Freshwater Physicochemical Programme
State of the Environment Monitoring
Annual Report
2016-2017

Technical Report 2017-64

Taranaki Regional Council

ISSN: 1178-1467 (Online)

Private Bag 713

Document: 2128817 (Word)

STRATFORD

Document: 2132991 (Pdf)

October 2018

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. As set out in the Regional Policy Statement for Taranaki (2010), the quality of the region's fresh water resources is of primary importance for the region's communities, including iwi, economic sectors, and social and cultural sectors. To inform the community of the state of, pressures upon, and trends in water quality in the region, a number of monitoring programmes have been put in place. 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 were used as the basis for the first five-year SEM report published in 2003, 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, and the nineteen year period 1995-2014 as presented in the fourth SEM report (TRC, 2015a)

In the year under review, surveys continued to be performed regularly in the second week of every month from July 2016 to June 2017, under a narrower range of flow conditions than typical, ranging through some moderate freshes to low mid-summer flows. This year was characterised by much higher median flows sampled by the programme in almost all rivers and streams. Each sampling run measured up to 22 physical and chemical water quality parameters at thirteen sites representing eight selected ring plain catchments and three eastern hill-country catchments. Two of the sites were established the year before, to increase representation of the eastern hill-country, in anticipation of the government's requirement that the Council must establish Freshwater Management Units and have representative monitoring across the entire region.

The twelve months of water quality data are presented for each of the Council's thirteen 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 two 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, Whenuakura and Waitara Rivers sites in these rivers' lower reaches.

Over the 2016-2017 monitoring year, flows at times of sampling were much higher than usual, with no flood or very low flows sampled. In general terms, for the eleven sites monitored for more than 10 years, water quality was comparatively poorer in clarity though similar in suspended solids concentrations, and poorer in bacteria numbers and nutrient levels, to past quality. Narrower temperature ranges, mainly due to lower maximum temperatures, and higher median water temperatures, were measured in the 2016-2017 period compared with ranges and medians measured during the first 21 years of the SEM programme. The 2016-2017 median dissolved reactive and/or total phosphorus levels were higher at six sites and lower at two sites. Median nitrate and/or total nitrogen species' levels were higher at seven sites, while median ammonia nitrogen levels were lower at three sites and higher at three 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 1995-2017 period.

For the third time, results are also compared with the compulsory national water quality criteria set out in the National Objectives Framework (NOF) that is part of the National Policy Statement for Freshwater Management 2014 (NPS-FW). The NOF assigns grades ('attribute states') for indicators ('attributes'), from A (best) to D (worst), with a National Bottom Line of acceptability being a C state. During the 2017-2018 year, the Ministry for the Environment amended the NOF grading system so that the 4 grades, with the bottom grade being unacceptable, were removed from the NOF in respect of *E coli*. Instead, there is now a matrix of categorisation, with 4 separate criteria to each be considered and the overall grading being the worst of the four. There are now five grades, and no bottom line, for *E coli*. Councils are to identify by the end of 2018 what their target is for water quality as defined by *E coli*. The Government has stated that as a whole, 80% of the country's waterways should be within the top 3 categories by 2030, and 90% by 2040. It should be noted that these percentages do not necessarily apply at the regional level. For the purpose of comparisons, this report uses the five-step categories, with rivers in either of the bottom two categories being deemed unacceptable for recreational purposes.

The Resource Management Act (RMA) requires that particular regard be given to the *'maintenance and enhancement of the quality of the environment'*. Therefore a key determinant for the Council is to identify where trends in water quality show no change ('*maintenance*') and/or improvement ('*enhancement*'), in either case aligning with the objective of the RMA, or alternatively show decline. 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 2017 are summarised and presented for all thirteen Council sites briefly in the current Annual Report. In addition, this report presents trend analysis for the two NIWA sites in Taranaki.

Also, for the third time, trends over the most recent period (the last seven years) have been incorporated into this report. Previously, they were calculated and presented separately; for the sake of convenience and completeness of reference they have now been included herein. These data help identify and evaluate the current state of flux in water quality, rather than those trends that are more historical in nature.

Long term (22-year) physicochemical trends have shown some significant deterioration in some aspects of water quality (particularly phosphorus) 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). On the other hand, there has been a significant long term improvement in total nitrogen at three of the eleven sites monitored, with only one site that is showing deterioration in this measure. Long term trends for faecal coliforms and enterococci bacteria showed statistically significant changes over the 22-year period for one or other species at four sites, out of eleven, with improvement at one site (Punehu Stream at Wiremu Road) and deterioration at three sites (Waiwhakaiho River at SH3, Mangaoraka Stream at Corbett Road and Punehu Stream at SH45). Significant deteriorations in black disc clarity were recorded at two sites, one 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 and total phosphorus, and with reduction in nitrate and total nitrogen by slightly less than the rate defined as significant. 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 five parameters have significantly deteriorated (both phosphorus species, both bacteriological species and black disc) and in the mid-reaches of the Waiwhakaiho River, where four parameters have deteriorated significantly (dissolved phosphorus, nitrate, ammonia and faecal coliforms), and no parameters show significant long term improvement. More recent data for these sites indicate the deterioration has reduced.

Analysis of recent trends indicates a better direction in water quality, although the latest seven-year trends do not show the same wide-spread improvements that had been evident in recent years. The latest rolling seven-year trend is more positive than the long-term trend, with fewer sites and measures showing significant deterioration, particularly in nutrient concentrations. Other measures (bacteria, organics, aesthetics) show no regional pattern of change in either direction.

This report on the results of the 2016-2017 monitoring period also includes recommendations for the 2017-2018 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.

Recommendations provide for the continuation of this programme.

Table of contents

List of tables

List of figures

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 comprises a number of individual monitoring activities, many of which are undertaken and managed on an annual basis (from 1 July to 30 June). For some of 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 2014 period) has been published (TRC, 2015a). The provision of appropriate computer software statistical procedures 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 2016-2017 monitoring year, the twenty-second 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, another site in the 2003-2004 period, and two more sites in the 2015-2016 period. The latter change was brought about because of the direction within the Government's '*National Policy Statement for Freshwater Management 2014*', that all freshwater within each region must be included within a 'Freshwater Management Unit' (FMU), for each of which the regional council is obliged to set objectives and limits (bottom lines for quality measures that are related to community values for that water body), and to undertake representative monitoring that demonstrates progress towards the objectives for that FMU. The NPS objectives and limits are to be set by 31 December 2025, or if particular circumstances apply, by 31 December 2030. The Taranaki Regional Council is seeking to establish objectives and limits as appropriate for the Taranaki region through the current review of the Regional Fresh Water Plan for Taranaki.

The Taranaki Regional Council's SEM programme also includes a freshwater biological component encompassing the same thirteen sites plus forty-six additional sites, which is reported separately (see TRC, 2017a).

The physicochemical programme has been designed to provide a general picture of water quality for nine 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 nine of the sixty-nine catchments in the Taranaki region and 44% 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.

Notwithstanding the wide coverage of the region through the existing representative sites, in 2015-2016 the Council undertook an extended survey programme that involved regular sampling across a large number of additional catchments, to confirm (or otherwise) the degree of representation afforded by the current programme. An analysis of the alignment between the additional surveys and the ongoing programme is set out in this report.

The existing programme also meshes with a national programme, which has been operated by the National Institute of Water and Atmospheric Research (NIWA) since January 1989. This National Rivers Water Quality Network (NRWQN) 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). Until recently, the programme included 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 SH45). Data from these sites are presented within this report (sections 4.2.2 and 4.4) and previous reports.

