 NTU and suspended solids concentrations of 150 and 49 g/m^3, during flood flows of 32 and 25 m^3/s recorded in July 2013 and June 2014 respectively. Fresh flows (in excess of 10 m^3/s) were usually coincident with a general deterioration in water quality as emphasised by elevated turbidity, suspended solids, some nutrient species' (particularly total phosphorus) levels and bacterial counts (e.g. in July, August, and October 2013, and May and June 2014, Figure 8).

Maximum mid-afternoon pH values in the late summer to mid autumn period (8.1 to 8.2 units) were moderate for the lower reaches of a Taranaki river in early afternoon, an indication of the limited influence of algal photosynthetic activity on water quality (despite significant algal substrate cover) in this reach of the river system where more turbid conditions and silt deposition on the substrate have been typical of the site.

Dissolved oxygen concentrations however, were consistently high (median of 10.4 g/m^3) and the median saturation level was 102%. On the majority of occasions BOD_5 concentrations were indicative of relatively low organic content (i.e. less than 1.0 g/m^3). The median bacteriological numbers (185 enterococci and 340 faecal coliforms per 100 ml) were more typical of the impacts of developed farmland run-off and possibly stock access to the lower reaches of this eastern hill country river.

Water temperatures varied over a moderate range of 10.9 C with a maximum (early afternoon) summer temperature of 18.9 C recorded in February 2014 during very low flow conditions, at which time dissolved oxygen saturation was 102% and pH was 8.1 units.

Brief comparison with the previous 1995-2013 period

The range of flows sampled during the 2013-2014 period was narrower than the range sampled over the previous eighteen-year period despite the proportionately larger number of floods and freshes sampled during the latest period. The median sampled flow in the 2013-2014 period was markedly higher (by 2346 l/sec) than that sampled over the longer term. Median black disc clarity was very similar (within 0.03 m) and median turbidity was slightly higher (by 0.5 NTU) in the most recent period, while the median suspended solids concentration was higher by 2 g/m^3.

All nitrogen nutrient species' median concentrations decreased slightly in the latest period, while phosphorus species were very similar or slightly higher compared to the medians for the previous eighteen-year period with ammoniacal nitrogen (25%), and total nitrogen (20%) showing the principal decreases. Median bacterial numbers increased markedly for enterococci (by 121 per 100 mls) and faecal coliforms (by 105 per 100 ml) in the 203-2014 period.

Median dissolved oxygen saturation level was relatively similar (2% higher) in the 2013-2014 period while median pH levels were within 0.1 unit between periods. Maximum pH was 0.2 unit lower than the maximum previously recorded.

The range of water temperatures was much narrower (by 8.8 C) in the latest twelve-month period than over the previous eighteen-year period while median water temperature was 0.8 C higher during 2013-2014, due to a much lower maximum temperature (by 5.1 C) and higher minimum temperature (by 3.7 C) recorded in the 2013-2014 sampling year.

4.2 Comparative water quality for the nineteen-year (1995-2014) period

4.2.1 TRC data

In addition to the site descriptions of water quality measured during the 2013-2014 monthly sampling programme, a general comparison between the eleven sites of the programme may be made for the nineteen-year sampling period to date (1995-2014) using statistical (tabular and graphical) data summaries. These have been provided for each individual site in Tables 5, 8, 11, 14, 17, 20, 23, 26, 29, 32 and 35. Comparative statistics for selected parameters are provided in Table 36 and in the form of the 'box and whisker' plots of Appendix II.

These site comparisons for the summary data over the eighteen year record are discussed within groupings of parameters as follows.

Appearance (turbidity, black disc clarity, suspended solids, absorbance)

The water quality at all but two of the sites has been clean and clear with very low suspended solids concentrations (median: 3 g/m^3 or lower) and low turbidity levels (median: less than 2 NTU) except during flood flow conditions. The exceptions are the sites in the lower reaches of the Mangaehu River and the Waingongoro River. The former is an eastern hill-country catchment which was typically slightly cloudy due to fine colloidal solids and yellow-brown in appearance under most flow conditions. A slightly elevated median suspended solids concentration (4 g/m^3) has been recorded at this site, but median turbidity level (3.5 NTU) is significantly higher for this river than at any other site. The site in the lower reaches of the longest ringplain river (Waingongoro) also has elevated median suspended solids concentration (5 g/m^3) and turbidity (2.3 NTU). The site in the mid-reaches of the Stony River has shown marked variability, with erosion events in the headwaters the major contributing factor.

Generally upper catchment sites have exhibited higher aesthetic quality with a gradual deterioration toward the mid to lower reaches of the streams and rivers sampled.

Black disc clarity has shown greater variation between sites although similar trends of decreasing clarity down catchments occurred. Highest clarity was found in the upper reaches of the Patea River and the mid reaches of the Stony River (when not impacted by upper catchment erosion events) and the Waiwhakaiho River, with these sites' median clarities greater than 3.0 metres and maxima in excess of 8 metres at times. All but two other sites have achieved a median black disc clarity in excess of 1.5 metres. Due to the elevated turbidity of the Mangaehu River, the median clarity in the lower reaches of the river was only 0.84 metre while the site in the lower reaches of the Waingongoro River also had a relatively low median black disc value of 1.18 metres. Greatest variability was found at the Stony River site which has been the subject of several severe upper catchment erosion events at irregular intervals during the nineteen year period.

Table 36 Some comparative water quality data for the eleven TRC SEM sites for the nineteen-year period July 1995 to June 2014 (n = 228 samples)

Site	Black disc		BOD_5	Conductivity @ 20°C	Faecal coliform bacteria		Nutrients					pH		Dissolved oxygen saturation			Suspended solids	Temperature			Turbidity
							Ammonia	Nitrate	Total N	DRP	Total P										
Unit	(m)		(g/m^3)	(mS/m)	(nos per 100 ml)		(g/m^3N)	(g/m^3N)	(g/m^3N)	(g/m^3P)	(g/m^3P)			(%)			(g/m^3)	(°C)			(NTU)
	Maximum	Median	Median	Median	Minimum	Median	Median	Median	Median	Median	Median	Maximum	Median	Min	Med	Range	Median	Maximum	Median	Range	Median
Maketawa Stream at Tarata Road*	5.23	2.60	<0.5	8.5	50	315	0.009	0.25	0.39	0.022	0.034	7.9	7.6	90	98	12	<2	17.6	11.4	12.8	0.8
Mangaoraka Stream at Corbett Road	4.73	1.86	0.6	14.4	120	775	0.021	0.84	1.10	0.009	0.022	8.1	7.6	83	96	24	2	20.5	13.0	14.7	1.6
Waiwhakaiho River at SH3	8.05	3.06	<0.5	12.2	23	210	0.008	0.11	0.20	0.024	0.034	8.5	7.9	91	100	17	<2	18.3	11.0	13.5	0.7
Stony River at Mangatete Road	13.1	3.32	<0.5	9.7	<1	8	<0.003	0.02	0.06	0.018	0.024	8.2	7.8	87	99	17	<2	16.6	10.8	10.9	0.8
Punehu Stream at Wiremu Road	4.53	1.84	<0.5	8.6	3	120	0.006	0.03	0.15	0.022	0.034	8.3	7.7	87	100	19	2	19.2	11.8	14.2	1.7
Punehu Stream at SH45	3.57	1.54	1.0	16.0	51	515	0.041	0.92	1.36	0.044	0.080	8.6	7.7	90	99	24	3	21.0	13.3	16.0	1.8
Waingongoro River at Eltham Road	4.39	1.68	0.7	11.2	6	190	0.018	1.11	1.44	0.019	0.038	8.6	7.8	92	102	29	3	20.8	12.4	15.2	1.5
Waingongoro River at SH45 **	4.34	1.18	1.0	16.4	3	220	0.034	1.87	2.40	0.057	0.100	9.1	7.8	89	101	52	5	22.0	13.7	16.6	2.3
Patea River at Barclay Road	9.10	4.38	<0.5	6.1	<1	20	<0.003	0.02	0.08	0.018	0.024	8.0	7.5	90	98	13	<2	14.7	9.2	11.0	0.5
Patea River at Skinner Road	4.68	1.82	0.9	9.9	2	230	0.054	0.92	1.22	0.038	0.066	8.8	7.8	87	102	34	2	21.8	12.8	16.5	1.5
Mangaehu River at Raupuha Road	4.04	0.84	0.6	9.8	6	250	0.012	0.10	0.30	0.006	0.020	8.4	7.7	83	100	35	4	24.0	13.8	19.7	3.5

[Notes: * for the period July 2003 to June 2014 (n = 132 samples); ** for the period July 1998 to June 2014 (n = 192 samples)]

Absorbances (at 340 nm /cm) have been generally relatively low. They are indicative of slight dissolved colour particularly at the Mangaehu River site, and also at both the upper and lower Punehu Stream sites, and to a slightly lesser extent at the site in the lower Waingongoro River. Absorbances at 770 nm /cm were very low indicating that any apparent dissolved colour was seldom due to the scattering effects of small colloidal particles.

Water temperature, pH, and conductivity

Coldest median water temperature (9.2 C) has been measured at the upper site on the Patea River (altitude: 500 m asl) with increased median water temperatures in a downstream direction as might be expected. Highest maximum water temperatures have been recorded in the lower reaches of the Mangaehu River (24.0 C), the Waingongoro River (22.0 C), and the smaller Punehu Stream (21.0 C), and in the mid reaches of the Patea River (21.8 C); these four sites also exhibiting four of the five highest medians (13.8 C, 13.7 C, 13.3 C, and 12.8 C) and widest ranges (19.7 C, 16.6 C, 16.0 C and 16.5 C) respectively of water temperatures. Atypically, relatively high median (11.8 C), maximum (19.2 C) and a wide range (14.2 C) of water temperatures have been recorded in the upper reach of the Punehu Stream at Wiremu Road, probably due to the open, bouldery nature of the 2 km reach between the National Park and the sampling site (altitude: 270 masl).

Highest pH values (8.5 to 9.1) have been recorded at the mid and lower ringplain river and stream sites due to algal photosynthetic effects coincidental with more extensive substrate algal cover under warmer, mid to late summer, low flow conditions. pH values at all sites were slightly alkaline i.e., medians ranging from 7.5 to 7.9, typical of ring plain rivers and streams.

Conductivity, a measure of the degree of mineralisation of the water, increased with distance downstream but median values were all indicative of relatively low total ionic content (i.e. <16.5 mS/m @20°C). Greatest variability was generally recorded in the mid to lower reaches of the larger rivers and streams which were subject to wider ranges of flow.

Dissolved oxygen and biochemical oxygen demand

Very high median dissolved oxygen concentrations characterised all ten ring plain sites and the lower reach site in the Mangaehu River. Ranges were relatively narrow at most sites (< 30% at eight sites) and median values were 96% saturation or higher at all sites. Summer-autumn lower flow conditions, coincident with more extensive algal substrate cover, resulted in supersaturation on occasions at various sites in the mid to lower reaches of streams and rivers. The narrowest saturation range (<15%) was found in the upper reaches of the Patea River and the mid reaches of the Maketawa Stream, with wider saturation ranges (>20%) recorded at mid and lower catchment sites, and the widest (52%) in the lower reaches of the longest ringplain river where substrate periphyton cover may be more extensive.

Biochemical oxygen demand (BOD_5), a measure of the amount of biodegradable matter present, was generally less than 1 g/m^3 (i.e. no medians greater than 1.0 g/m^3), indicative of low organic enrichment at all sites. Median values were highest in the lower reaches of the Punehu Stream (1.0 g/m^3) and Waingongoro River (1.0

g/m^3) and the mid reaches of the Mangaoraka Stream, Waingongoro and Patea Rivers, all sites downstream of point and non-point source discharges.
Elevated BOD_5 levels (>2 g/m^3) have been measured from time to time at most sites during fresh and flood flow conditions reflecting the influence of non point source farmland and stormwater run-off and have reached 2.4 g/m^3 under summer low flow conditions downstream of Stratford in the Patea River at the Skinner Road site.

Nutrients (nitrogen and phosphorus)

Nutrients such as nitrate, ammoniacal nitrogen and dissolved reactive phosphorus may readily be taken up by the flora of rivers and streams. An abundance of these nutrient forms may result in prolific and objectionable growths of attached filamentous algae (periphyton) particularly when in combination with low river flows, increased temperatures, and a plentiful supply of energy in the form of light (autotrophic growths) and/or organic matter (heterotrophic growths). Highest nutrient concentrations were recorded at the lower sites in the ring plain rivers and streams sampled, consistent with increased non-point source run-off and point source discharges through each ring plain catchment e.g., increases of 800% and 135% in median total nitrogen and total phosphorus respectively over the length of the Punehu Stream; 1425% and 175% respectively through the mid reaches of the Patea River; and 66% and 160% respectively through the mid to lower reaches of the Waingongoro River. Elevated nitrate concentrations often reflect high groundwater inputs, particularly after very wet weather (winter-spring) conditions when groundwater levels are higher and therefore contribute more proportionately to river/stream baseflows. Highest median concentrations of dissolved reactive phosphorus (DRP), total phosphorus, ammoniacal, nitrate and total nitrogen were generally found at the lower Punehu Stream site, mid Patea River (Skinner Road) site, mid and lower Waingongoro River sites, and to a slightly lesser degree at the site in the Mangaoraka Stream. However, relatively low dissolved reactive phosphorus concentrations (median of <0.01 g/m^{3}P) in the Mangaoraka Stream reflect the source of this ring plain stream which rises outside of the National Park, compared with the documented natural sources of dissolved phosphorus from within the park found in ringplain rivers and streams (TCC, 1984 and TRC, 2010). Relatively low dissolved reactive phosphorus (median of <0.01 g/m^{3}P) measured at the site in the lower reaches of the Mangaehu River reflect the river's eastern hill country catchment source.

Bacteria

Poor bacteriological water quality (median faecal coliform numbers from 220 to 775 per 100 mls) has been recorded at the sites in the lower reaches of the Maketawa Stream, Punehu Stream, Waingongoro River, Mangaehu River, and particularly the Mangaoraka Stream. Relatively poor bacteriological quality (medians from 190 to 230 per 100 mls) in the mid reaches of the Waiwhakaiho, Waingongoro, and Patea Rivers, also reflect non-point source run-off and point source discharges (and possibly stock access) to these developed farmland river and streams. The cumulative impacts of several dairy pond treatment systems' discharges to the Mangatawa Stream have impacted upon Punehu Stream quality (TRC, 2011). One of the site's (Mangaoraka Stream) counts have continuously exceeded 120 faecal coliforms per 100 mls indicative of consistently poor bacteriological quality.

The sites in the mid reaches of the Waiwhakaiho, Waingongoro and Patea Rivers have had comparatively good bacteriological water quality on occasions.

The sites in the Patea River's upper reaches (at Barclay Road) and the Stony River in mid-reach (at Mangatete Road) generally recorded very high bacteriological water quality with median faecal coliform numbers of 20 and 8 per 100 mls respectively.

The upper site in the Punehu Stream (at Wiremu Road) however has had an unexpectedly high median faecal coliform count of 120 per 100 mls, probably reflecting stock access to this stream and farm seepage and surface run-off over the 2 km reach between the National Park and Wiremu Road.

Enterococci numbers reflected the trends outlined above for faecal coliform bacteria, with the highest median counts generally recorded at the sites in the lower reaches of the Mangaoraka Stream and the Punehu Stream and lowest median counts in the Stony River and in the upper reaches of the Patea River.

4.2.2 NIWA data

A summary of the comparable nineteen years of data for the three Taranaki region sites included in the NIWA national network (see Figure 1) is presented in Table 37. One of the sites (Waingongoro River at SH45) is also a TRC SEM site sampled under similar protocols by both TRC and NIWA but six days later in each month by NIWA.

Table 37 Some comparative water quality data for the three NIWA SEM sites for the nineteen-year period July 1995 to June 2014 (n = 228 samples)

Site Unit	Black disc (m)		BOD_5 (g/m^3)	Conductivity @ 20°C (mS/m)	Nutrients					pH		Dissolved oxygen saturation %	Temperature (°C)			Turbidity (NTU)	Flow (m^3/sec)
					Amm-N (g/m^3N)	Nitrate (g/m^3N)	Total N (g/m^3N)	DRP (g/m^3P)	TP (g/m^3P)								
	Maximum	Median	Median	Median	Median	Median	Median	Median	Median	Maximum	Median	Median	Maximum	Median	Range	Median	Median
Waitara River at Bertrand Road	3.2	0.48	0.7	8.8	0.011	0.31	0.56	0.006	0.034	8.6	7.7	102	23.2	13.8	16.7	8.5	28.5
Manganui River at SH3	7.7	4.09	<0.5	6.3	0.006	0.09	0.18	0.009	0.015	7.9	7.5	101	18.7	10.6	14.6	0.9	1.00
Waingongoro River at SH45	2.9 (4.34)	1.28 (1.18)	1.0 (1.0)	16.5 (16.4)	0.028 (0.034)	1.90 (1.87)	2.20 (2.40)	0.049 (0.057)	0.097 (0.100)	9.1 (9.1)	7.9 (7.8)	103 (101)	23.0 (22.0)	13.7 (13.7)	16.7 (16.6)	2.5 (2.3)	5.30 (4.82)

[Notes ( ) = TRC data for the period July 1998 to June 2014 (n = 192 samples); NIWA data – BOD_5 (n = 85 samples)]

These data indicate more turbid (cloudier) appearance in the lower reach of the Waitara River (median black disc clarity of 0.48 metres and turbidity of 8.5 NTU) with very clear conditions toward the upper reach of the Manganui River. Lower Waitara River median clarity and particularly turbidity were the worst of all thirteen sites monitored in the region, reflecting the significant impact of the eastern hill country component of this large river's catchment. (Similar patterns are noted in the Mangaehu River [Table 36]). Median water temperatures were typical of those found at comparable sites elsewhere in the region (Tables 36 and 37), while median pH, conductivity, dissolved oxygen and BOD_5 levels were also typical. Median nutrient concentrations were within the range of medians found at other regional sites monitored by TRC and were comparable with similarly located sites (in terms of position in the river reach).

A comparison of data for the Waingongoro River site in the lower reach (at SH45) between sixteen years of TRC state of the environment monitoring and the same years of NIWA network monitoring (Table 37) indicates very similar median water quality for all parameters despite the (six day) sampling protocol difference between programmes. Allowing for this difference in timing, sampled median flow conditions were also very similar, providing greater validity to the physicochemical water quality comparisons.

4.2.3 Comparisons with guideline values for various usages

The nineteen years of state of the environment monitoring (SEM) data may be summarised and compared with various published guidelines and standards for different water usages (TRC, 2006a and TRC, 2009). As the monitoring programme samples all weather conditions on a systematically random basis there will always be data which fail to meet standards on some occasions. Therefore, the median statistic has been used to assess compliance with guidelines and standards in Table 38.

Table 38 Comparison of 1995-2014 SEM (TRC and NIWA) sites' median water quality with guideline values for various usages

Usage	Aesthetics		Contact recreation		Prevention of undesirable growths			Stock water		Aquatic ecosystems					Irrigation	Drinking water	
Parameter	Black disc	BOD_5	*E.coli*	BOD_5	DRP	TP	TN	Faecal coliforms	Faecal coliforms	Black disc	DO Saturation	NO_3	NH_4	Temp	TN	TP	NO_3
Guideline	>1.6 m	<3g/m³	<550/ 100mls	<3g/m³	<0.03 g/m³P	<0.03 g/m³P •	<0.6 g/m³N •	<1000/ 100mls	Median <100/100 mls	>0.8m	>80%	<0.4 g/m³N	<0.9 g/m³N	<25 C	<25 g/m³N	<0.8 g/m³P	<11.3 g/m³N
Reference	1,2	2,3	2,3	2	1,2	1	1	1,2	1			1,2	1	2	1	1	1,2
Site																	
Maketawa Stream at Tarata Road	✓	✓✓	✓	✓✓	✓	x	✓	✓	x	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Mangaoraka Stream at Corbett Road	✓	✓	x	✓	✓	✓	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓	✓✓
Waiwhakaiho River at SH3	✓	✓	✓	✓	✓	x	✓	✓	x	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Stony River at Mangatete Road	✓	✓✓	✓	✓✓	✓	✓	✓	✓	✓	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓	✓✓
Punehu Stream at Wiremu Road	✓	✓	✓	✓	✓	x	✓	✓	x	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Punehu Stream at SH45	x	✓	✓	✓	x	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓✓	✓✓
Waingongoro River at Eltham Road	✓	✓	✓	✓	✓	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓	✓✓
Waingongoro River at SH45	x	✓	✓	✓	x	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓✓	✓✓
Patea River at Barclay Road	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Patea River at Skinner Road	✓	✓	✓	✓	x	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓	✓✓
Mangaehu River at Raupuha Road	x	✓	✓	✓	✓✓	✓	✓	✓	x	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Manganui River at SH 3	✓	✓✓	✓	✓✓	✓	✓	✓	✓	✓	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Waitara River at Bertrand Road	x	✓✓	✓	✓✓	✓	x	✓	✓	x	x	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Summary of sites (13) in compliance	9	13	12	13	10	6	8	13	3	12	13	8	13	13	13	13	13

Key:
✓✓ = maximum (*minimum) value also meets usage guideline
✓ = median value, meets usage guideline
x = median value, does not meet usage guideline
• = 80% of values to meet usage guidelines

References:
1 = ANZECC, 2000
2 = TRC, 2003 & TRC, 2009
3 = MfE, 2003

4.2.3.1 Aesthetics

Most sites met the aesthetic quality guidelines although the four sites which did not achieve the black disc clarity were all situated in the lower reaches of catchments, two of which (Mangaehu and Waitara Rivers) are eastern hill country catchments.

4.2.3.2 Contact recreation

The Council's and NIWA's programmes do not necessarily collect samples representative of water quality typical of conditions at times when contact recreation is likely, as is stipulated in the MfE guidelines, and therefore care should be taken when comparing results against the guideline. It should also be noted that most of the SEM sites in the programme are not contact recreational sites; the streams are too shallow, cold and/or small at these locations. A specific recreational water quality SEM programme is structured around the requirements of the MfE guidelines and reported separately (TRC, 2014), and on the Council's website (www.trc.govt.nz). However, the sites' data presented in Table 38 are indicative of bacteriological conditions likely to exist at contact recreational sites in the vicinity of the reaches of the streams/rivers monitored.

One site (in the lower reaches of the Mangaoraka Stream) consistently failed to meet the guideline, while most of the other sites have failed to meet instantaneous guidelines ('Alert' and 'Action' modes (TRC, 2014) occasionally under spring-summer low flow conditions (refer to individual tables of 2013-2014 data) and under flood flow conditions (when contact recreation suitability is not an issue).

4.2.3.3 Undesirable growths

Algal growth smothers habitat and food sources for aquatic life and looks unattractive. Exceedance of guideline values at some sites is therefore of concern. However, exceedances of the guidelines for the prevention of undesirable nuisance growths will not necessarily result in nuisance growths occurring in the region's streams. Rather, excessive algal growths are most likely to occur in mid to late summer-autumn under conditions of warm, low flows, absence of recent rain events to scour the growths, and strong sunlight.

In the lower reaches of most Taranaki catchments, elevated nutrient levels are high enough to promote algal growth under low flow conditions. Most lower river/stream sites illustrated exceedances of nutrient guideline values (Table 38). This is true particularly of total nitrogen and total phosphorus species which generally increased in concentration downstream. Dissolved reactive phosphorus levels were more variable with levels decreasing or remaining relatively stable downstream of the National Park boundary (where dissolved reactive phosphorus is present from natural sources).

The Council has a separate SEM programme that focuses specifically on nuisance growths at various freshwater indicator locations in the region (TRC, 2006b and TRC, 2014a). In general, periphyton growths are more likely and more prolific in drier summers, when flows decrease and there is less scouring and disturbance of stream beds, more sunlight, higher temperatures, less grazing by macroinvertebrates, and less dilution of discharges containing nutrients. The lower reaches of ring plain streams in southern and western Taranaki particularly can experience nuisance growths particularly in the mid summer-early autumn period.

4.2.3.4 Stock water

The bacteriological guideline for stock water was previously 1000 faecal coliforms per 100 mls. All median values at all sites comfortably met this guideline. Given that higher faecal coliform levels in streams generally occur under conditions of heavy rainfall, when stream water is less likely to be utilized, individual results above this guideline generally do not indicate a need for concern.

The ANZECC (2000) water quality guideline stipulates a limit of 100 thermo-tolerant coliforms (which includes faecal coliforms) per 100 mls, for median values. As noted above, with many Council samples gathered at times when stock would not need water, the guideline is not necessarily appropriate as a basis for evaluating the regional water quality data. It may be noted that at five of the ten sites shown in Table 38 as otherwise exceeding the bacteriological guidelines, the 25^{th} percentile result (see Appendix I) satisfies the criterion. All sites complied with the nitrate-N guideline.

4.2.3.5 Aquatic ecosystems

While all sites complied with the ammonia-N and temperature guidelines, five sites (in the middle to lower reaches of catchments) had median values above the guideline for nitrate-N and one site under the visibility guideline. The Council has a separate SEM programme that focuses specifically on the macroinvertebrate fauna of 57 sites in the region (including all of the eleven sites in the physicochemical programme and the two NIWA sites) and none of these sites' communities have illustrated significant deterioration, while four (mainly lower reach) of the 11 sites in the physicochemical programme have shown significant improvements in stream 'health' trends over the eighteen years (1995 to 2013) to date (TRC, 2006c, Stark and Fowles, 2006 and TRC, 2013a).

4.2.3.6 Irrigation

All sites met the relevant nutrient guidelines for irrigation water.

4.2.3.7 Drinking water

The drinking water nitrate standard was complied with at all sites, although all sites would require treatment to achieve bacteriological drinking water standards.

4.3 Trends in physicochemical water quality data from 1995 to 2014

4.3.1 Introduction

Nineteen years of physicochemical water quality data have been collected up to 30 June 2013. This data has been analysed for trends since the accumulation of 10 year's data. Previous trend analysis has been reported in TRC (2006, 2009, 2009a, 2010, 2011, 2012, and 2013). An update of the trends including data from the 2013-2014 monitoring year can now be provided. It does not include a detailed interpretation of the results. This will be provided in the next five yearly State of the Environment Report (next due in early 2015).

4.3.2 Trend analysis methods

The trend analysis involves a flow adjustment of the raw data for each variable at each site, followed by trend analysis accounting for any seasonal pattern. This analysis has been adopted throughout New Zealand for water quality trend analysis (Scarsbrook and McBride, 2007).

Flow adjustment is necessary because most water quality variables are subject to either dilution (decreasing concentration with increasing flow) or land run-off (increasing concentration with increasing flow). Flow adjustment was performed using LOWESS (LOcally WEighted Scatterplot Smoothing), within the Time Trends software[1], with a 30% span. Every data-point in the record was then adjusted depending on the value of flow (adjusted value=raw value – smoothed value + median value (where the smoothed value is that predicted from the flow using LOWESS)).

The non-parametric trend analysis was then applied to the whole data set for each parameter at each site which takes into account the seasonal variability in the data.

This analysis is based on two key measures:

- The seasonal Kendall slope estimator (SKSE) which measures the magnitude of the trend, and
- The associated seasonal Kendall trend test which determines whether the trend is significant.

Statistically significant trends were determined using a p-value < 0.05 or <0.01. If a p-value is less than 0.05 (or 0.01), then there is a less than 5% (or 1%) chance of finding a trend when there is not one. In the data presented below, p-values are expressed as a percentage and highlighted if the percentage is less than 5% (statistically significant) or less than 1% (very statistically significant).

The slope of the trend (SKSE) is expressed in units of change per year, and can also be expressed in terms of relative change (RSKSE) which is the percent of change per year. A positive SKSE or RSKSE indicates a positive (increasing) trend, and a negative SKSE or RSKSE indicates a negative or decreasing trend. The RSKSE allows comparisons in the slope between parameters and sites and is used in the tables below.

It is recognised that the statistical significance of a trend does not necessarily imply a ‘meaningful’ trend i.e., one that is likely to be relevant in a management sense. Ballantine and Davies-Colley (2009) have determined a ‘meaningful’ trend as one for

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[1] Trend analysis prior to 2009 has been conducted with Datadesk software. A comparison of the Time trends and Datadesk software was undertaken during the 2009 trend analysis to ensure that the different software packages produced similar results. Refer to Hope (2009) for details of this analysis.

which the RSKSE is statistically significant and has an absolute magnitude > 1 percent per year. This approach has also been adopted below.

4.3.3 Results of trend analysis

Table 39 summarises the significant trends recorded for each water quality parameter at the 11 sites monitored in the physicochemical state of the environment monitoring programme where there is sufficient data. This year's trend includes the Maketawa Stream at Tarata Road as there are now eleven years of data for this site. Figure 9 shows the trends graphically for a selected number of sites and parameters where significant trends were recorded.

Of the nutrients, DRP and to a lesser extent total phosphorus, have shown a significantly deteriorating trend at a number of sites, including the upper and middle catchments which would be less subject to anthropogenic pressures. Six out of eleven sites have shown a significant deterioration in DRP. When compared with other nutrients, the deterioration in total phosphorus, nitrate and ammonia-N are more concentrated in the middle and lower catchment where more land use intensification and urbanisation occurs. Nitrate also showed significant deteriorating trends at two sites, one at a mid-catchment site and one at a lower catchment site. However, total nitrogen improved significantly at six sites (mainly at the upper Patea River at Barclay Road and Punehu Stream at Wiremu Road), middle (Stony River at Mangatete Road and Maketawa Stream at Tarata Road), and the lower catchment (Waingongoro River at SH45 and Mangaehu River at Raupuha Road). On the whole the remainder of the sites remained stable. Ammonia-N showed generally stable trends throughout the catchment with the exception of the Waiwhakaiho River at SH3 and Waingongoro River at SH45 where significant trends of deterioration have been apparent.

Generally, mid catchment sites appear to be showing the most deterioration in nutrients, and although the lower catchment sites show almost a similar number of deteriorations there has been marked improvement in the Waingongoro River at SH45 (significant improvement in DRP, total phosphorus and nitrate). This is a positive aspect as the lower catchment would be under the most pressure from land use intensification and upstream influences. The Waiwhakaiho River at SH3 and the Punehu Stream at SH45 have the greatest number of deteriorating trends in relation to nutrients (three out of five nutrients are deteriorating significantly for these two sites (Table 39)). [Note: There has been some more recent improvement at the Waingongoro River, Eltham Road site where only two nutrient species now show deteriorating trends].