However, it should be noted that as of January 2016 NIWA has withdrawn from water quality sampling and analysis at the Waingongoro River site on SH45, following a rationalisation of the monitoring network nation-wide. NIWA has noted that part of the rationale for ceasing monitoring at this site was that the Council data are seen by them as robust and reliable, and hence NIWA's work could be viewed as unnecessary duplication from the perspective of national water quality reporting. From this Council's perspective, it meant the loss of a quality control measure, although a large number of other QA/QC measures remain in place.

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, make 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 (Figure 1).

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
Whenuakura River	at Nicholson Road	WNR000450
Waitara River	at Autawa Road	WTR000540

All sites are described in detail and referenced with location maps, photographs, GPS and map references on the internal electronic TRC site reference system (ESAM) which is integrated into the existing LAB 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 intensive 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.

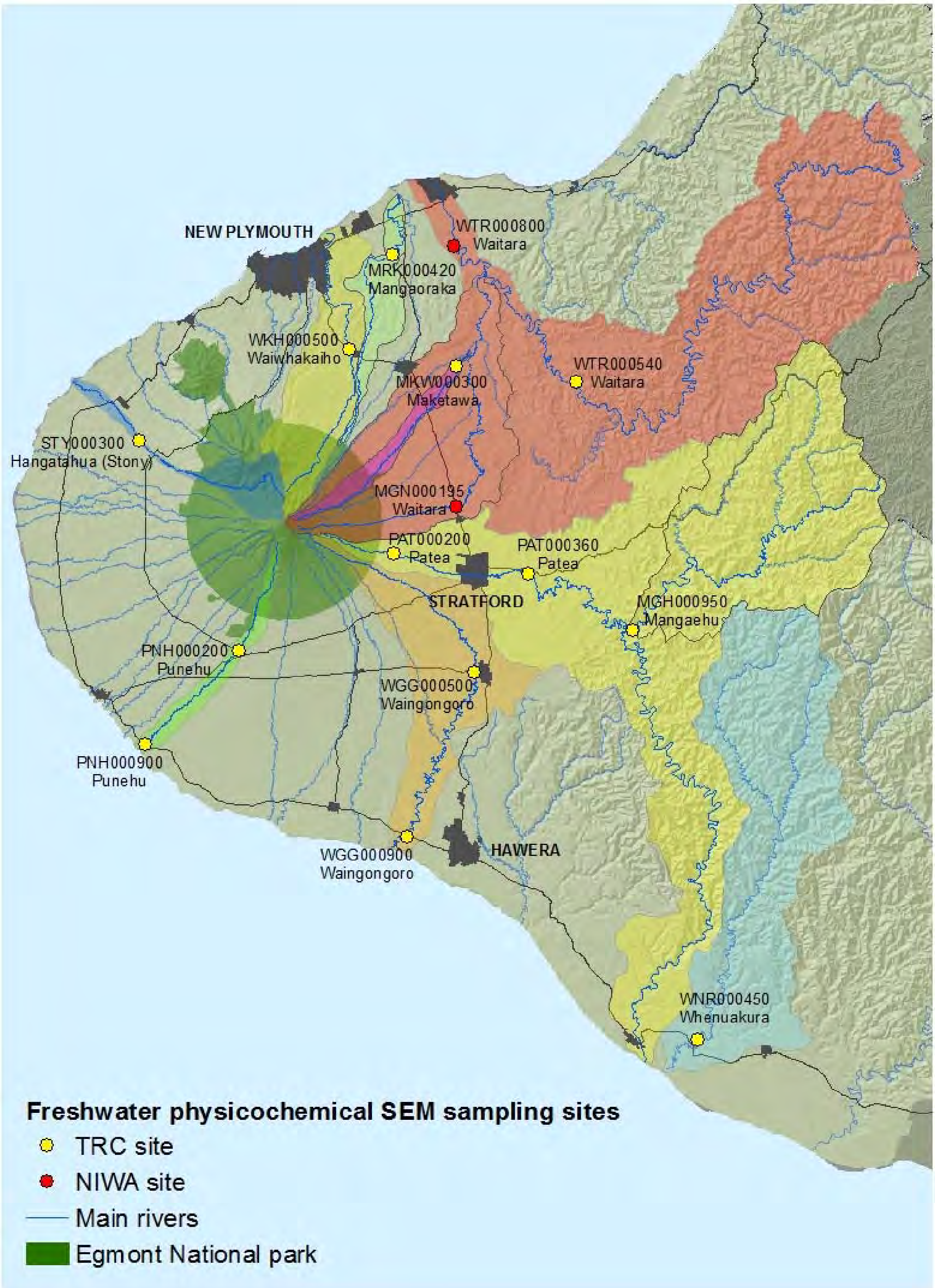


Figure 1 Freshwater physicochemical SEM sampling sites

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, 2016 and 2017.

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 for a national representative basin from 1970 until 2011, when the station was closed. 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 after hydro station closure by NIWA.

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 have occurred 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 June 2010.

This site was part of the NIWA (NZ rivers) survey network from January 1989 to December 2015, and has been monitored by the Council since July 1998.

Sites Patea River catchment: Patea River at Barclay Road and at 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 gas-fired 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.

Sites Waitara River at Autawa Road (1) and at Bertrand Road (2, NIWA)

The Autawa Road site, in the mid reaches of the eastern hill country part of the Waitara catchment, is representative of a combination of upland agricultural development and native forest. It is 6.1 km above the hydrological recording station that was established in 1970 at Tarata for a national representative basin, with the discharge from the Motukawa power station in between, and has been monitored by the Council for physicochemical water quality since July 2015.

The Bertrand Road 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 are utilised for this site.

Site Manganui River at SH3

This site was a Taranaki ring plain survey site and is currently one of the two Taranaki sites in the NIWA (NZ rivers) survey network in conjunction with the hydrological recording station that was established for a national representative basin in 1971. 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 are utilised for this site.

Site Whenuakura River at Nicholson Road

This site is in the lower reaches of an eastern hill county catchment in the southern part of the region that has largely been developed for agriculture, with some production forestry and native forest. It is an established hydrological recording station 10.7 km from the coast in the upper section of tidal river, above the saline influence, and has been monitored by the Council for physicochemical water quality since July 2015.

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 (mTEC)	cfu/100 mL	Laboratory
Enterococci bacteria	cfu/100 mL	Laboratory

The instrument used for turbidity measurement was changed in January 2016, from a Hach 2100A to a WTW Cyberscan turbidimeter. All the water samples collected monthly since June 2006, a period of almost ten years, had been tested with both instruments, providing data for comparative analysis on performance of the two meters, and for turbidity trend analysis using the replacement meter.

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 three months). These samples were unidentified for laboratory processing 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 2016 to June 2017 are presented for each of the thirteen sites. Statistical summaries of these data and the cumulative data for nine sites (July 1995 to June 2017), one site in the lower Waingongoro River (July 1998 to June 2017), one site in the lower Maketawa Stream (July 2003 to June 2017), and one site each in the lower Whenuakura River and mid Waitara River (July 2015 to June 2017) 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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100mL	cfu/100 mL
13 Jul 2016	0825	0.012	0.002	0.000	30	1.44	0.6	9.0	12.1	101	0.030	210	28
10 Aug 2016	0820	0.011	0.002	0.000	27	2.12	<0.5	8.8	12.1	100	0.018	80	20
14 Sep 2016	0800	0.015	0.003	0.000	27	2.63	<0.5	9.0	10.9	100	0.022	270	170
12 Oct 2016	0705	0.015	0.004	0.000	27	1.89	<0.5	8.6	10.2	98	0.025	830	96
09 Nov 2016	0720	0.032	0.007	0.000	22	1.94	<0.5	7.0	10.7	101	0.024	850	900
14 Dec 2016	0700	0.018	0.004	0.000	30	1.38	<0.5	9.1	10.4	100	0.025	430	170
11 Jan 2017	0700	0.019	0.005	0.000	34	3.50	<0.5	9.5	9.7	101	0.033	300	160
08 Feb 2017	0700	0.016	0.004	0.000	32	4.38	<0.5	9.3	9.7	100	0.030	1000	410
08 Mar 2017	0710	0.021	0.005	0.000	34	1.30	1.1	9.4	10.1	98	0.049	4900	12000
13 Apr 2017	0800	0.038	0.009	0.000	27	1.10	0.7	8.7	9.8	100	0.041	6700	4000
10 May 2017	0800	0.014	0.003	0.000	32	3.62	<0.5	9.4	10.6	99	0.030	240	200
14 Jun 2017	0805	0.037	0.008	0.000	25	0.83	0.8	7.6	11.3	100	0.036	1800	1600

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
13 Jul 2016	0825	210	1.608	0.008	0.001	0.40	7.6	2	7.0	0.01	0.41	0.035	1.0
10 Aug 2016	0820	80	2.486	0.008	0.002	0.72	7.6	<2	6.8	0.03	0.75	0.025	0.9
14 Sep 2016	0800	270	2.366	0.015	0.003	0.48	7.6	2	11.1	0.12	0.60	0.031	1.7
12 Oct 2016	0705	830	3.025	0.018	0.003	0.64	7.7	<2	12.6	0.09	0.73	0.036	1.3
09 Nov 2016	0720	860	2.378	0.010	0.002	0.40	7.6	2	12.0	0.12	0.52	0.038	0.8
14 Dec 2016	0700	430	2.293	0.014	0.002	0.36	7.7	<2	12.8	<0.01	0.37	0.033	0.7
11 Jan 2017	0700	300	1.657	0.013	0.003	0.30	7.8	<2	16.6	0.06	0.36	0.046	0.8
08 Feb 2017	0700	1000	2.141	0.007	0.002	0.48	7.8	<2	16.5	0.06	0.54	0.035	0.9
08 Mar 2017	0710	5000	1.594	0.023	0.003	0.22	7.8	2	13.1	0.12	0.34	0.062	1.8
13 Apr 2017	0800	6700	2.911	0.078	0.012	0.65	7.5	3	15.3	0.36	1.02	0.070	2.5
10 May 2017	0800	250	1.677	0.009	0.002	0.45	7.6	<2	12.3	0.02	0.47	0.042	0.9
14 Jun 2017	0805	1900	2.078	0.026	0.004	0.40	7.6	3	9.3	0.21	0.60	0.068	3.9

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

Table 4 Statistical summary of data from July 2016 to June 2017: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.011	0.038	0.017	12	0.010
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.009	0.004	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.000	0.000	12	0.000
ALKT	Alkalinity total	g/m^3 $CaCO_3$	22	34	28	12	4
BLACK DISC	Black disc transparency	m	0.83	4.38	1.92	12	1.13
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	1.1	<0.5	12	0.2
CONDY	Conductivity @ 20°C	mS/m	7.0	9.5	9	12	0.8
DO	Dissolved oxygen	g/m^3	9.7	12.1	10.5	12	0.8
PERSAT	Dissolved oxygen saturation	%	98	101	100	12	1
DRP	Dissolved reactive phosphorus	g/m^3P	0.018	0.049	0.030	12	0.009
ECOL	E. coli bacteria	cfu/100 mL	80	6700	630	12	2114
ENT	Enterococci bacteria	cfu/100 mL	20	12000	185	12	3453
FC	Faecal coliform bacteria	cfu/100 mL	80	6700	630	12	2130
FLOW	Flow	m^3/s	1.594	3.025	2.217	12	0.49
NH_4	Ammoniacal nitrogen	g/m^3N	0.007	0.078	0.014	12	0.020
NO_2	Nitrite nitrogen	g/m^3N	0.001	0.012	0.002	12	0.003
NO_3	Nitrate nitrogen	g/m^3N	0.217	0.718	0.424	12	0.149
pH	pH		7.5	7.8	7.6	12	0.1
SS	Suspended solids	g/m^3	<2	3	2	12	0
TEMP	Temperature	°C	6.8	16.6	12.4	12	3.2
TKN	Total kjeldahl nitrogen	g/m^3N	<0.01	0.36	0.08	12	0.1
TN	Total nitrogen	g/m^3N	0.34	1.02	0.53	12	0.2
TP	Total phosphorus	g/m^3P	0.025	0.070	0.037	12	0.015
TURBY	Turbidity	NTU	0.7	3.9	0.9	12	0.95

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

Table 5 Statistical summary of data from July 2003 to June 2017: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.002	0.141	0.017	168	0.022
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.031	0.004	168	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	168	0.000
ALKT	Alkalinity total	g/m^3 $CaCO_3$	7	34	28	168	6
BLACK DISC	Black disc transparency	m	0.21	5.23	2.55	168	1.13
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	2.3	<0.5	168	0.3
CONDY	Conductivity @ 20°C	mS/m	3.2	12.6	8.6	168	1.2
DO	Dissolved oxygen	g/m^3	9.0	12.5	10.5	168	0.8
PERSAT	Dissolved oxygen saturation	%	90	103	98	168	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.055	0.024	168	0.008
ECOL	E. coli bacteria	cfu/100 mL	50	26000	325	168	2570
ENT	Enterococci bacteria	cfu/100 mL	6	12000	175	168	1585
FC	Faecal coliform bacteria	cfu/100 mL	50	26000	330	168	2580
FLOW	Flow	m^3/s	0.838	17.2	1.982	168	2.413
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.093	0.010	168	0.016
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.012	0.002	168	0.002
NO_3	Nitrate nitrogen	g/m^3N	0.008	0.918	0.266	168	0.209
pH	pH		6.8	7.9	7.6	168	0.2
SS	Suspended solids	g/m^3	<2	55	<2	168	7
TEMP	Temperature	°C	4.8	18.0	11.6	168	3.0
TKN	Total kjeldahl nitrogen	g/m^3N	-0.01	0.52	0.07	168	0.10
TN	Total nitrogen	g/m^3N	<0.05	1.02	0.40	168	0.23
TP	Total phosphorus	g/m^3P	0.018	0.180	0.035	168	0.024
TURB	Turbidity (Hach 2100A)	NTU	0.5	14	0.9	150	1.8
TURBY	Turbidity (Cyberscan WTW)	NTU	0.4	30	1.2	145	4.0

Discussion

2016-2017 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.92 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 4.38 m) was recorded in mid-summer under near median flow conditions (2.14 m^3/s). No floods, but some small freshes, and no low flows were sampled during the year, with moderate elevations in turbidity (1.8 to 3.9 NTU) and in suspended solids concentrations (3 g/m^3) under fresh flow conditions (1.59 to 2.91 m^3/sec) sampled in autumn and winter 2017. Slightly poorer water quality conditions apparent at the time these minor fresh flows were recorded with increases in bacterial number (6,700 faecal coliforms/100 mL), BOD_5 (1.1 g/m^3), and some nutrients (e.g. TN [1.02 g/m^3] and TP [0.07 g/m^3]) recorded, and black disc visibility decrease to 0.83 m.

pH was unusually stable (7.5 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 0825 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: < 0.5 g/m^3). Bacteriological quality was typical of the lower reaches of developed ring plain catchments subject to agricultural impacts, with median faecal coliform and enterococci numbers of 630 and 185 (per 100 mL) respectively. Water temperature varied over a moderate range of 9.8 °C with a maximum late summer (early morning) river temperature of 16.6 °C recorded in January 2017.