Deterioration in phosphorus species appeared to be increasing at a steady but slow rate at the Waingongoro River at Eltham Rd, Mangaoraka Stream at Corbett Rd, and Punehu Stream at SH45 sites (Figure 9). The Waiwhakaiho River at SH3 site did not exhibit a meaningful trend in this year's analysis whereas it did in the previous year's shorter period (2013). The Patea River at Barclay Road site also showed an increasing DRP trend. The Punehu Stream at SH45 has only recently shown very significant deteriorating trends in dissolved reactive phosphorus, and there has also been a deteriorating trend in total phosphorus and nitrate (Table 40). Nitrogen species appear to have peaked between 2003 and 2005, and particularly in the Waingongoro River there have been steadily improving (decreasing) since then (Figure 9). The Waingongoro River at SH45 is showing a very significant improving trend in dissolved reactive phosphorus, total phosphorus and nitrate (Figure 8). It is probable that this has been due to the more recent reduction in meatworks' discharges (over spring and summer) to the river at Eltham and the elimination of all Eltham WWTP municipal discharges in the catchment (since mid-2010)

Table 39 Meaningful' trends in surface water quality at 11 State of the Environment Monitoring sites in Taranaki- 1995-2014 (p<5% and RSKSE (%change/yr) >1%)

		Water Quality Variable															
Catchment Level	Location	Dissolved Reactive P	Total Phosphorus	Nitrate	Ammonia-N	Total Nitrogen	Faecal coliforms	Enterococci	Conductivity	Black Disc	Suspended Solids	Temp°C	Biochemical O_2 Demand	pH	Total no. sites: Improvement 😊	No change 😐	Deterioration ☹️
Upper	Patea River Barclay Rd	☹️	😐	😐	😐	😊	😐	😐	😐	😐	😐	😐	😐	😐	1	11	1
Upper/ Middle	Punehu Stream Wiremu Rd	😐	😐	😐	😐	😊	😐	😐	😐	😐	😐	😐	😐	😐	1	12	0
Middle	Stony River Mangatete Road	☹️	☹️	😐	😐	😊	😐	😐	😐	☹️	☹️	😐	😐	😐	1	8	4
Middle	Maketawa Stream Tarata Road*	😐	😐	🙂	😐	😊	😐	😐	😐	😐	😐	😐	🙁	😐	2	10	1
Middle	Patea River Skinner Rd	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	0	13	0
Middle	Waiwhakaiho SH3	☹️	😐	☹️	☹️	😐	🙁	😐	😐	☹️	😐	😐	😐	😐	0	8	5
Middle	Waingongoro Eltham Rd	☹️	☹️	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	0	11	2
Lower	Mangaoraka Stream Corbett Rd	☹️	☹️	😐	😐	😐	☹️	☹️	😐	☹️	😐	😐	☹️	😐	0	7	6
Lower	Waingongoro SH45**	😊	😊	😊	🙁	😊	😐	😐	😐	😐	😐	😐	☹️	😐	4	7	2
Lower	Punehu Stream SH45	☹️	☹️	☹️	😐	😐	😐	☹️	😐	😐	🙂	😐	😐	😐	1	8	4
Lower	Mangaehu River Raupuha Rd	😐	😐	😐	😐	😊	😐	😐	😐	😐	😐	😐	😐	😐	1	12	0
Total no. sites: Improvement 😊		1	1	2	0	6	0	0	0	0	1	0	0	0			
No change 😐		4	6	7	9	5	9	9	11	8	9	11	8	11			
Deterioration ☹️		6	4	2	2	0	2	2	0	3	1	0	3	0			

Key:

*Matetawa Tarata Road: Data for this site only for the past 11 years: 2003 - 2014

**Waingongoro SH45: Data for this site only for the past 16 years: 1998 - 2014

😊 statistically very significant **improvement** P<0.01 (1%)

🙂 statistically significant **improvement** P<0.05 (5%)

😐 **no statistically significant change**

🙁 statistically significant **deterioration** P<0.05 (5%)

☹️ statistically very significant **deterioration** P<0.01 (less than 1% probability that the trend is due to natural variability and doesn't represent an actual change)

Upper catchment site | Mid-catchment site | Lower catchment site

Table 40 *p*-values (%) and trend slopes (% change per year) for flow and seasonally adjusted water quality variables at 11 Taranaki sites. Significant deteriorations are shown in orange (*p*<5%) and red (*p*<1%) and significant improvements are shown in light green (p<5%) and dark green (p<1%). 'Real' trends (i.e., the change is ecologically significant) are highlighted (>1% change per year).

Catchment Level	Location	Water Quality Variable													
		Dissolved Reactive P		Total Phosphorus		Nitrate		Ammonia-N		Total Nitrogen		Faecal coliforms		Enterococci	
		p-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr
Upper	Patea River Barclay Rd	0.05	1.13	37.96	0.21	0.06	-0.64	81.63	-0.13	0.00	-3.87	14.03	-1.83	46.10	1.34
Upper/ Middle	Punehu Stream Wiremu Rd	20.68	0.40	99.19	0.00	41.91	0.70	21.79	1.25	0.00	-2.21	7.06	-1.97	92.76	0.12
Middle	Stony River Mangatete Road	0.06	0.88	0.94	1.15	76.96	-0.24	19.26	-0.27	0.00	-4.62	42.50	-1.11	94.36	-0.04
Middle	Maketawa Stream Tarata Road	6.21	1.52	11.06	1.22	3.66	-2.69	51.46	0.97	0.32	-2.48	80.47	-0.63	77.02	0.61
Middle	Patea River Skinner Rd	49.86	-0.23	46.10	-0.23	6.75	0.48	42.50	0.53	86.37	0.04	9.17	-2.11	83.20	0.23
Middle	Waiwhakaiho SH3	0.03	1.09	1.00	0.62	0.17	2.06	0.01	3.63	32.73	-0.40	2.84	2.25	49.86	0.80
Middle	Waingongoro Eltham Rd	0.00	4.06	0.00	2.99	4.03	0.67	30.77	0.94	16.65	0.37	8.06	-2.48	66.41	-0.68
Lower	Mangaoraka Stream Corbett Rd	0.02	2.70	0.16	2.03	7.06	-0.56	10.39	1.44	2.19	-0.58	0.40	2.87	0.00	6.90
Lower	Waingongoro SH45*	0.00	-2.69	0.19	-2.01	0.00	-1.35	1.21	2.19	0.00	-1.06	74.52	-0.45	70.62	0.55
Lower	Punehu Stream SH45	0.00	2.88	0.02	1.75	0.01	1.59	69.37	-0.39	1.86	0.79	19.26	-1.47	0.09	3.90
Lower	Mangaehu River Raupuha Rd	13.24	0.83	87.96	0.06	35.81	-0.47	29.82	-0.73	0.27	-1.28	6.75	-1.97	69.37	0.53
Total no. sites: Improvement ☺		1		1		2		0		6		0		0	
No change ☺		4		6		7		9		5		9		9	
Deterioration ☹		6		4		2		2		0		2		2	

Table 40 (cont) *p*-values (%) and trend slopes (% change per year) for flow and seasonally adjusted water quality variables at 11 Taranaki sites. Significant deteriorations are shown in orange (*p*<5%) and red (*p*<1%) and significant improvements are shown in light green (p<5%) and dark green (p<1%). 'Real' trends (i.e., the change is ecologically significant) are highlighted (>1% change per year).

Catchment Level	Location	Water Quality Variable											
		Conductivity		Black Disc		Suspended Solids		Temp °C		Biochemical O_2		pH	
		p-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr
Upper	Patea River Barclay Rd	10.39	-0.16	94.33	0.02	55.78	0.00	10.83	-0.31	25.55	0.00	67.88	-0.01
Upper/ Middle	Punehu Stream Wiremu Rd	0.00	0.31	16.04	-0.55	95.97	0.01	3.48	-0.47	26.65	-0.11	0.01	-0.09
Middle	Stony River Mangatete Road	51.15	-0.06	0.00	-3.25	0.03	11.33	11.75	-0.24	57.34	0.00	6.75	-0.04
Middle	Maketawa Stream Tarata Road	77.02	-0.08	73.60	-0.41	35.68	0.80	70.24	-0.19	4.08	2.49	100.00	0.00
Middle	Patea River Skinner Rd	49.86	0.04	9.97	-0.66	62.07	-0.08	56.48	-0.10	8.06	1.05	24.55	-0.04
Middle	Waiwhakaiho SH3	0.15	-0.32	0.04	-1.23	76.96	0.01	0.84	-0.53	22.94	0.27	0.00	-0.09
Middle	Waingongoro Eltham Rd	59.25	-0.07	10.39	-0.71	48.59	0.16	5.63	-0.33	8.79	1.06	1.12	-0.06
Lower	Mangaoraka Stream Corbett Rd	10.83	0.17	0.00	-2.17	8.24	1.14	6.46	-0.33	0.84	1.41	19.26	-0.02
Lower	Waingongoro SH45*	59.41	-0.08	14.19	0.69	45.09	-0.49	3.64	-0.39	0.02	2.88	0.00	-0.15
Lower	Punehu Stream SH45	21.42	0.18	87.96	-0.05	4.89	-1.60	1.67	-0.42	68.62	0.11	0.00	-0.11
Lower	Mangaehu River Raupuha Rd	24.55	-0.12	19.96	-0.67	28.89	-0.93	2.07	-0.44	21.42	-0.56	12.73	0.04
Total no. sites: Improvement ☺		0		0		1		0		0		0	
No change 😐		11		8		9		11		8		11	
Deterioration ☹		0		3		1		0		3		0	

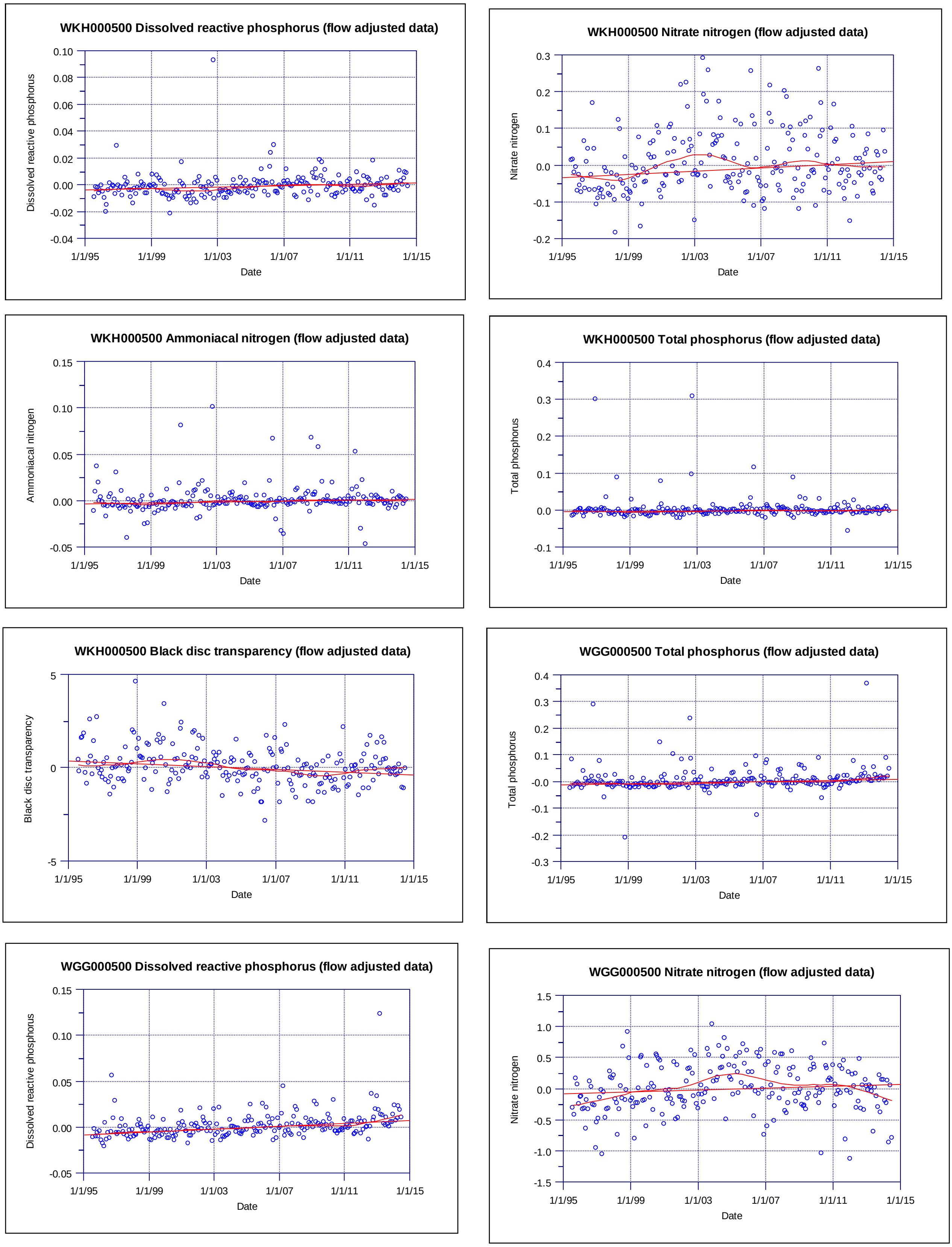
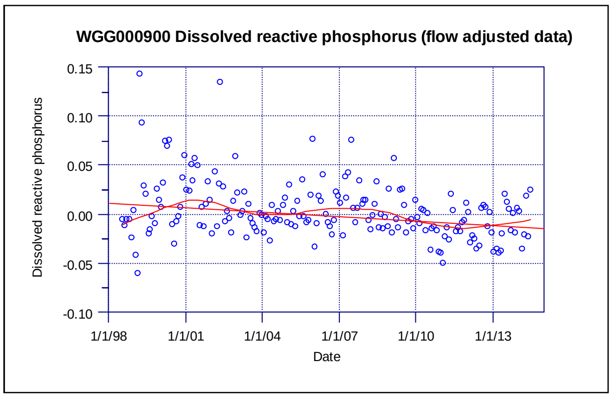
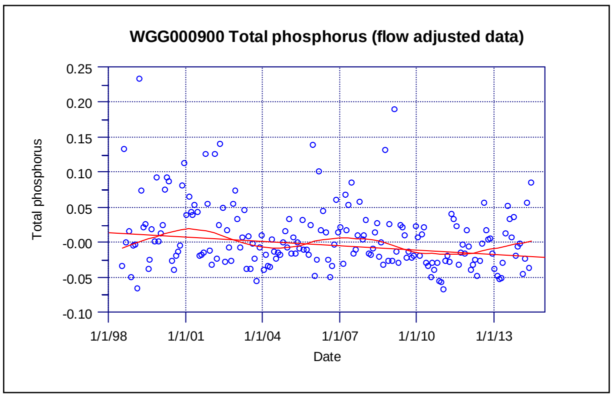
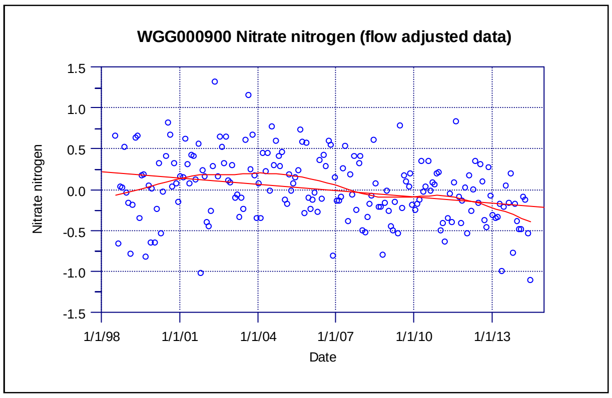
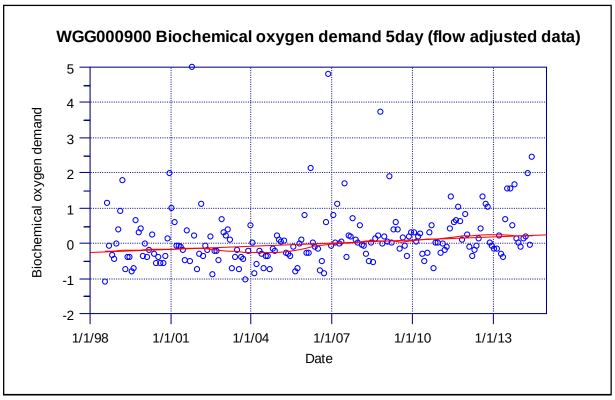


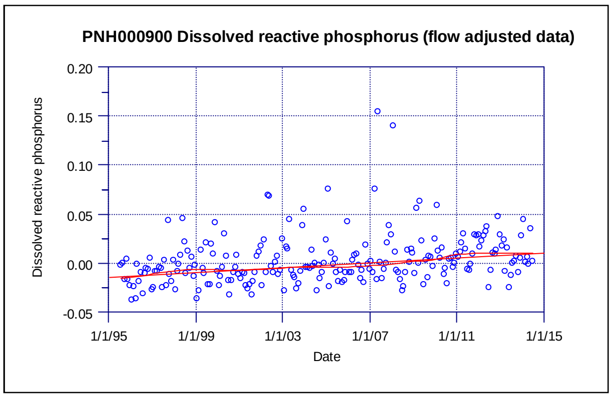
Figure 9 Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

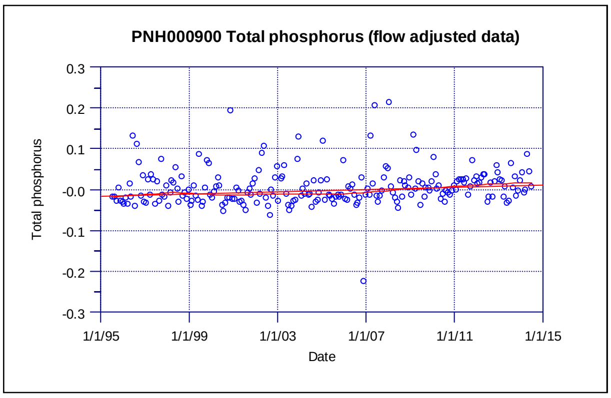












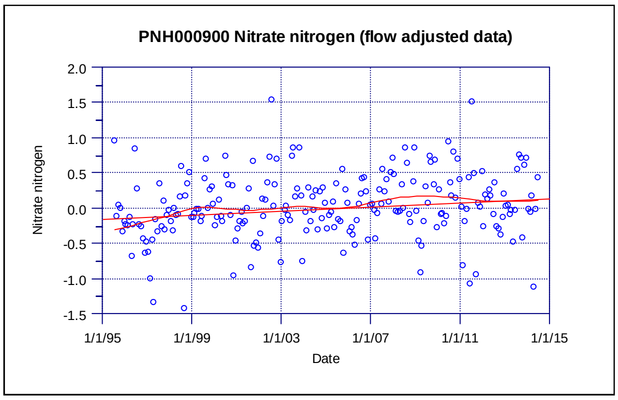


Figure 9 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

Figure 9 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

Faecal coliforms and enterococci bacteria generally showed little statistically significant change over the 19 year period, although the Waiwhakaiho River at SH3 and Mangaoraka Stream at Corbett Rd sites indicated deteriorating trends in faecal coliforms whereas the Waingongoro River at Eltham Road no longer showed an improving trend in faecal coliforms. There has been a very significant deteriorating trend in enterococci in the lower catchment site of the Mangaoraka Stream at Corbett Road and this has now been reflected in faecal coliform levels after this year's trend analysis. There was also a deteriorating trend (of a lower significance) at the lower catchment site in the Punehu Stream at SH45 for enterococci bacteria but this was not reflected in the faecal coliform trend.

Traditional indicators of pollution, organic matter (BOD), suspended solids, clarity (black disc), conductivity (dissolved matter) have generally shown no apparent trends at most sites over the 19 year period. However, the Stony River showed deterioration in clarity and suspended solids as a result of the significant erosion events that have occurred in the headwaters of this catchment in recent years and the LOWESS curve (Figure 9) indicates periods of erosion and recovery over time. Deterioration in clarity has also been significant in the Waiwhakaiho River (SH3) and the Mangaoraka Stream (Corbett Road), where steady declines throughout the period are apparent (Figure 9). There is no longer an improvement in clarity at the Waingongoro SH45 site but a continued improvement in suspended solids at the Punehu Stream SH 45 site. There have been two additional deterioration trends in BOD_5 at the Maketawa Stream at Tarata Rd (although concentrations have been very low (i.e. <1 g/m^3)) and Mangaoraka Stream at Corbett Rd sites since the 2013 year trend analysis and a continued deterioration at the Waingongoro River at SH45 site. Some significant trends in water temperature and pH have been noted (Table 40). However the rates of change per year in most of these cases have been less than 1% and therefore not 'meaningful' changes.

5. Conclusions

The physicochemical component of the SEM programme which commenced in July 1995, with monthly sampling performed at nine river and stream sites, in seven selected catchments, continued from July 2013 through to June 2014. From mid 1998 an additional site in the lower reaches of the Waingongoro River was included and a site in the lower reaches of the Maketawa Stream was added in mid 2003. Sampling in the year under review coincided randomly with a narrower range of flow conditions in the 2013-2014 period (in comparison with the previous eighteen year period), ranging from moderate freshes through to very low flow conditions but was characterised by several fresh events, more than during the previous year. This report provides monthly data for up to 22 parameters and a statistical summary of the twelve months' data for each of the sites, and compares this period's water quality with the previous 18 years' data. It also provides an up-to-date statistical summary of the 19 years' data to date for all sites and discusses, in brief, comparative water quality at these sites.

River and stream waters were generally of moderate to good quality, particularly at sites in the upper reaches of ring plain catchments with some deterioration in a downstream direction coincident with increased run-off, possible stock access and point source discharges. This was illustrated particularly by decreased clarity and increased nutrient levels and bacteriological numbers, and wider water temperature and pH ranges in a downstream direction. Aesthetic quality deterioration was also coincident with increased flows following, or during, the several freshes. However, dissolved oxygen levels remained high and there was little evidence of significant organic contamination (i.e. BOD_5 concentrations were generally less than 1.0 g/m^3 except during freshes).

The eastern hill country river (Mangaehu River) site in the lower reaches of the river was characterised by some dissolved colour, relatively high turbidity, poorer clarity, and slightly elevated suspended sediment concentrations.

Although the upper site in the Punehu Stream was located within 3 km of the National Park boundary, influence of the open developed farmland section of the relatively short reach below the National Park boundary on aspects of water quality has been documented. This was illustrated by poorer clarity, and higher temperature and bacteriological numbers than might be expected for a ring plain stream sampled in the reach near the National Park boundary. The relatively open nature of the reach between the National Park and the sampling site contributed to these aspects of the water quality measured, although more recently riparian plating has been initiated in this reach.

During the 2013-2014 period, median flows sampled were entirely higher than typical of those sampled during the previous eighteen-year period with median flows higher over the latest period (by 5 to 59%), compared with the long-term sampled flow record. The south-western ringplain catchment (Punehu Stream) median flows were the highest over the latest period compared with the long-term sampled flow record.

Table 41 Comparison of 2013-2014 water quality with previous long-term (1995-2013) data (using median values) for each SEM site

Parameter Site	Black disc	Conductivity @ 20°C	BOD_5	Faecal coliform bacteria	Enterococci bacteria	Nutrients					pH	Dissolved oxygen saturation	Suspended solids	Temperature	Turbidity	Flow (l/sec)	Flow (%)
						Ammonia -N	Nitrate-N	Total N	DRP	Total P							
Maketawa Stream at Tarata Road	X	=	X	XX	XX	=	XX	=	X	X	=	=	=	=	X	+516	27↑
Mangaoraka Stream at Corbett Road	=	=	XX	XX	XX	✓	=	=	=	X	=	=	X	=	X	+224	19↑
Waiwhakaiho River at SH3	=	=	=	XX	XX	X	=	✓	=	=	=	=	=	=	=	+486	13↑
Stony River at Mangatete Road	=	=	=	XX	XX	=	✓✓	=	=	=	=	=	=	=	X	+186	5↑
Punehu Stream at Wiremu Road	=	=	=	=	=	XX	XX	=	=	=	=	=	=	=	XX	+115	27↑
Punehu Stream at SH45	=	=	X	X	XX	XX	X	X	=	X	=	=	X	=	=	+458	59↑
Waingongoro River at Eltham Road	X	=	=	XX	X	X	=	=	XX	X	=	=	=	=	=	+570	35↑
Waingongoro River at SH45	X	=	X	XX	=	X	✓	=	=	=	=	=	=	=	X	+647	14↑
Patea River at Barclay Road	=	=	=	=	✓✓	X	=	=	=	=	=	=	=	=	=	+28	13↑
Patea River at Skinner Road	=	=	X	XX	XX	X	=	=	=	=	=	=	=	=	=	+1341	46↑
Mangaehu River at Raupuha Road	=	=	=	XX	XX	✓	=	=	=	X	=	=	X	=	=	+2346	34↑

[KEY: Improvement by ≥50% (✓✓); 21-49% (✓): no significant change (=): deterioration by 21 to 49% (X); ≥ 50% (XX)]

[Notes: Maketawa Stream data collection commenced in mid 2003; Waingongoro River at SH45 data collection commenced in mid 1998]

Generally water quality in the 2013-2014 period (Table 41) showed similar to slightly worse black disc clarity, and suspended solids levels, but worse turbidity levels compared with the long-term monitoring record. Median water temperatures at mid and lower catchment sites were similar during the latest period but narrower temperature ranges were measured at all of the eleven sites in the year under review mainly due to lower maximum temperatures (in comparison with the longer period) during the 2013-2014 sampling period.

Median dissolved oxygen saturation and pH showed no significant differences in the latest period (Table 41), but BOD_5 concentrations increased at four lower reach and one mid-reach sites (particularly in the Mangaoraka Stream) although they remained relatively low.

A majority of sites' median nutrient levels remained similar in the 2013-2014 period to those over the longer period. A few improvements in median nutrient species (ammonia N at two sites, nitrate N at two sites, and total N at one site) were recorded. The Waingongoro River site in the lower reaches showed minimal further improvement in median nutrient levels following the diversion of the major point source discharge (Eltham WWTP) out of the catchment coincident with three median nutrient concentrations deteriorating at the upstream Eltham Road site. Deterioration was found in median dissolved reactive phosphorus (at two sites), total phosphorus (at five sites) and ammonia N (at seven sites) [Table 41].

Bacteria numbers showed improvement at one site in terms of median enterococci numbers but there was deterioration at eight sites during the 2013-2014 period. No sites showed improvement in median faecal coliform bacteria numbers while nine sites showed deterioration. This general trend of deterioration in bacteriological water quality during 2013-2014 probably in part reflected the increased frequency of sampling of freshes during the 2013-2014 period.

This TRC programme is complemented by the three sites surveyed by NIWA as a component of the New Zealand surface water quality network (Smith et al, 1989). These sites' data have been made available for TRC usage and a brief summary and discussion have been provided in this report. Other aspects (e.g. trends) will be reported upon elsewhere by NIWA although the Waingongoro River site in the lower reaches showed an improvement in two median nutrient levels coincident with the diversion of the major point source discharge (Eltham WWTP) out of the catchment.

A further trend assessment was performed upon eleven TRC sites over the 1995-2014 period (including one site for the 1998-2014 period and one site for the 2003-2014 period) and summarised in this Annual Report. This complements the reports prepared for the 1995 to 2008 period presented in TRC, 2009a and the period 1995 to 2009 presented in TRC, 2009. A significant improvement in aspects of temporal water quality (mainly nutrients) has been found at the site in the lower Waingongoro River, subsequent to relatively more recent reductions in waste loadings discharged by industry and/or the township to the river in mid catchment at Eltham.

In conclusion, long term (19-year) physicochemical trends have indicated significant deterioration for some parameters at some sites, especially for nutrients in most of the middle and lower catchments. Dissolved reactive phosphorus, and total phosphorus, have been the main nutrients showing significant deterioration in the Waingongoro

River at Eltham Road and Punehu Stream at SH 45 where nitrate has also deteriorated. The Waiwhakaiho River site at SH3 has also recorded a significant deterioration in DRP, nitrate, and ammonia-N. The trend for these three sites has indicated that phosphorus level is increasing at a steady but slow rate. All three sites are situated in catchments with intensive agricultural land use. However there has been a significant improvement in total nitrogen at six of the eleven sites monitored.

Three sites (one mid reach and two lower reach) have shown significant long term deterioration in BOD_5 although concentrations have remained consistently below $1g/m^3$ at the mid reach Maketawa Stream site.

Faecal coliforms and enterococci trends generally have not altered significantly over the 19-year period with two sites showing significant deterioration in the lower or mid reaches. Fluctuating trends for black disc clarity and suspended solids reflect the historical erosion events in the headwaters of the Stony River. Significant deteriorations in black disc clarity were also recorded for the Waiwhakaiho River at SH3 and the Mangaoraka Stream at Corbett Road. All sites have had insignificant trends for conductivity, temperature, and pH.

On a site specific basis comparing the 2013-2014 period with the previous 18-year historical record, the Maketawa Stream and Punehu Stream (at SH45 sites) have shown most change in water quality with eight of the thirteen parameters recording significant deterioration. These sites are representative of developed farmland lower catchments. Other sites with at least five parameters showing significant declines included lower reach sites in the Waingongoro River and Mangaoraka Stream and the mid-reach site in the Waingongoro River. Main declines were found for ammoniacal nitrogen and bacterial species. Least change in comparative water quality was found at the Stony River (mid-reach) and Patea River (upper reach) sites.

6. Recommendations

1. THAT the freshwater physicochemical component of the SEM programme continue in a similar format for the 2014-2015 monitoring year.
2. THAT an additional (split) sample be collected on at least one occasion during the monitoring year, in conjunction with the intra-laboratory quality control programme, for analysis by an external, accredited laboratory.
3. THAT the appropriate trend analysis reported on the datasets for all Taranaki sites over the ten year (1995-2005) period (TRC, 2006a), the 1995-2009 period (TRC, 2009), and the 1995-2014 period (current report), be updated for the 1995-2015 period at the conclusion of the 2014-2015 year.

7. Acknowledgements

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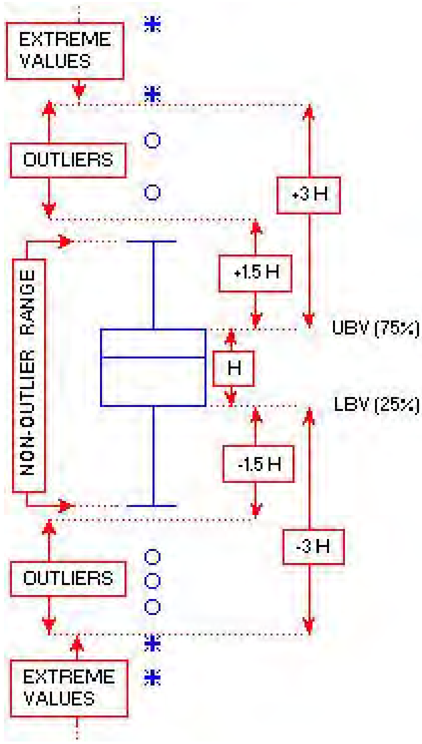
Appendix I

Statistical ‘Box & Whisker’ Plots of 1995-2014 Water Quality Parameters for all SEM sites

Interpretation of Box and Whisker Plots (produced using STATISTICA)

Box and whisker plots are a useful method of summarising data in a graphical form that allows rapid comparisons of data groups. The data is represented as a box with a whisker from each end.



The median (middle value of the sorted data; half of the data is either side of the median) is represented by a single horizontal line (or ◊ point).

The top and bottom of the box represent the upper (UBV) and lower (LBV) hinges respectively. The median splits the ordered group of data in half and the hinges split the remaining halves in half again. This means that 50% of the data lies within the box.

Hspread, comparable to the interquartile (25% and 75%) range is the difference between the values of the two hinges, i.e., Upper hinge – Lower hinge = Hspread. The inner fences (within whiskers) are defined as follows:

Lower fence = lower hinge - (1.5 x Hspread)
Upper fence = upper hinge + (1.5 x Hspread)

The outer fences (outside whiskers) are defined as follows:

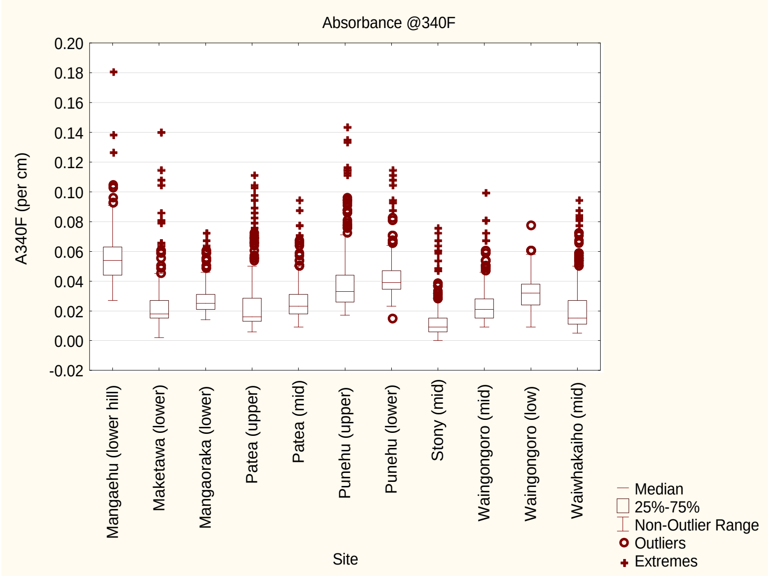
Lower fence = lower hinge - (3 x Hspread)
Upper fence = upper hinge + (3 x Hspread)

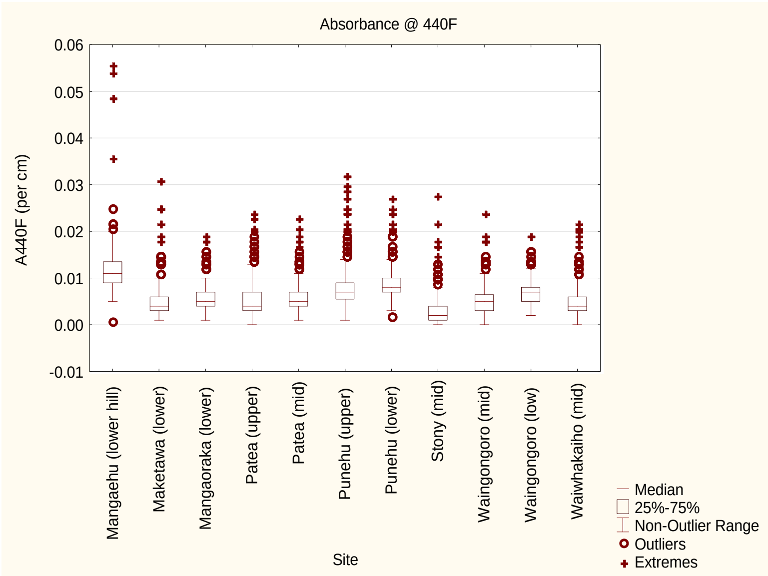
The whiskers show the range of values that lie within the inner fences. Values outside the inner fence are plotted as open circles (o). Values outside the outer fence are plotted as asterisks (*).