Brief comparison with the previous 2003-2016 (thirteen year) period

The flow range sampled at this site during 2016-2017 was the narrowest recorded, for the second successive year, while the median sampled flow was higher than that for the previous thirteen-year period (by 325 L/s). Generally, stream water quality was slightly poorer in appearance/clarity (lower median black disc clarity [by 0.68 m] and median suspended solids level, though median turbidity was lower [by 0.3 NTU]). Bacterial water quality was poorer, with a significantly higher median faecal coliform number by 300 cfu/100 mL and a slightly higher median enterococci number by 10 cfu/100 mL. Median water temperature was higher [by 0.9°C] while the maximum water temperature was lower [by 1.4°C] than the maximum previously recorded. Other physicochemical aspects of water quality were very similar for the two periods. Relatively narrow ranges for parameters such as suspended solids, conductivity, turbidity, pH and total phosphorus reflected the lack of flood events sampled. Median pH values were identical, and the maximum pH value was 0.1 unit lower than that of the past thirteen-year record. For nutrients, nitrogen species all had higher median values (nitrate by 70%), and total and dissolved phosphorus were higher (by 9 and 25%, respectively) during the monitoring year in comparison with the medians of the previous thirteen 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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100 mL	cfu/100mL
13 Jul 2016	0900	0.021	0.004	0.000	44	1.88	<0.5	15.6	11.6	100	0.010	240	92
10 Aug 2016	0850	0.019	0.003	0.000	32	1.54	<0.5	13.4	11.5	99	0.009	210	1000
14 Sep 2016	0825	0.029	0.006	0.001	34	1.23	1.3	13.9	10.4	98	0.019	3400	20000
12 Oct 2016	0735	0.021	0.004	0.001	34	1.62	0.6	13.3	9.9	98	0.013	700	200
09 Nov 2016	0810	0.031	0.008	0.000	37	1.27	0.6	13.1	10.4	101	0.018	780	220
14 Dec 2016	0730	0.025	0.005	0.000	40	0.81	0.7	14.3	10.0	99	0.012	2700	2900
11 Jan 2017	0730	0.027	0.006	0.000	47	3.04	0.5	15.4	9.4	97	0.009	870	310
08 Feb 2017	0730	0.038	0.008	0.001	37	1.20	0.5	13.5	9.7	100	0.011	1700	2800
08 Mar 2017	0740	0.028	0.006	0.000	59	1.71	1.8	18.1	9.8	96	0.007	3500	10000
13 Apr 2017	0830	0.033	0.007	0.000	40	1.51	0.5	14.6	9.5	99	0.014	3100	2800
10 May 2017	0840	0.021	0.004	0.000	43	2.02	<0.5	15.3	10.4	99	0.009	800	420
14 Jun 2017	0835	0.036	0.009	0.000	42	0.35	1.8	15.4	10.7	98	0.051	11000	18000

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
13 Jul 2016	0900	240	1.038	0.017	0.003	1.07	7.6	<2	8.9	0.17	1.24	0.017	1.6
10 Aug 2016	0850	210	2.701	0.024	0.004	1.57	7.4	3	8.8	0.11	1.68	0.024	2.2
14 Sep 2016	0825	3500	2.918	0.087	0.009	1.13	7.5	5	12.7	0.54	1.68	0.057	4.0
12 Oct 2016	0735	700	2.367	0.030	0.007	1.30	7.6	4	14.2	0.13	1.44	0.027	1.6
09 Nov 2016	0810	780	1.371	0.014	0.003	0.94	7.7	<2	13.9	0.14	1.08	0.035	1.1
14 Dec 2016	0730	2800	1.579	0.010	0.003	0.90	7.6	3	16.4	<0.10	1.00	0.031	1.9
11 Jan 2017	0730	1100	1.146	0.023	0.002	0.80	7.7	2	16.8	0.08	0.88	0.022	1.2
08 Feb 2017	0730	1800	2.666	0.019	0.003	0.90	7.6	4	16.6	0.32	1.22	0.027	4.1
08 Mar 2017	0740	3500	0.742	<0.003	0.003	0.60	7.8	2	14.1	0.09	0.69	0.020	2.4
13 Apr 2017	0830	3100	1.900	0.048	0.004	1.07	7.5	<2	16.6	0.19	1.26	0.029	2.4
10 May 2017	0840	800	1.342	0.021	0.003	1.01	7.6	<2	13.4	0.15	1.16	0.020	1.5
14 Jun 2017	0835	11000	1.379	0.105	0.016	1.25	7.6	14	11.2	0.79	2.06	0.141	12.

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

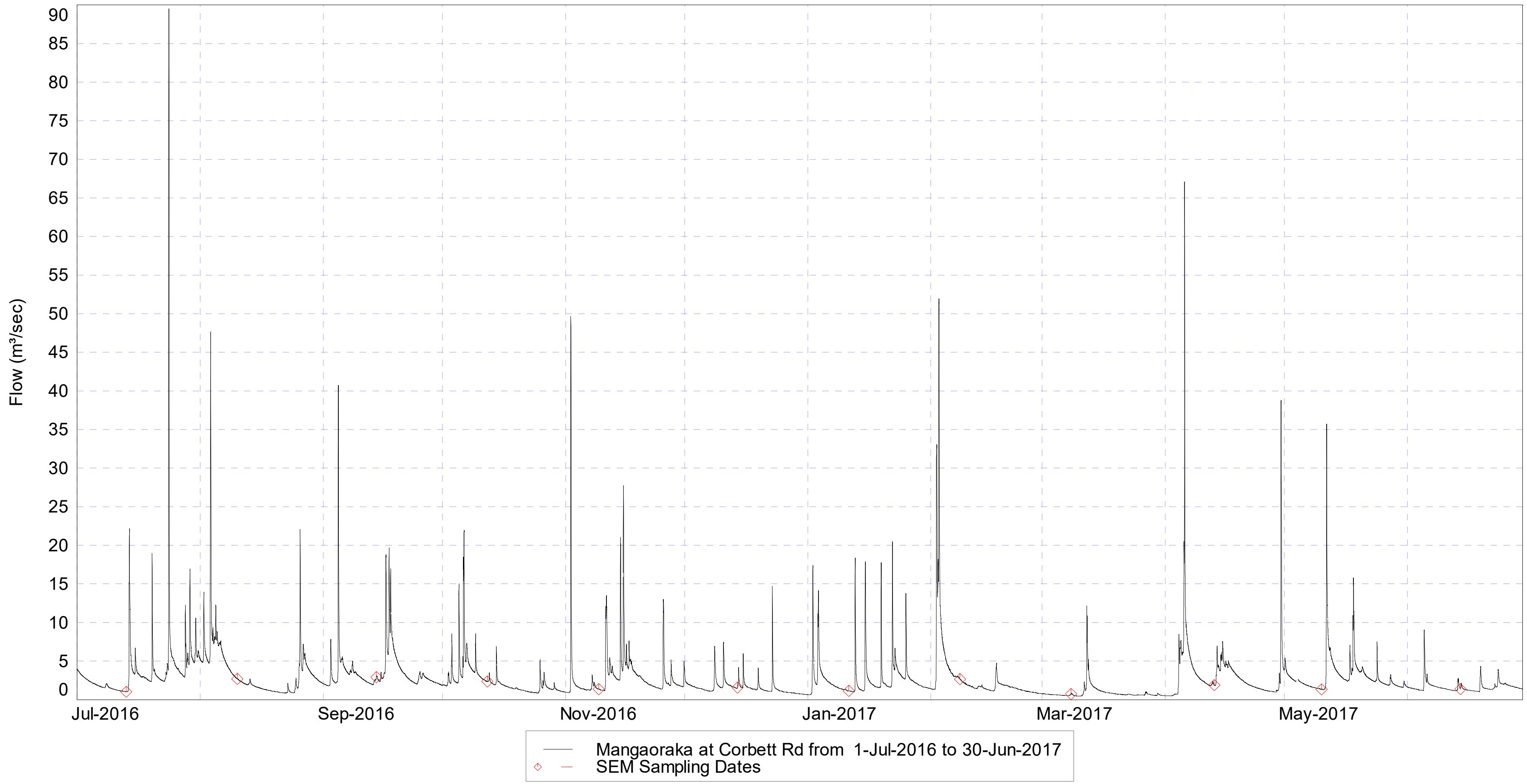


Figure 2 Flow record for the Mangaoraka Stream at Corbett Road

Table 7 Statistical summary of data from July 2016 to June 2017: Mangaoraka Stream at Corbett Road

Parameter		Units	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.019	0.038	0.028	12	0.006
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.009	0.006	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m^3 $CaCO^3$	32	59	40	12	7
BLACKDISC	Black disc transparency	m	0.35	3.04	1.52	12	0.66
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	1.8	0.6	12	0.5
CONDY	Conductivity @ 20°C	mS/m@20C	13.1	18.1	14.4	12	1.4
DO	Dissolved oxygen	g/m^3	9.4	11.6	10.2	12	0.7
PERSAT	Dissolved oxygen saturation	%	96	101	99	12	1
DRP	Dissolved reactive phosphorus	g/m^3 P	0.007	0.051	0.012	12	0.012
ECOL	E. coli bacteria	cfu/100mL	210	11000	1285	12	2971
ENT	Enterococci bacteria	cfu/100mL	92	20000	1900	12	7147
FC	Faecal coliform bacteria	cfu/100mL	210	11000	1450	12	2963
FLOW	Flow	m^3/s	0.742	2.918	1.479	12	0.731
NH_4	Ammoniacal nitrogen	g/m^3 N	<0.003	0.105	0.022	12	0.031
NO_2	Nitrite nitrogen	g/m^3 N	0.002	0.016	0.003	12	0.004
NO_3	Nitrate nitrogen	g/m^3 N	0.597	1.566	1.036	12	0.254
PH	pH	pH	7.4	7.8	7.6	12	0.1
SS	Suspended solids	g/m^3	<2	14	<2	12	3
TEMP	Temperature	˚C	8.8	16.8	14.0	12	2.8
TKN	Total kjeldahl nitrogen	g/m^3 N	0.08	0.79	0.14	12	0.22
TN	Total nitrogen	g/m^3 N	0.69	2.06	1.23	12	0.38
TP	Total phosphorus	g/m^3 P	0.017	0.141	0.027	12	0.034
TURBY	Turbidity	NTU	1.1	12	2.0	12	3

A statistical summary of the 22 years' data collected since 1 July 1995 is presented in Table 8.

Table 8 Statistical summary of data from July 1995 to June 2017: Mangaoraka Stream at Corbett Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.014	0.074	0.025	264	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.019	0.006	264	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0	264	0.001
ALKT	Alkalinity total	g/m^3 $CaCO_3$	14	108	40	264	18
BLACK DISC	Black disc transparency	m	0.055	4.73	1.80	264	0.88
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	14	0.6	264	1.4
CONDY	Conductivity @ 20°C	mS/m	5.6	28.7	14.5	264	3.8
DO	Dissolved oxygen	g/m^3	7.8	11.8	10.1	263	0.8
PERSAT	Dissolved oxygen saturation	%	83	107	97	263	4
DRP	Dissolved reactive phosphorus	g/m^3P	<0.003	0.074	0.009	264	0.009
ECOL	E. coli bacteria	cfu/100 mL	80	60000	800	240	6834
ENT	Enterococci bacteria	cfu/100 mL	31	180000	390	264	13239
FC	Faecal coliform bacteria	cfu/100 mL	84	60000	800	264	7471
FLOW	Flow	m^3/s	0.16	34.1	1.186	264	2.924
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.308	0.021	264	0.047
NO_2	Nitrite nitrogen	g/m^3N	0.001	0.039	0.005	264	0.005
NO_3	Nitrate nitrogen	g/m^3N	0.05	1.73	0.84	264	0.31
pH	pH		6.9	8.1	7.6	264	0.2
SS	Suspended solids	g/m^3	<2	310	2	264	26
TEMP	Temperature	°C	5.8	20.5	13.2	264	2.9
TKN	Total kjeldahl nitrogen	g/m^3N	<0.01	4.46	0.195	264	0.43
TN	Total nitrogen	g/m^3N	0.27	5.18	1.10	264	0.52
TP	Total phosphorus	g/m^3P	0.007	0.860	0.023	264	0.089
TURB	Turbidity (Hach 2100A)	NTU	0.8	100	1.6	245	8.6
TURBY	Turbidity (Cyberscan WTW)	NTU	0.6	59	2.1	145	6.9

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

2016-2017 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 (median: 1.5 NTU) than might be expected given the concentration of suspended solids (median: <2 g/m^3). This was due to the very fine, colloidal nature of suspended material in the stream at this site partly as a consequence of the headwaters being situated below the National Park. The maximum black disc value of 3.04 m coincided with mid-summer, moderate flow conditions, while the poorest turbidity conditions (12 NTU and 0.35 m black disc) were recorded during a small fresh in early winter 2017, with some increase in suspended sediment, BOD_5 and high faecal bacteria number. All nutrient species, both nitrogen and phosphorus, indicated poorest water quality during this minor fresh.

The relative absence of freshes near the sampling occasions throughout the year contributed to the slightly elevated pH values (up to 7.8), though these levels were similar to those recorded previously. 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 (< 1.9 g/m^3) were indicative of relatively good physicochemical water quality, but the very high median bacterial numbers (1,900 enterococci and 1,400 faecal coliforms cfu/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 8.0 °C with a maximum (mid-morning) temperature of 16.8 °C in January 2017 during a period of moderate flow conditions. Dissolved oxygen saturation did not fall below 96% during the period, with this minimum recorded during a period of low flow conditions (Figure 3).