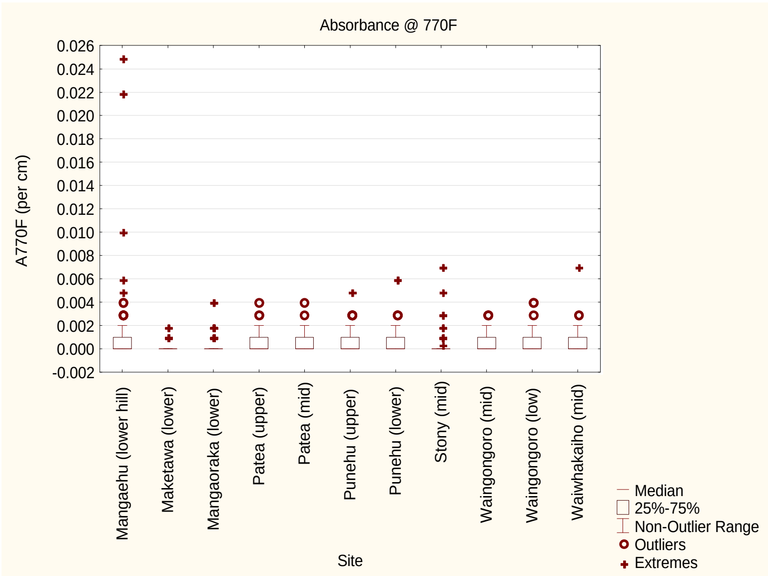
Site locations

Stream	Location
Maketawa Stream	at Tarata Road
Mangaehu River	at Raupuha Road
Mangaoraka Stream	at Corbett Road
Patea River	at Barclay Road
Patea River	at Skinner Road
Punehu Stream	at Wiremu Road
Punehu Stream	at SH45
Stony River	at Mangatete Road
Waingongoro River	at Eltham Road
Waingongoro River	at SH45
Waiwhakaiho River	at SH3

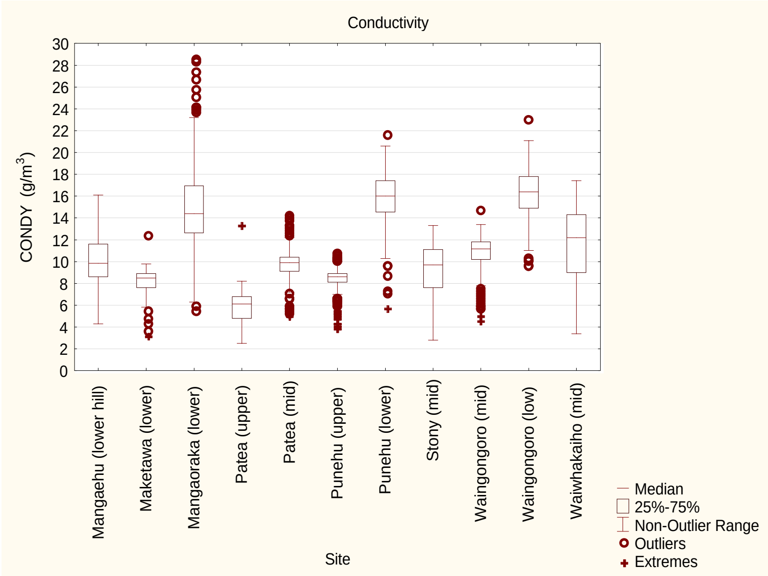
Absorbance (1 cm)

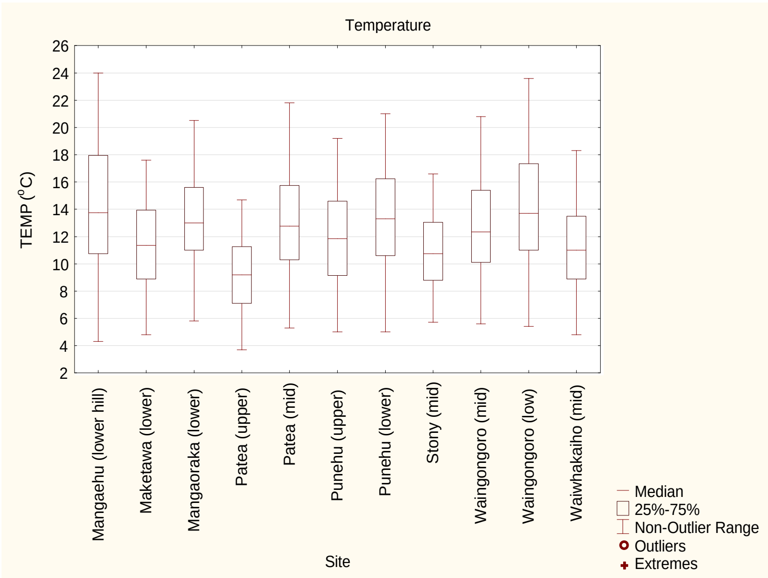


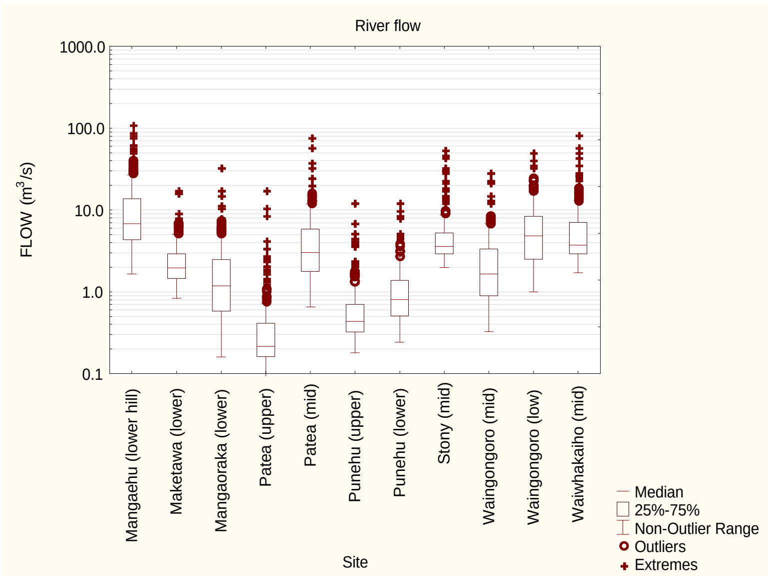


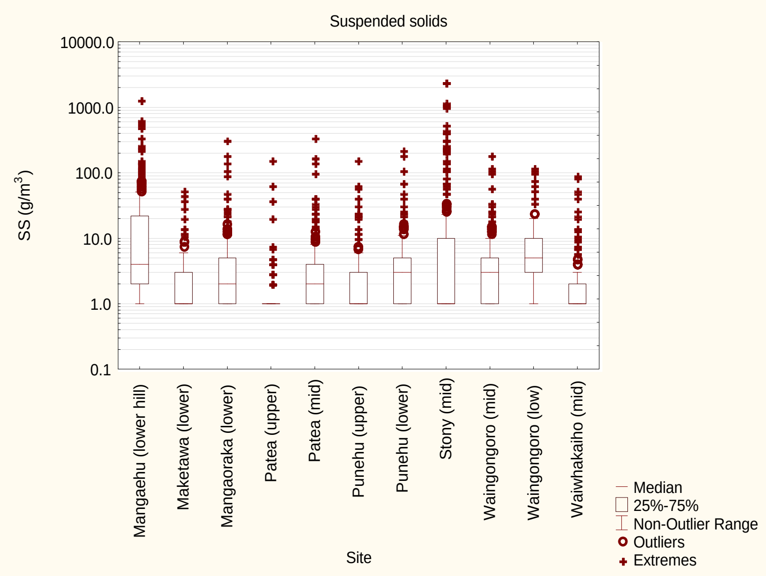


Physical Quality

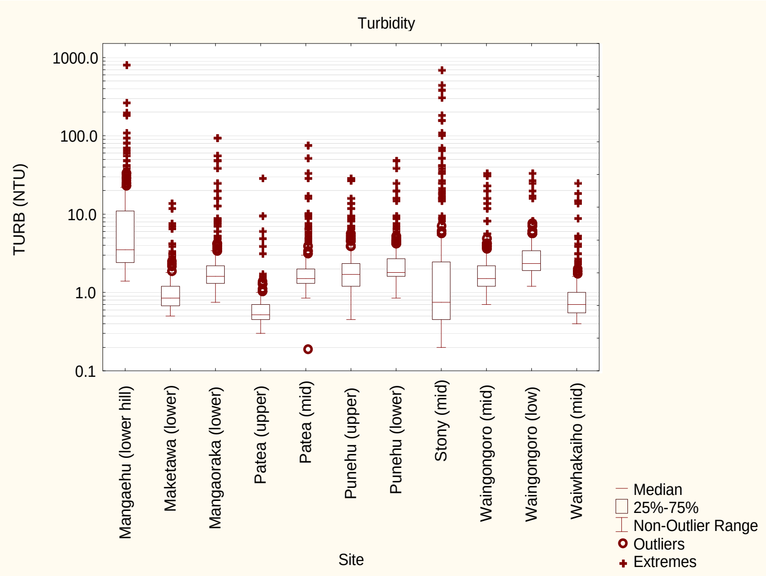




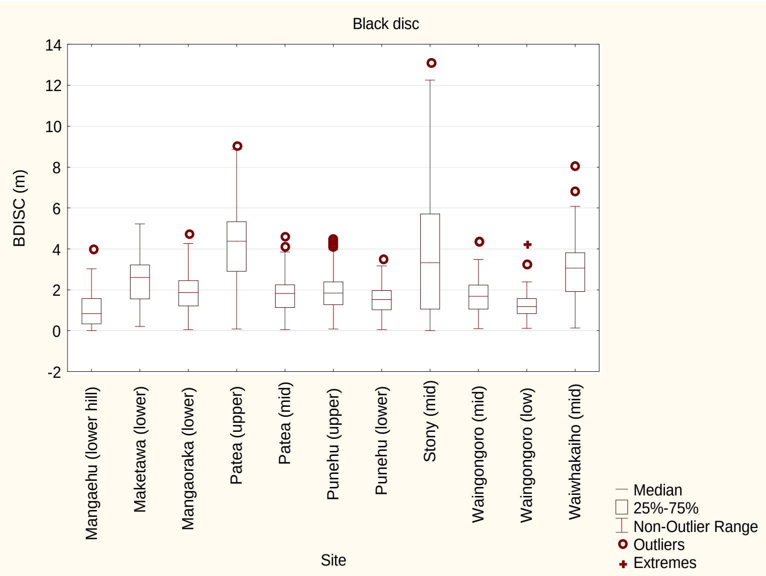




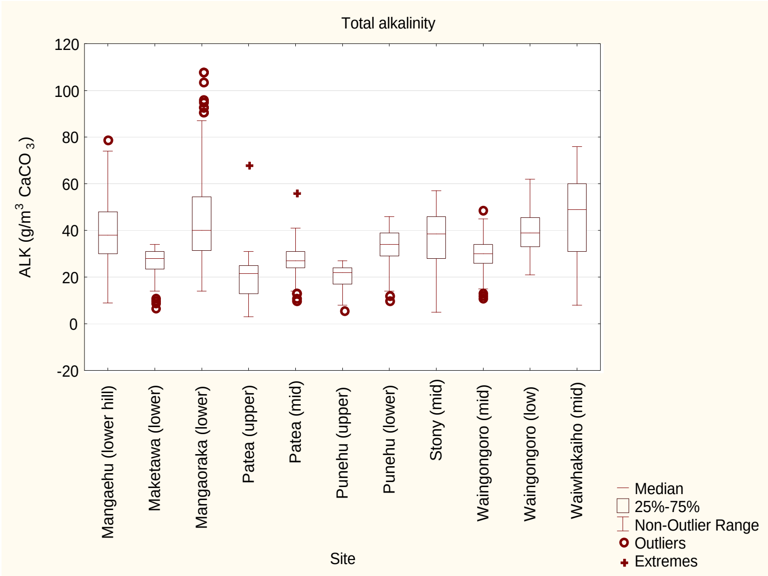
Suspended solids
SS (g/m^3)
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



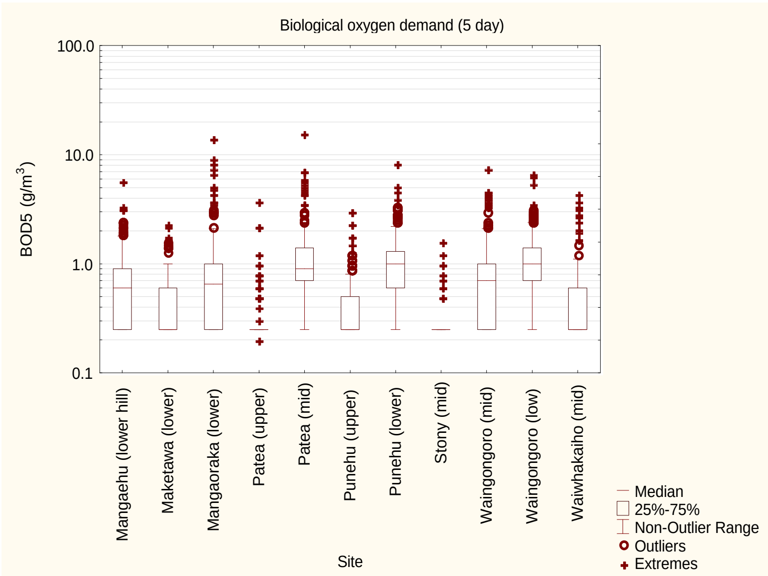
Turbidity
TURB (NTU)
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



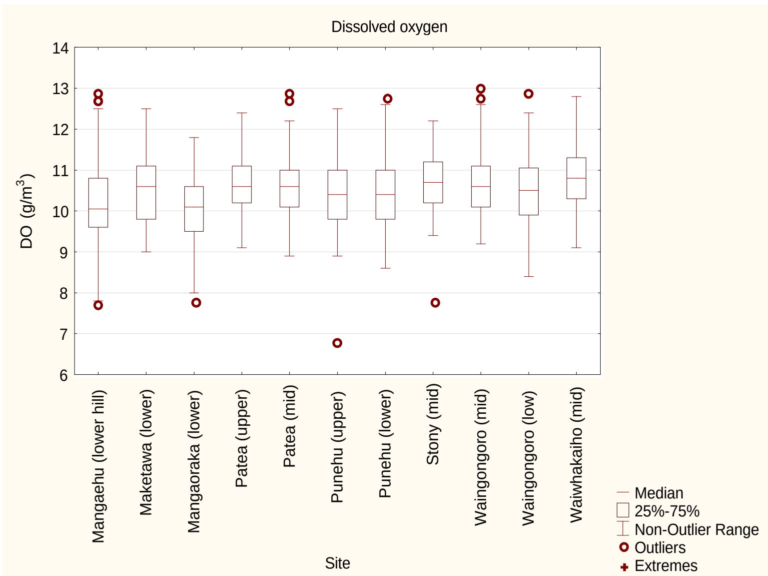
Black disc
BDISC (m)
14
12
10
8
6
4
2
0
-2
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