Brief comparison with the previous 1995-2016 period

Aesthetic stream water quality at this site during the 2016-2017 period was similar [median black disc clarity lower by 0.31 m, median suspended solids level lower, and median turbidity slightly lower, by 0.1 NTU]. Bacterial water quality deteriorated as reflected in higher median faecal coliform number by 660 cfu/100 mL and median enterococci number by 1,525 cfu/100 mL. Median water temperature was 1.0 °C higher in the 2016-2017 period although the maximum water temperature (16.8 °C) was 3.7 °C lower than the previous maximum recorded. Median conductivity was similar. The median flow sampled during 2016-2017 (1.479 m^3/sec) was significantly higher (by 327 L/s) than the median of flows sampled over the previous 21-year period. Moderate ranges for parameters such as suspended solids, turbidity, pH, and BOD_5 reflected the few smaller freshes sampled on occasions during the 2016-2017 period (Figure 3), rather than high floods occasionally sampled in the past. Median pH value was the same and maximum pH was 0.3 unit lower than the past record. All nitrogen and phosphorus nutrient species had similar or higher median values during the monitoring year in comparison with the previous 21-year record.

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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100mL	cfu/100mL
13 Jul 2016	0935	0.009	0.002	0.000	59	3.70	<0.5	14.7	12.1	102	0.036	48	7
10 Aug 2016	0915	0.008	0.002	0.000	46	4.22	<0.5	12.4	12.5	102	0.022	48	580
14 Sep 2016	0900	0.022	0.006	0.001	30	1.40	0.9	9.5	11.3	101	0.021	2900	1200
12 Oct 2016	0810	0.01	0.001	0.000	44	3.12	<0.5	11.6	10.6	102	0.028	210	60
09 Nov 2016	0840	0.016	0.005	0.001	36	1.85	0.7	9.8	11.1	105	0.020	1500	77
14 Dec 2016	0800	0.014	0.003	0.000	46	1.04	0.5	12.2	10.6	100	0.021	1400	290
11 Jan 2017	0805	0.012	0.003	0.000	56	4.64	<0.5	13.4	10.0	101	0.029	420	42
08 Feb 2017	0800	0.014	0.004	0.000	51	2.66	<0.5	12.9	10.3	105	0.031	550	100
08 Mar 2017	0815	0.014	0.003	0.000	69	2.30	0.8	16.4	11.0	104	0.047	1200	2200
13 Apr 2017	0900	0.033	0.008	0.001	40	1.43	<0.5	10.5	10.1	102	0.032	550	290
10 May 2017	0910	0.01	0.003	0.000	57	3.85	<0.5	14.4	11.1	103	0.032	340	31
14 Jun 2017	0900	0.053	0.013	0.001	26	0.30	2.6	9.4	11.6	102	0.038	10000	3000

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
13 Jul 2016	0935	48	2.901	0.005	<0.001	0.15	8	<2	7.3	0.01	0.16	0.036	0.6
10 Aug 2016	0915	51	5.101	0.004	0.001	0.33	7.7	2	6.0	0.04	0.37	0.029	1.4
14 Sep 2016	0900	2900	10.492	0.038	0.004	0.21	7.8	3	10.1	0.23	0.44	0.039	2.2
12 Oct 2016	0810	210	5.806	0.006	0.002	0.24	8	<2	12.0	0.08	0.32	0.030	0.7
09 Nov 2016	0840	1500	6.478	0.014	0.001	0.13	8	2	11.7	0.09	0.22	0.031	1.0
14 Dec 2016	0800	1400	5.716	0.015	0.003	0.20	7.8	<2	12.0	<0.05	0.25	0.037	1.4
11 Jan 2017	0805	450	3.323	0.006	0.002	0.08	8.1	<2	14.9	0.01	0.09	0.035	0.4
08 Feb 2017	0800	550	3.979	0.004	0.002	0.22	8.1	<2	15.7	<0.01	0.23	0.033	0.5
08 Mar 2017	0815	1200	2.574	0.004	<0.001	0.02	8.2	3	12.0	0.09	0.11	0.058	0.7
13 Apr 2017	0900	560	5.582	0.005	0.003	0.18	7.8	<2	14.4	<0.12	0.30	0.043	0.9
10 May 2017	0910	340	2.961	0.005	0.002	0.15	8	<2	11.5	0.03	0.18	0.038	0.6
14 Jun 2017	0900	10000	16.886	0.101	0.005	0.25	7.6	19	8.8	0.75	1.00	0.153	12

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

Table 10 Statistical summary of data from July 2016 to June 2017

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.008	0.053	0.014	12	0.013
A440F	Absorbance @ 440nm Filtered	/cm	0.001	0.013	0.003	12	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	26	69	46	12	13
BDISC	Black disc transparency	m	0.30	4.64	2.48	12	1.38
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	2.6	<0.5	12	0.6
CONDY	Conductivity @ 20'C	mS/m	9.4	16.4	12.3	12	2.2
DO	Dissolved Oxygen	g/m^3	10.0	12.5	11.0	12	0.8
PERSAT	Dissolved Oxygen Saturation %	%	100	105	102	12	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.020	0.047	0.030	12	0.008
ECOL	E.coli bacteria	cfu/100 mL	48	10000	550	12	2770
ENT	Enterococci bacteria	cfu/100 mL	7	3000	195	12	983
FC	Faecal Coliforms	cfu/100 mL	48	10000	555	12	2768
FLOW	Flow	m^3/s	2.574	16.886	5.342	12	4.066
NH_4	Ammoniacal nitrogen	g/m^3N	0.004	0.101	0.006	12	0.028
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.005	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m^3N	0.02	0.33	0.19	12	0.08
PH	pH	pH	7.6	8.2	8.0	12	0.2
SS	Suspended solids	g/m^3	<2	19	<2	12	5
TEMP	Temperature	°C	6.0	15.7	11.8	12	2.9
TKN	Total Kjeldahl nitrogen	g/m^3N	<0.01	0.75	0.05	12	0.21
TN	Total nitrogen	g/m^3N	0.09	1.00	0.24	12	0.24
TP	Total phosphorus	g/m^3P	0.029	0.153	0.036	12	0.034
TURBY	Turbidity	NTU	0.4	12	0.8	12	3.2

A statistical summary of the 22 years' data collected since 1 July 1995 is presented in Table 11.

Table 11 Statistical summary of data from July 1995 to June 2017: Waiwhakaiho River at SH3

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.005	0.095	0.014	264	0.018
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.022	0.003	264	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.007	0.000	264	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	8	76	49	264	17
BDISC	Black disc transparency	m	0.13	8.05	3.06	264	1.42
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	5.0	<0.5	264	0.6
CONDY	Conductivity @ 20'C	mS/m	3.4	17.4	12.2	264	3.2
DO	Dissolved Oxygen	g/m^3	9.1	12.8	10.8	264	0.7
PERSAT	Dissolved Oxygen Saturation %	%	91	110	101	264	3
DRP	Dissolved reactive phosphorus	g/m^3P	<0.004	0.108	0.025	264	0.011
ECOL	E.coli bacteria	cfu/100 mL	23	56000	205	240	4435
ENT	Enterococci bacteria	cfu/100 mL	1	33000	100	264	2750
FC	Faecal Coliforms	cfu/100 mL	23	83000	215	264	6628
FLOW	Flow	m^3/s	1.705	83.44	3.780	264	9.71
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.148	0.008	264	0.021
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.010	0.002	264	0.001
NO_3	Nitrate nitrogen	g/m^3N	0.01	0.47	0.11	264	0.10
PH	pH	pH	6.8	8.5	7.9	264	0.3
SS	Suspended solids	g/m^3	<2	89	<2	264	10
TEMP	Temperature	°C	4.8	18.3	11.2	264	2.9
TKN	Total Kjeldahl nitrogen	g/m^3N	<0.01	1.95	0.07	264	0.21
TN	Total nitrogen	g/m^3N	<0.05	2.10	0.20	264	0.23
TP	Total phosphorus	g/m^3P	0.014	0.437	0.035	264	0.044
TURB	Turbidity (Hach 2100A)	NTU	0.4	26	0.7	245	2.8
TURBY	Turbidity (Cyberscan WTW)	NTU	0.3	35	0.7	145	3.7

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.

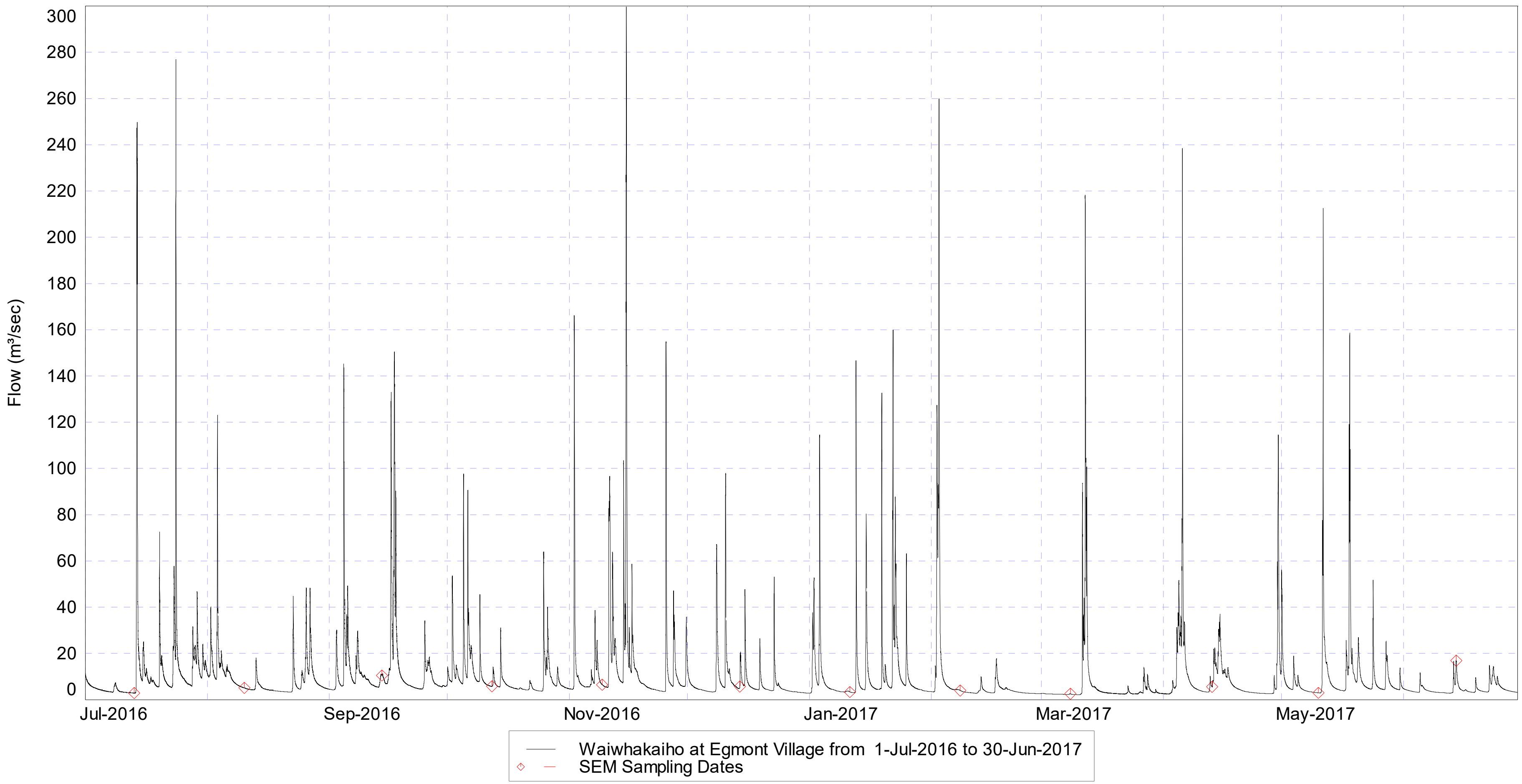


Figure 3 Flow record for the Waiwhakaiho River at SH3 Egmont Village

Discussion

2016-2017 period

During the 2016-2017 period there was no re-occurrence of the severe orange discolouration of the river which occurred in November 2013 when an iron-oxide laden seepage discharge from the Kokowai Stream entered the main river within the National Park. Discolouration had extended downstream beyond the mid reaches, but the river cleared within a few days of this event (TRC, 2014.) [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 2016-2017 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 2.48 m and 0.8 NTU respectively. The maximum black disc value (4.64 m) was recorded in mid-summer moderate flow conditions (3.23 m^3/sec) (Figure 4), with the worst conditions (black disc clarity of 0.30 m) during the peak of a fresh in June 2017 when the turbidity increased noticeably (12 NTU) with a change in suspended solids concentration (19 g/m^3). Generally, poorer water quality was recorded at the time of this fresh flow when elevated faecal coliform bacterial numbers (10,000 cfu/100 mL) and increased colour (absorbances @ 340 nm and 440 nm), together with decreased clarity and conductivity, were recorded.

A maximum pH value of 8.2 was recorded under moderate flow conditions in early autumn, with values of ≥7.8 units on ten occasions throughout 2016-2017. pH values could be expected to have risen further later in the day, as all sampling at this site was undertaken no later than 0935 hrs.

Very good water quality was indicated by high dissolved oxygen concentrations (median saturation of 102%) and low BOD_5 levels (median of < 0.5 g/m^3). Bacteriological quality was moderate, with median faecal coliform and enterococci numbers (555 and 195 per 100 mL, respectively) typically reflecting agricultural catchment influences in the relative frequency of small freshes during, or immediately prior to, sampling surveys during 2016-2017.

River water temperatures recorded a moderate range of 9.7 °C during the period with a maximum mid-morning water temperature of 15.7 °C recorded in February 2017 during a period of low flow conditions.

Brief comparison with the previous 1995-2016 period

River water quality measured by the 2016-2017 survey in many aspects was generally poorer than that recorded over the previous 21-year period. Median black disc clarity was lower (by 0.64 m) with median turbidity higher by 0.1 NTU, but median suspended solids levels were identical between periods. Bacteriological water quality deteriorated as reflected in increases in median faecal coliform number of 345 cfu/100 mL and in enterococci number by 98 cfu/100 mL. A moderate range of water temperatures (9.7 °C) was recorded in the most recent twelve-month period. Median water temperature was 0.7 °C higher in the most recent period while the maximum temperature was 2.6 °C lower than that recorded during the previous twenty-one years.

Median sampled flow over the 2016-2017 period was significantly higher (by 1,599 L/s, or 43%) than for the flows sampled in the previous 21-year period, with an absence of samplings near floods or during very low flows.