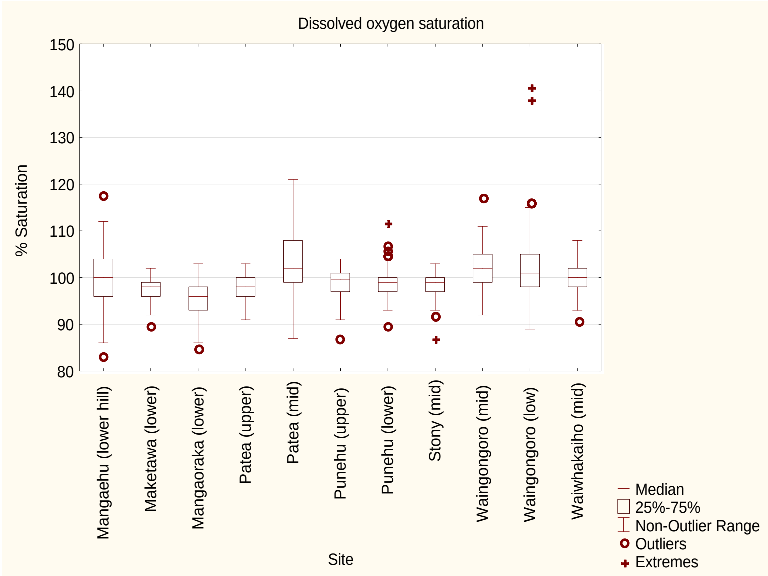
Total alkalinity
ALK (g/m³ CaCO₃)
120
100
80
60
40
20
0
-20
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

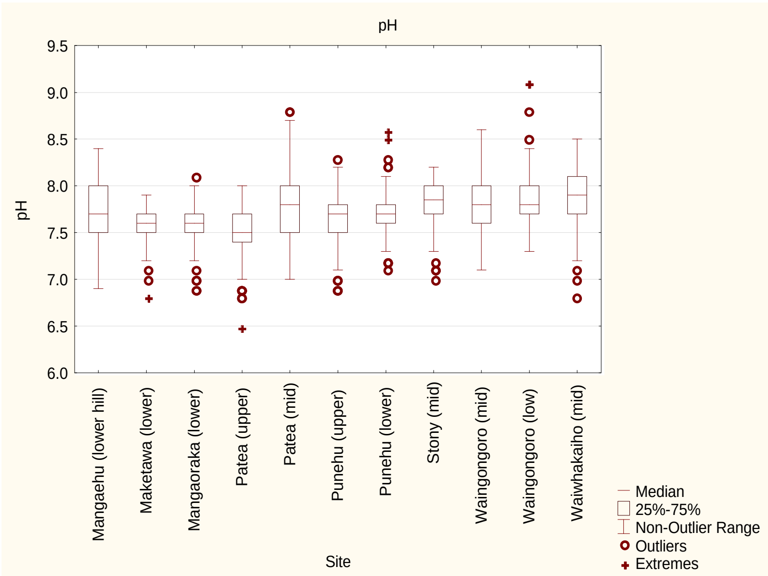


Biological oxygen demand (5 day)
BOD5 (g/m³)
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

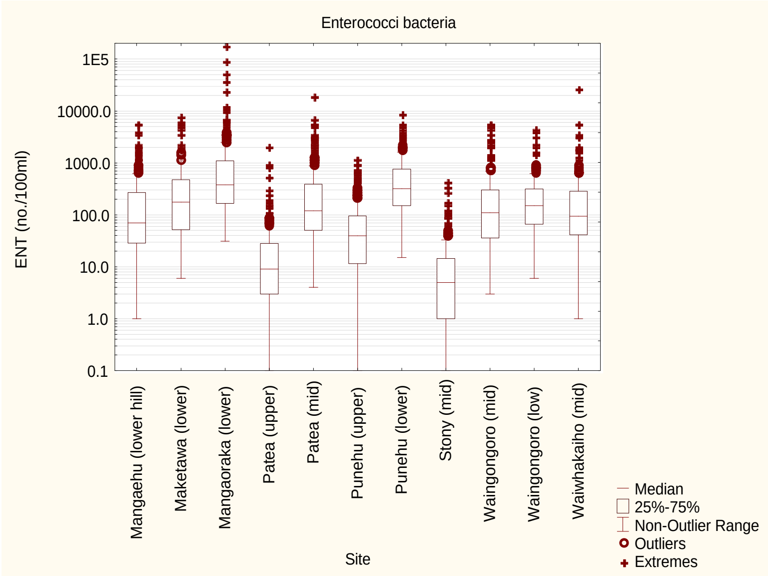


Dissolved oxygen
DO (g/m³)
14
13
12
11
10
9
8
7
6
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

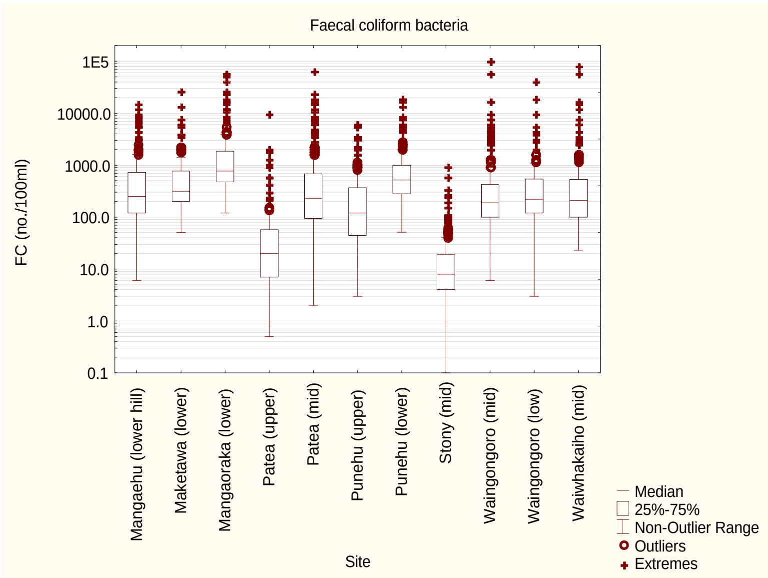

Dissolved oxygen saturation
% Saturation
150
140
130
120
110
100
90
80
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pH
pH
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

Bacteria

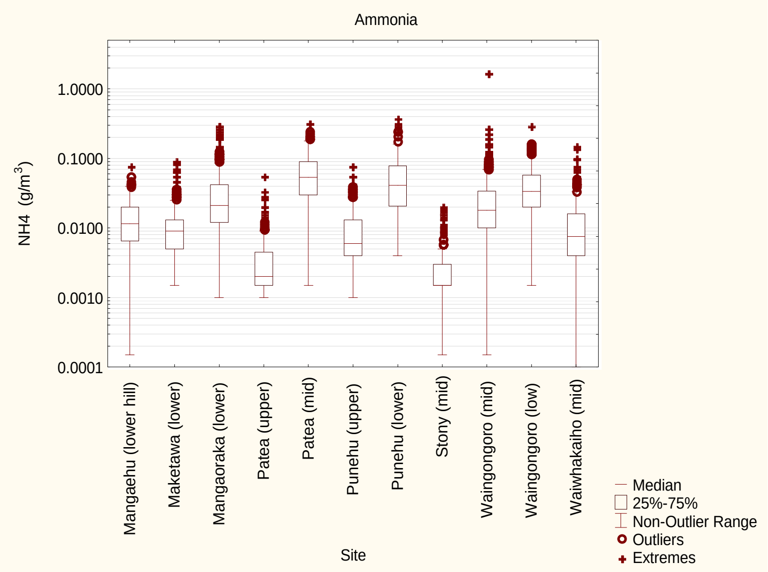


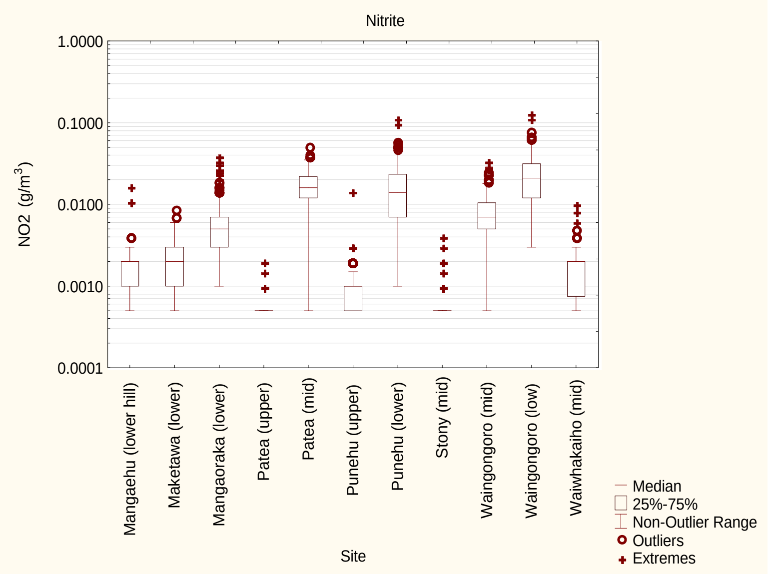
Enterococci bacteria
ENT (no./100ml)
1E5
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

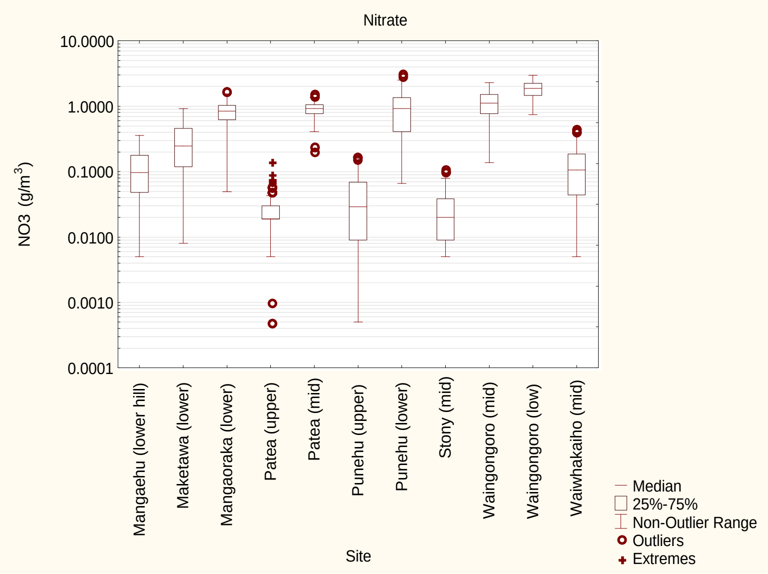


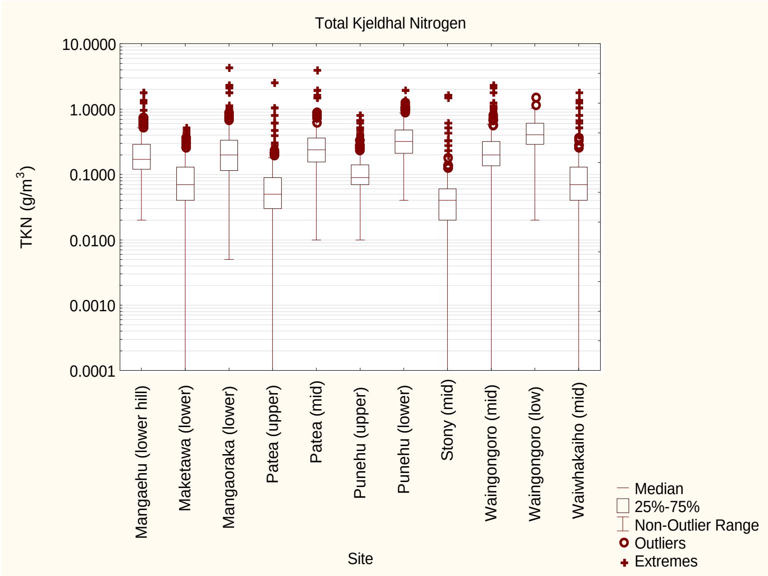
Faecal coliform bacteria
FC (no./100ml)
1E5
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

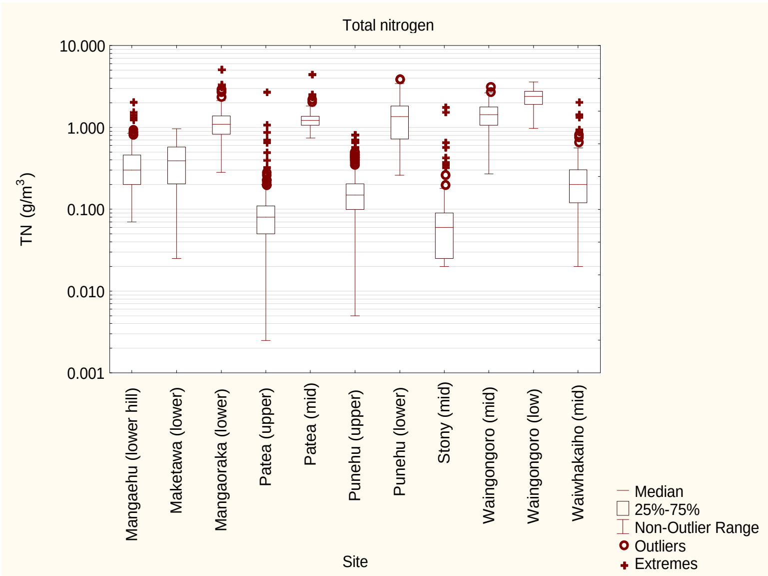
Nutrients

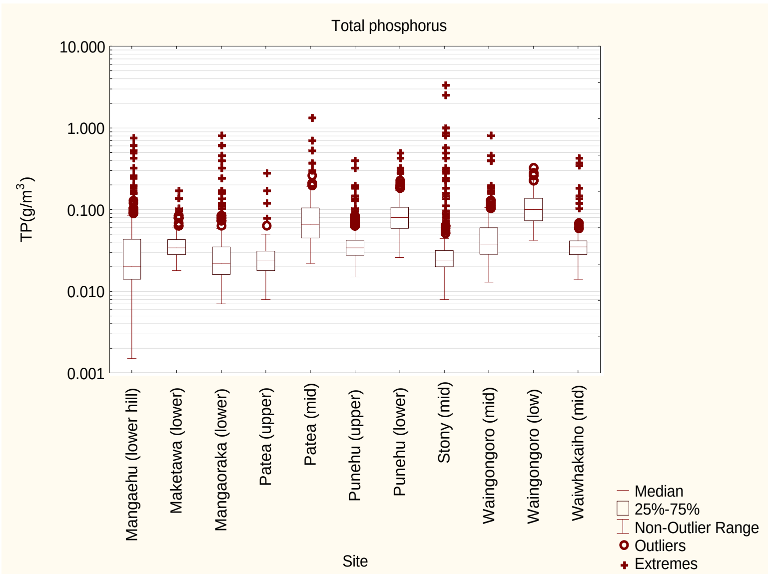

Ammonia
NH4 (g/m3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

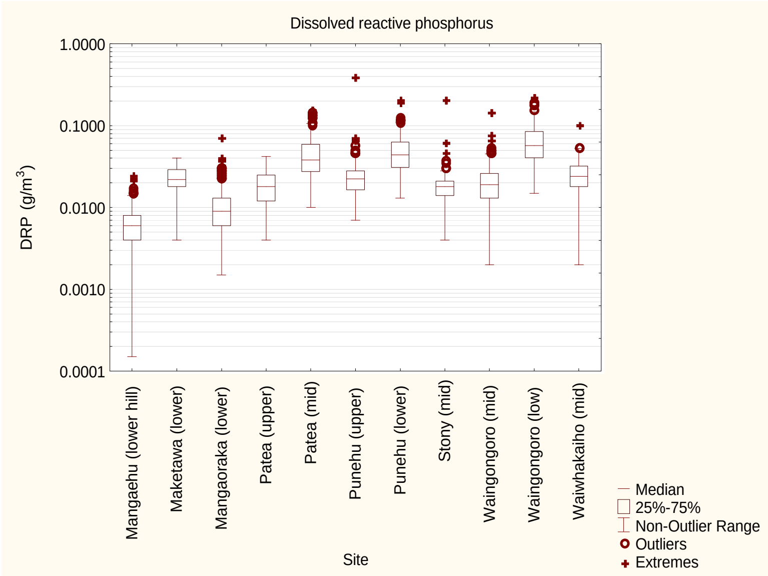

Nitrite
NO2 (g/m3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Nitrate
NO3 (g/m3)
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Total Kjeldhal Nitrogen
TKN (g/m3)
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Total nitrogen
TN (g/m3)
10.000
1.000
0.100
0.010
0.001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Total phosphorus
TP(g/m3)
10.000
1.000
0.100
0.010
0.001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Dissolved reactive phosphorus
DRP (g/m3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

Appendix II

Issues 3.3.6 & 3.3.7 of the TRC Regional Policy Statement

3.3.6 *ISSUE: Water quality degradation resulting from diffuse source contamination*

OBJECTIVE

To maintain and enhance the quality of the water resources of Taranaki for water supply purposes, contact recreation, shellfish gathering for human consumption, aesthetic purposes, cultural purposes and aquatic ecosystems by avoiding, remedying or mitigating the adverse effects on water quality of diffuse source runoff of sediment, nutrients or other contaminants from land.

POLICIES

Policy One: Land use and management practices

Land use practices which reduce adverse effects on water quality and which maintain and enhance the quality and life-supporting capacity of water will be encouraged and promoted including:

- *the careful application of the correct types and quantity of fertiliser;*
- *the careful use of agrichemicals;*
- *land development and restoration of disturbed land to reduce diffuse source discharge of contaminants to water;*
- *stock control procedures to avoid, remedy or mitigate the effects of stock entry to rivers, trampling and pugging by stock and accelerated erosion from overgrazing; and*
- *land management practices, including the discharge of contaminants to land, that avoid or reduce contamination of groundwater aquifers.*

Policy Two: Management of riparian margins

The vegetation along riparian margins of all Taranaki lakes and rivers will, as far as is practicable, be retained and enhanced and, where appropriate, the retirement and planting of riparian margins will be promoted on all or parts of the following priority ring plain catchments:

*Waingongoro**
*Manganui**
Te Henui
Huatoki
Mangorei
*Patea**
Oakura
Timaru
*Waitara**
*Waiwhakaiho**
*Kapuni**
Hangatahua/Stony
*Waiongana**
Tapuae
Tawhiti
*Waiaua**
Taungatara
*Mangatoki**
*Kaupokonui**
Kai Auai
Maketawa
Kahouri
Mangaoraka
Warea
Okahu
*Punehu**
Ngatoro-nui
*Ngatoro**
*Pungareere**

** Waterways which are also community water supply catchments*

In addition, regard shall be had to the following criteria in determining other priority catchments, subcatchments or reaches of rivers and lakes for the promotion of riparian vegetation:
- existing degraded water quality including high water temperature, suspended solids, nitrate levels and dissolved reactive phosphate levels;
- existing degraded habitat quality including instream habitat and the extent or loss of existing vegetation;
- the intensity of land uses, their proximity to watercourses and the actual or potential contamination from diffuse sources;
- the actual or potential use of water for community, industrial and domestic water supplies;
- spiritual and cultural values and customary uses of tangata whenua;
- actual or potential scenic, amenity and recreational values including fishery values, indigenous fish and their habitat and the habitat of trout; and
- actual or likely conflicts among competing water uses and values and the potential for riparian management to reduce those conflicts.

In determining what is `practicable' and `appropriate' in relation to the retention or planting of riparian vegetation in all catchments the following criteria will apply:
- the physical characteristics of the site and catchment;
- the riparian management objectives and benefits sought;
- the costs of establishing riparian margins relative to the benefits.

METHODS OF IMPLEMENTATION

In relation to land use and management practices:

_ The Taranaki Regional Council will:

- **Encourage** the preparation of **waste management codes of practices** by the industries that may generate liquid and solid waste by-products which may be applied or disposed of to land, including **poultry, piggery and other similar farming operations** and, when appropriate, include such codes in a regional discharges to land plan.

- **Prepare and distribute guidelines** related to the management practices to be adopted to reduce the effects of organic waste discharges from **silage pits** and feed lots and to reduce the effects of river crossings by stock.

- Until new regional plans are prepared, continue to **implement, administer and monitor** the rules and conditions outlined in the Taranaki Regional Council Transitional Regional Plan regarding the application of registered **fertilisers** to land and the use of **herbicides and pesticides.**

- **Prepare** a **regional discharges to land plan** containing rules and other methods to effectively manage the **discharge of contaminants to land** including drilling muds and cuttings, sludges, fertiliser, agrichemicals, spray irrigated piggery and dairy effluent, poultry effluent storage and disposal and discharges from silage pits and feedlots.

- **Discuss** with manufacturers and suppliers of **agrichemicals and other chemicals,** the strengthening of the education and information provision role they play with a view to minimising the likelihood and potential effects of spray application on water quality.

- **Consider,** in conjunction with relevant authorities, the merits of the location, methods of application and subsequent management of the discharge of contaminants to land, in a way that avoids adverse effects on receiving water quality.

- **Recognise** that the actual and potential effects of **agricultural waste discharges** to land will vary according to proximity to and assimilative capacity of water bodies, stock numbers and type and size of operation and **adopt,** within a **discharges to land plan**, a graded approach for rule making discretion to reflect the varying effects which might arise.

- **Recognise** that the quantity and quality of **agricultural waste** discharged to land will vary and use the public notification and non-notification provisions of the Act to reflect the magnitude of potential effects.

- Prepare **guidelines** and farm management plans, and generally **promote** and provide **advice** on methods to assist land users and developers to avoid or minimise accelerated erosion and associated runoff to waterways resulting from the use and development of land.

- **Promote and encourage** community awareness of the need to protect groundwater quality, particularly in those areas recognised as being important for **recharge** of groundwater aquifers.

- **Recognise** local **nitrate contamination** of shallow groundwater aquifers as an inevitable product of intensive agricultural production and **promote** land management practices, including those related to the discharge of contaminants to land and the application of nitrogen-based fertilisers to land, which have the effect of reducing levels of this contamination.

- **Prepare and include in a regional sustainable land use plan,** rules designed to control or prohibit **vegetation clearance** on steep or erodible land and the effects of the use and development of land on those classes of land where significant erosion may occur or where excessive sediment runoff to waterways could result.

- **Promote,** through the **provision of free advisory services** and model demonstration areas (in co-operation with selected land-holders), **sustainable land use** practices which do not give rise to excessive sediment and nutrient runoff and consequent water quality effects.

- **Promote appropriate control of land use** by other agencies under **other legislation** including the Conservation Act 1987, the Reserves Act 1977, and the Queen Elizabeth the Second National Trust Act 1977 for the purpose of maintaining and enhancing water quality.

_ Territorial authorities may wish to consider the following methods:

- **Include** in **district plans**, policies, rules, guidelines or other information to avoid, remedy or mitigate the adverse effects of land use activities and management practices on water quality.

- Generally **encourage and promote**, as appropriate, land use practices which maximise the quality of water.

In relation to the management of riparian margins:

_ The Taranaki Regional Council will:

- **Promote** the protection and planting of riparian margins through **education and advocacy** to **land owners**.

- **Advocate** as appropriate to relevant agencies, the use of **other legislation** (such as the Conservation Act 1987, the Reserves Act 1977 and the Queen Elizabeth the Second National Trust Act 1977) for the purpose of promoting the protection and planting of riparian margins.

- **Promote the planting of riparian margins** by offering technical advice and assistance, preparing riparian management plans in conjunction with landowners and by establishing joint venture programmes for specific catchments and coastal strips.

- **Promote** the planting of riparian margins as a member of the **Taranaki Tree Trust.**

- **Prepare** and implement, in conjunction with interested and affected parties, a **riparian management and implementation strategy** to outline a regional approach to riparian management in the Taranaki region.

- **Include in regional plans** and **resource consents**, rules, criteria, conditions, guidelines or information for the maintenance or enhancement of riparian vegetation.

_ Territorial authorities may wish to consider the following methods:

- **Include** in **district plans** and **resource consents**, provisions or conditions for the retention or planting of riparian vegetation, including rules for the creation of esplanade reserves and esplanade strips when land is subdivided.

- **Provide riparian buffer zones** for land uses such as aggregate extraction adjacent to waterways.

- **Plant** riparian margins on **land owned** by the territorial authority.

EXPLANATION

The objective, policies and methods of implementation in relation to diffuse source contamination of water have been adopted to maintain and enhance water quality by avoiding, remedying or mitigating the adverse effects of land use and management practices on the quality of water including freshwater in rivers and in groundwater and coastal water. This is a major *issue for Taranaki because of the actual and potential adverse effects on water resources arising from intensive agricultural land use. The methods of implementation described contain a mix of advocacy, codes of practice, information provision and a stated intention to prepare rules within plans and the consideration of consent applications.*

With respect to Policy One, the preparation of a regional discharges to land plan will establish standards for agricultural waste discharges to land, to avoid or mitigate adverse effects on water quality. The effects of such discharges on water quality will vary according to stock numbers and the type of discharge method used. A graded approach to decision-making will be adopted to reflect this variation. Those operations with few or minor adverse effects will be `permitted' or `controlled' while discharge activities with more significant actual or potential effects will be made `discretionary' or `prohibited'.

The preparation of a regional sustainable land use plan will recognise the impacts on water quality of activities on land. The plan will contain rules to control activities on certain classes of land but will emphasise advice and education, codes of practice and the preparation of individual farm management plans to prevent or minimise adverse effects on water quality.

Management of riparian zones and the protection of streambank vegetation is important in controlling diffuse source contamination from land and improving the water quality of adjacent waterways and coastal water. The purpose of Policy Two concerning the management of riparian margins is to avoid, remedy or mitigate the adverse water quality effects resulting from the removal of riparian vegetation and to maximise the benefits of riparian margins. The catchments listed in Policy Two have been selected because they already receive relatively high volumes of diffuse source contamination and because of the potential benefits of riparian management in enhancing the value of these catchments for water supply purposes, scenic and recreational use, Maori cultural and spiritual values and instream habitat.

Emphasis in implementing Policy Two is placed on education, advocacy and advice and on voluntary agreements with landowners to establish and maintain suitable riparian vegetation and the preparation, by the Taranaki Regional Council, of a riparian management strategy.

Rules could be incorporated into regional and district plans and conditions attached to resource consents to retain or establish riparian vegetation.

The criteria for determining priority catchments provide the basis for a consistent and coordinated approach to riparian management in Taranaki.

The criteria in Policy Two for determining what is practicable and appropriate provide the basis for judging the practicality and appropriateness of implementing the policy in any particular case. The criteria recognise that it may not be practical or appropriate to require the retention or planting of riparian margins to the same extent in all localities because of differing physical characteristics from place to place, because of different riparian management objectives or because of different costs that may be involved relative to the benefits that will be obtained. Some flexibility is required.

However riparian management is of considerable importance to Taranaki because of the benefits of riparian vegetation and riparian management to the achievement of a number of the region's environmental objectives. It is the desire of the Taranaki Regional Council that progress be made in implementing riparian management objectives throughout Taranaki.

Related policies

Section 3.2.1, *All policies relating to land degradation and loss of the productive capabilities of land through accelerated erosion;* ***Section 3.2.3,*** *All policies relating to the actual or potential loss of indigenous and other vegetation and the habitats of indigenous fauna;* ***Section 3.2.10,*** *Policy One, Protection of natural features and landscapes;* ***Section 3.2.11,*** *Policy One, Amenity values, and Policy Two, Heritage values;* ***Section 3.3.7,*** *All policies relating to the discharge of contaminants from point sources;* ***Section 3.5.1,*** *Policy One, Protection of natural character (of the coastal environment).*

ENVIRONMENTAL RESULTS ANTICIPATED

- Improvement in water quality and instream habitat.
- Enhanced scenic, amenity, landscape and recreational values and spiritual and cultural values of tangata whenua.
- Reduced streambank erosion.

Appendix III

SEM Physicochemical Programme
TRC Intra-lab Quality Control
Report 2013-2014

Background

The Resource Management Act 1991 (RMA) established a requirement for local authorities to undertake environmental monitoring. Section 35 of the RMA requires, among other things, that the state of the environment in the region be monitored to an extent which enables local authorities to effectively carry out the functions under the RMA. In 1995, the Taranaki Regional Council (the 'Council') established a state of the environment monitoring (SEM) programme for the region. This programme is outlined in the Council's 'State of the Environment Monitoring Procedures Document', 1997.

A network of nine freshwater sites was developed in mid-1995 for physiochemical monitoring on a long-term basis to provide information on trends in the state of surface water quality in the Taranaki region. This network was extended to ten sites in the 1998-99 period and eleven sites in the 2003-2004 period. Sampling is carried out on the second Wednesday of each month for the entire year. The programme also meshes with a similar national programme operated by the National Institute of Water and Atmospheric Research (NIWA) since 1989, which includes three sites in Taranaki.

As a quality control measure of the TRC laboratory precision for this programme, and as part of general quality assurance practices at the Council, a sample is collected from one of the eleven monitoring sites (chosen randomly) every three to four months and split on site for duplicate analyses. For quality control purposes, this sample is unidentified and is analysed in exactly the same way and at the same time as other samples, and recorded on the Council's database. In conjunction with the sampling undertaken by NIWA, a sample from one of the three network sites is split in the field from time to time as a quality control procedure for TRC laboratory analytical accuracy assessment. These comparisons between Council and NIWA results are reported in Appendix IV. The results of the internal Taranaki Regional Council quality control sampling for the 2013-2014 period are presented and discussed in this Appendix (III) to the report.

Introduction

Quality assurance (for precision and accuracy) is an essential aspect of any laboratory and monitoring programme. Quality control is an essential tool in this assurance, and is carried out by the Council for the SEM programme at up to four times per year, and annually for NIWA monitoring.

This report presents the results from the QC sample and precision results for the routine sample from which it was split, and compares the difference of each result from the mean of the two results. The difference is presented as a percentage of the mean and levels of these differences are expressed as follows:

Difference from mean (%)	Symbol/Comment
<10%	✓
10-20%	*
21-50%	**
>50%	***

The acceptability of the precision of pairs of analyses varies from parameter to parameter and the symbols defined above are only a guideline. For instance a 20% difference is acceptable for bacteriological samples, as there can be considerable variation in bacteriological counts, whereas pH measurements should not vary by more than 0.2 unit between subsamples.

There are various reasons why sub-sample results may differ, including discrepancies in laboratory equipment and/or techniques and general within sample variation. Sampling variation should be minimal as only a single sample has been collected for splitting into duplicate sub-samples prior to analyses. The amount of variation in results can differ from one type of analysis to another, and this report identifies those techniques that are more prone to variation. Once these methods are identified, it is possible to determine whether differences in results are significant and if so, whether these are due to laboratory discrepancies. Attempts to eliminate these problems can then be made wherever possible.

Results

Comparisons of split samples are presented in chronological order for the annual sampling period between July 2013 and June 2014.

First QC exercise

These split samples were collected from the Waingongoro River site at SH45 on 10 September 2013 under moderate recession flow conditions (5.49 m^3/sec) and in overcast conditions. Results are presented in Table 1.

Table 1 Results of SEM QC sampling on 10 September 2013

Site: WGG000900					
Date: 10 September 2013				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.026	0.025	2	✓
A440F	/cm	0.006	0.005	9	✓
A770F	/cm	0.001	0.000	100	***
ALKT	g/m^3 $CaCO_3$	38	38	0	✓
BOD5	g/m^3	1.6	1.6	0	✓
CONDY	mS/m @ 20°C	17.1	17.1	0	✓
DRP	g/m^3-P	0.041	0.042	1	✓
ENT	/100ml	16	20	11	*
ECOL	/100ml	110	100	5	✓
FC	/100ml	110	100	5	✓
NH4	g/m^3-N	0.031	0.032	2	✓
NO2	g/m^3-N	0.022	0.021	2	✓
NO3	g/m^3-N	2.238	2.229	< 1	✓
pH	pH	7.8	7.8	0	✓
SS	g/m^3	9	8	6	✓
TKN	g/m^3-N	0.58	0.63	4	✓
TN	g/m^3-N	2.84	2.88	< 1	✓
TP	g/m^3-P	0.098	0.097	< 1	✓
TURB	NTU	3.5	3.3	3	✓

Comments:

The difference of 0.001 units in filtered absorbance readings at 770 mm was not significant as it was within acceptable equipment performance tolerance. The difference between enterococci counts for the paired samples was within acceptable tolerance levels for bacteriological samples (20%).

Overall results showed extremely good laboratory analytical precision performance, with 17 of 19 pairs of results being within the 10% guideline and 15 of these pairs showing < 6% difference in paired results.

Second QC exercise

These split samples were collected from the Punehu Stream site at Wiremu Road on 13 November 2013 under clear, moderately low flow (0.379 m^3/sec), and fine sunny weather conditions. Results are presented in Table 2.

Table 2 Results of SEM QC sampling on 13 November 2013

Site: PNH000200					
Date: 13 November 2013				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.028	0.030	3	✓
A440F	/cm	0.006	0.006	0	✓
A770F	/cm	0.001	0.001	0	✓
ALKT	g/m^3 $CaCO_3$	22	22	0	✓
BOD5	g/m^3	< 0.5	< 0.5	0	✓
CONDY	mS/m @ 20°C	9.3	9.3	0	✓
DRP	g/m^3-P	0.023	0.026	6	✓
ENT	/100ml	5	1	67	***
ECOL	/100 ml	25	23	4	✓
FC	/100ml	25	23	4	✓
NH4	g/m^3-N	< 0.003	< 0.003	0	✓
NO2	g/m^3-N	0.001	0.001	0	✓
NO3	g/m^3-N	0.019	0.019	0	✓
pH	pH	7.5	7.5	0	✓
SS	g/m^3	< 2	< 2	0	✓
TKN	g/m^3-N	0.03	0.04	14	*
TN	g/m^3-N	< 0.05	0.06	≥ 10	*
TP	g/m^3-P	0.026	0.028	4	✓
TURB	NTU	2.0	1.9	3	✓

Comments:

Although the difference in enterococci bacterial count was outside the acceptable tolerance level for bacteriological samples (20%) there was only a very small difference of 4 per 100 mls in the low numbers found. The TKN paired results were significantly different but again at low concentrations and as a result of the small difference in total nitrogen results from which they were calculated (not analysed). None of these results were outliers in terms of the historical record for this site.

Otherwise, overall laboratory analytical precision performance was good, with 16 of the 19 pairs of results recorded within the 10% guideline.

Third QC exercise

These split samples were collected from the site in the Waiwhakaiho River at SH3 on 12 February 2014 under very low, clear flow (2.39 m^3/sec), and fine weather conditions. Results are presented in Table 3.

Table 3 Results of SEM QC sampling on 12 February 2014

Site: WKH000500					
Date: 12 February 2014				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.010	0.010	0	✓
A440F	/cm	0.002	0.002	0	✓
A770F	/cm	0.000	0.001	100	***
ALKT	g/m^3 $CaCO_3$	66	67	< 1	✓
BOD5	g/m^3	0.6	< 0.5	≥ 10	✓
CONDY	mS/m @ 20°C	15.5	15.5	0	✓
DRP	g/m^3-P	0.041	0.040	1	✓
ENT	/100ml	230	390	26	**
ECOL	/100ml	200	250	11	*
FC	/100ml	200	250	11	*
NH4	g/m^3-N	0.009	0.012	14	*
NO2	g/m^3-N	< 0.001	< 0.001	0	✓
NO3	g/m^3-N	0.019	0.019	0	✓
PH	pH	8.0	8.1	6	✓
SS	g/m^3	< 2	< 2	0	✓
TKN	g/m^3-N	0.07	0.07	0	✓
TN	g/m^3-N	0.09	0.09	0	✓
TP	g/m^3-P	0.049	0.052	2	✓
TURB	NTU	0.8	0.8	0	✓

Comments:

The difference of 0.001 units in filtered absorbance readings at 770 nm was not significant as it was within acceptable equipment performance tolerance. The difference in BOD_5 paired results was about 10% for these samples but at this low concentration the < 0.03 g/m^3 difference was within the acceptable tolerance level for this parameter.

The difference between ammonia N paired results was significant (14%) at a relatively low concentration. The differences between pairs of *E.coli* and faecal coliform bacterial counts were within acceptable tolerance levels (20%) whereas the difference in enterococci counts was just outside this level for bacteriological samples.

Otherwise 13 pairs of parameters analysed were well within acceptable agreement, representing good laboratory analytical precision for these samples.

Fourth QC exercise

These split samples were collected from the site in the Waiwhakaiho River at SH3 on 11 June 2014 under slightly turbid, fresh flow conditions (18.5 m^3/sec), and overcast weather. The results are presented in Table 4.

Table 4 Results of SEM QC sampling on 11 June 2014

Site: WKH000500					
Date: 11 June 2014				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.050	0.050	0	✓
A440F	/cm	0.011	0.010	5	*
A770F	/cm	0.001	0.001	0	✓
ALKT	g/m^3 $CaCO_3$	20	20	0	✓
BOD5	g/m^3	0.7	0.9	13	*
CONDY	mS/m @ 20°C	5.9	5.9	0	✓
DRP	g/m^3-P	0.016	0.016	0	✓
ENT	/100ml	480	350	16	*
ECOL	/100ml	700	440	23	**
FC	/100ml	700	440	23	**
NH4	g/m^3-N	0.039	0.040	1	✓
NO2	g/m^3-N	0.003	0.003	0	✓
NO3	g/m^3-N	0.02	0.02	0	✓
PH	pH	7.4	7.3	< 1	✓
SS	g/m^3	3	3	0	✓
TKN	g/m^3-N	0.20	0.21	2	✓
TN	g/m^3-N	0.42	0.43	1	✓
TP	g/m^3-P	0.045	0.039	7	✓
TURB	NTU	1.5	1.5	0	✓

Comments:

The differences between pairs of *E.coli* and faecal coliform bacterial counts were just outside acceptable tolerance levels (20%) for bacteriological samples whereas the difference in enterococci counts was within this tolerance level.

The 13% difference in BOD_5 results (0.2 g/m^3) was not significant at this very low concentration (< 1 g/m^3).

Otherwise 15 of the 18 parameters' pairs of results were within the 10% guideline representing good laboratory analytical precision.

Summary

Four split samples were collected and analysed during this one-year (2013-2014) period for the assessment of internal laboratory analytical precision. The following table summarises the number of times each category of differences from the mean occurred for all analyses commonly performed on SEM samples.

	Difference from mean of pairs of split samples							
Parameter ID	**<10%**		**10-20%**		**21-50%**		**>50%**	
A340F	4	(93)	-	(7)	-	(0)	-	(0)
A440F	4	(72)	-	(19)	-	(7)	-	(2)
A770F	2	(75)	-	(0)	-	(9)	2	(16)
ALKT	4	(100)	-	(0)	-	(0)	-	(0)
BOD5	2	(87)	2	(12)	-	(0)	-	(1)
CONDY	8	(100)	-	(0)	-	(0)	-	(0)
DO*	-	(100)	-	(0)	-	(0)	-	(0)
DRP	8	(94)	-	(5)	-	(0)	-	(1)
ENT	0	(44)	2	(24)	1	(25)	1	(7)
ECOL	2	(50)	1	(33)	1	(15)	-	(2)
FC	2	(50)	1	(32)	1	(15)	-	(3)
NH4	3	(79)	1	(13)	-	(5)	-	(3)
NO2	4	(96)	-	(3)	-	(1)	-	(0)
NO3	6	(84)	-	(6)	-	(9)	-	(1)
pH	8	(100)	-	(0)	-	(0)	-	(0)
SS	4	(88)	-	(8)	-	(4)	-	(0)
TKN	3	(47)	1	(23)	-	(25)	-	(5)
TN	3	(81)	1	(12)	-	(7)	-	(0)
TP	4	(85)	-	(7)	-	(5)	-	(3)
TURB	4	(98)	-	(1)	-	(1)	-	(0)

[NB: () = % of QC samples for 1995 to 2014 period; * Winkler method to 2012]

This summary for the 2013-2014 period indicated:

- results from pairs of all three bacteriological species' samples were relatively precise with three sets of results falling just outside the acceptable variability (20%) and one set outside the 50% difference. This follows the historical trend for paired bacteriological analyses which have found at least 44% of the period's quality control samples within the 10% difference of the mean (for all three species), but 73% of samples within 20% of the mean for paired samples in all species.
- TKN analytical variability greater than 10% was recorded on two occasions, due to reliance on calculations from another nitrogen species which, however, was within acceptable precision tolerance. TKN duplicates have traditionally shown this variability with only 47% and 70% to date within 10% and 20% of the mean respectively.
- BOD$_5$ analytical variability of 10 to 13% was recorded on two occasions at very low concentrations and the difference of < 0.3 g/m^3 was considered acceptable.
- variability in split samples agreement for filtered absorbances at 340 nm, 440 nm, and 770 nm which had occurred occasionally, but almost entirely within equipment performance tolerance values, was occasionally recorded at 770 nm over the 2013-2014 period.

In general, laboratory analytical performance has been acceptable, with very good precision of results shown for a majority of parameters following the continuation of split-sampling field methodology to remove any sampling bias in the quality control programme. Some exceptions in analytical precision have been identified and these are being addressed by the laboratory. Additional inter-laboratory analyses are recommended as part of this process. No results from this exercise were statistical outliers in the context of the nineteen year historical database for all sites in the programme. The dissolved oxygen measurement was undertaken by field meter during the year and therefore has been removed from the intralab programme.

Appendix IV

SEM Physicochemical Programme
Inter-lab Quality Control Report 2013-2014

Introduction

A network of nine freshwater sites was developed in mid-1995 for physiochemical monitoring on a long-term basis to provide information on trends in the state of surface water quality in the Taranaki region. One further site was added to this network in the 1998-99 period and another in the 2003-2004 period (see Introduction). Sampling is carried out on the second Wednesday of each month for the entire year. The programme also meshes with a similar national programme operated by the National Institute of Water and Atmospheric Research (NIWA) since 1989, which includes three sites in Taranaki and is performed on the third Tuesday of each month throughout the year although part way through the 2013-2014 period NIWA adjusted the Waingongoro River site sampling to coincide with the timing of the TRC sampling protocol.

As a quality control measure for this programme, and as part of general quality assurance practices at the Council, a sample is collected randomly from one of the eleven monitoring sites every three to four months and split for duplicate analyses (see Appendix III). The additional sample is analysed in exactly the same way and at exactly the same time as other samples, and recorded on the Council's database. In conjunction with the sampling undertaken by NIWA, the Council also shares a duplicate sub-sample from time to time as a quality control procedure to assess accuracy of laboratory analytical performance. Normally a single sample is collected from one of the three sites and then split for sub-samples' analyses by each of the laboratories. Samples were collected from one of the three sites, on one occasion in the 2013-2014 year.

Quality assurance is an essential aspect of any laboratory and monitoring programme. Quality control is an essential tool in this assurance, and is carried out by the Council from time-to-time with NIWA monitoring.

This report presents the results from NIWA and TRC samples and compares the difference of each result from the mean of the two results. The difference is presented as a percentage of the mean, and levels of these differences are expressed as follows:

Difference from mean (%)	Symbol/Comment
<10%	✓
10-20%	*
21-50%	**
>50%	***

The acceptability of the precision of pairs of analyses varies from parameter to parameter and the symbols defined above are only a guideline. These differences may also be related to the precision of various methods, which can vary between laboratories.

There are various reasons why sample results may differ, including discrepancies in laboratory equipment and/or techniques and general sample variation. Sampling variation should be minimal as samples are normally collected and split into subsamples by both parties. The amount of variation in results can differ from one type of analysis to another, and this report identifies those techniques that are more prone to variation. Once these methods are identified, it is possible to determine whether differences in results are significant and if so, whether these are due to sample variability or laboratory discrepancies. Attempts to eliminate these problems can then be made wherever possible.

One quality control sampling run was performed with NIWA field staff during the 2013-2014 period on 14 May 2014. Sampling was performed during a steady recession flow (4.97 m^3/sec), eight days after a fresh flow (28 m^3/sec) in fine, overcast weather at the Waingongoro River site at SH45.

Results

2013-2014 exercise

Comparisons of the individual sample's analytical results for the Waingongoro River (at SH45) site are presented in Table 1. [Note: This interlab sample was taken separately (10 minutes later) from the regular sample collected for state of the environment purposes (see Table 24)].

Table 1 Results of SEM QC sampling by TRC & NIWA on 14 May 2014

WGG000900					
		Time:1230 (NZST)		**Difference from mean (%)**	**Comments**
Parameter	Units	TRC	NIWA		
A340F	/cm	0.016	0.021	14	*
A440F	/cm	0.005	0.004	11	*
BDISC	m	1.78	1.84	2	✓
CONDY	mS/m @ 20^{0}C	14.6	15.1	2	✓
DO	g/m^3	11.2	11.2	0	✓
DRP	g/m^3-P	0.038	0.029	13	*
ECOL	nos/100 ml	530	461	7	✓
NH4	g/m^3-N	0.018	0.018	0	✓
NO3	g/m^3-N	1.49	1.51	1	✓
pH	pH	7.8	7.9	< 1	✓
TEMP	°C	11.3	11.3	0	✓
TN	g/m^3-N	1.68	1.68	0	✓
TP	g/m^3-P	0.060	0.060	0	✓
TURB	NTU	2.2	4.8	37	**

[**Note:** N/A = not available; N/R = not reported]

Comments:

A significant difference in paired measurements between the two laboratories was recorded for turbidity, absorbance at 340 nm, and DRP of which turbidity paired samples analyses showed the most significant difference. Otherwise good analytical agreement was recorded for the other parameters.

Good operator field agreement was indicated by the similarity in the pairs of temperature, dissolved oxygen, and black disc measurements.

	Difference from mean of pairs of split samples							
Parameter ID	**<10%**		**10-20%**		**20-50%**		**>50%**	
A340F	-	(90)	1	(5)	-	(5)	-	(0)
A440F	-	(64)	1	(31)	-	(0)	-	(5)
CONDY	1	(92)	-	(4)	-	(0)	-	(4)
DO	1	(100)	-	(0)	-	(0)	-	(0)
DRP	-	(39)	1	(26)	-	(30)	-	(4)
ECOL	1	(13)	-	(50)	-	(37)	-	(0)
NH4	1	(33)	-	(21)	-	(21)	-	(25)
NO3	1	(88)	-	(8)	-	(4)	-	(0)
pH	1	(100)	-	(0)	-	(0)	-	(0)
TEMP	1	(100)	-	(0)	-	(0)	-	(0)
TN	1	(86)	-	(5)	-	(9)	-	(0)
TP	1	(59)	-	(27)	-	(14)	-	(0)
TURB	-	(38)	-	(42)	1	(21)	-	(0)

[NB: () - % of QC samples over the 1995 to 2014 period]

This summary indicates:

- generally good inter-laboratory analytical performance for most parameters while taking into account variations in laboratory methods and equipment performance tolerances.

- ammonia nitrogen and dissolved reactive phosphorus nutrient analyses and turbidity measurements have showed greatest variability between laboratories, while *E.coli* bacteriological counts have tended to vary more widely with lower counts more often recorded by the NIWA laboratory.

Acceptable inter-laboratory agreement has been apparent for most of the parameters analysed. An exception has been identified for DRP and further comparisons will be performed during future SEM programmes. Good field agreement was recorded for water temperature, dissolved oxygen and black disc measurements as normally recorded in the past.

Discussions with NIWA, Hamilton staff have determined that annual inter-laboratory comparisons will continue to be performed on <u>one</u> sample collected at one of the three NIWA sites (by TRC personnel) and <u>split on site for analysis</u> by each of the two laboratories, alongside the sample collected in the routine manner by NIWA field party staff.