Median concentration for nitrate showed an increase in the recent sampling period, while other nitrogen species were similar. The recent median DRP concentration also showed an increase, while median total phosphorus concentration was similar to that of the longer 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 was higher by 2% 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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100mL	cfu/100mL
13 Jul 2016	1035	0.006	0.001	0.000	46	1.92	<0.5	11.5	11.6	101	0.025	1	<1
10 Aug 2016	1020	0.005	0.001	0.000	41	1.98	<0.5	10.5	12.3	101	0.018	11	1
14 Sep 2016	1000	0.019	0.006	0.001	16	0.38	<0.5	6.7	11.5	101	0.013	90	<1
12 Oct 2016	0915	0.003	0.001	0.000	37	4.22	<0.5	9.7	10.6	100	0.024	8	8
09 Nov 2016	0940	0.014	0.005	0.001	32	0.36	<0.5	8.3	10.6	102	0.052	11	4
14 Dec 2016	0905	0.014	0.003	0.000	35	0.60	0.6	9.2	10.7	101	0.019	18000	1900
11 Jan 2017	0905	0.009	0.002	0.000	38	4.65	<0.5	9.6	10.3	101	0.019	11	<1
08 Feb 2017	0900	0.027	0.013	0.004	36	0.18	<0.5	8.8	10.3	102	0.031	11	3
08 Mar 2017	0915	0.007	0.001	0.000	49	2.42	<0.5	11.4	10.6	102	0.025	4	8
13 Apr 2017	1010	0.026	0.006	0.000	25	0.12	<0.5	6.6	10.1	101	0.017	63	40
10 May 2017	1015	0.007	0.002	0.000	45	2.50	<0.5	11.0	11.0	101	0.022	8	3
14 Jun 2017	1000	0.026	0.006	0.001	21	0.14	<0.5	6.4	11.8	102	0.013	4	3

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
13 Jul 2016	1035	1	2.751	<0.003	<0.001	0.05	7.9	<2	8.8	0.01	0.06	0.026	0.8
10 Aug 2016	1020	11	3.465	<0.003	<0.001	0.08	7.8	4	6.5	<0.01	0.09	0.025	2.2
14 Sep 2016	1000	90	7.933	<0.003	<0.001	0.02	7.6	72	9.3	0.05	0.07	0.109	38
12 Oct 2016	0915	8	3.756	0.004	<0.001	0.05	7.9	<2	11.4	0.05	0.10	0.024	1.1
09 Nov 2016	0940	12	3.459	<0.003	<0.001	0.04	7.8	46	12.5	0.07	0.11	0.110	29
14 Dec 2016	0905	18000	13.536	0.021	0.001	0.05	7.8	13	11.7	0.09	0.14	0.053	6.0
11 Jan 2017	0905	11	3.652	0.017	<0.001	0.03	7.9	<2	13.5	0.02	0.05	0.022	0.7
08 Feb 2017	0900	11	5.052	<0.003	0.001	0.06	7.9	130	13.9	<0.01	0.06	0.175	66
08 Mar 2017	0915	4	3.136	<0.003	<0.001	<0.01	8.1	4	12.4	0.02	0.05	0.029	1.5
13 Apr 2017	1010	63	11.900	<0.003	<0.001	0.03	7.7	360	14.2	<0.15	0.18	0.352	86
10 May 2017	1015	8	3.030	<0.003	<0.001	0.07	8.0	2	11.0	<0.01	0.08	0.022	1.6
14 Jun 2017	1000	4	8.375	<0.003	<0.001	0.02	7.5	130	8.2	0.04	0.06	0.155	39

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

Table 13 Statistical summary of data from July 2016 to July 2017 Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.003	0.027	0.012	12	0.009
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.013	0.002	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	16	49	36	12	10
BDISC	Black disc transparency	m	0.12	4.65	1.26	12	1.60
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	0.6	<0.5	12	0.
CONDY	Conductivity @ 20°C	mS/m	6.4	11.5	9.4	12	1.8
DO	Dissolved oxygen	g/m^3	10.1	12.3	10.6	12	0.7
PERSAT	Dissolved oxygen saturation %	%	100	102	101	12	1
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.013	0.052	0.020	12	0.010
ECOL	E.coli bacteria	cfu/100 mL	1	18000	11	12	5190
ENT	Enterococci bacteria	cfu/100 mL	<1	1900	3	12	547
FC	Faecal coliforms	cfu/100 mL	1	18000	11	12	5190
FLOW	Flow	m^3/s	2.751	13.536	3.704	12	3.724
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.021	0.002	12	0.006
NO_2	Nitrite nitrogen	g/m^{3}N	<0.001	<0.001	<0.001	12	0.
NO_3	Nitrate nitrogen	g/m^{3}N	0.004	0.080	0.044	12	0.022
pH	pH		7.5	8.1	7.8	12	0.2
SS	Suspended solids	g/m^3	<2	360	8	12	105
TEMP	Temperature	°C	6.5	14.2	11.6	12	2.4
TKN	Total kjeldahl nitrogen	g/m^{3}N	<0.01	<0.15	0.03	12	0.04
TN	Total nitrogen	g/m^{3}N	0.05	0.18	0.08	12	0.04
TP	Total phosphorus	g/m^{3}P	0.022	0.352	0.041	12	0.099
TURBY	Turbidity	NTU	0.67	86	4.1	12	29

A statistical summary of the 22 years' data collected since 1 July 1995 is presented in Table 14.

Table 14 Statistical summary of data from July 1995 to June 2017: Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.000	0.077	0.008	264	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.028	0.002	264	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.007	0.000	264	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	5	57	38	264	12
BDISC	Black disc transparency	m	<0.01	13.12	3.16	264	2.71
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.8	<0.5	264	0.1
CONDY	Conductivity @ 20°C	mS/m	2.8	13.3	9.7	264	2.4
DO	Dissolved oxygen	g/m^3	9.4	12.3	10.7	264	0.6
PERSAT	Dissolved oxygen saturation %	%	87	106	99	266	2
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.004	0.210	0.018	264	0.014
ECOL	E.coli bacteria	cfu/100 mL	<1	18000	8	240	1164
ENT	Enterococci bacteria	cfu/100 mL	<1	1900	5	264	136
FC	Faecal coliforms	cfu/100 mL	<1	18000	8	264	1111
FLOW	Flow	m^3/s	1.988	55.504	3.602	264	7.432
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.021	<0.003	264	0.003
NO_2	Nitrite nitrogen	g/m^{3}N	<0.001	0.004	<0.001	264	0.
NO_3	Nitrate nitrogen	g/m^{3}N	<0.01	0.11	0.02	264	0.02
pH	pH		7.0	8.2	7.8	264	0.2
SS	Suspended solids	g/m^3	<2	2500	<2	264	299
TEMP	Temperature	°C	5.7	16.6	10.8	264	2.5
TKN	Total kjeldahl nitrogen	g/m^{3}N	<0.01	1.78	0.04	264	0.16
TN	Total nitrogen	g/m^{3}N	<0.05	1.82	0.06	264	0.16
TP	Total phosphorus	g/m^{3}P	0.008	3.38	0.025	264	0.291
TURB	Turbidity (Hach 2100A)	NTU	0.2	700	0.8	245	66
TURBY	Turbidity (Cyberscan WTW)	NTU	0.2	1400	1.6	145	164

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

2016-2017

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 again in late May - early June 2011. Further erosion events in the headwaters were recorded during a dry period in February 2014 (see Photo 3, TRC 2014). Some headwater erosion was indicated after a flood event on mid-February 2016, and again on 2/3 February 2017. The minimum black disc value (0.12) and maximum turbidity (86 NTU) and suspended solids (360 g/m^3) values were recorded during a subsequent fresh (11.9 m^3/sec) in April 2017. Generally, wet weather and fresh flow conditions did not result in changes in nutrient or bacterial levels to the extent found in other monitored ringplain streams, with the exception of total phosphorus, which increased to a greater degree in particulate form (maximum of 0.35 g/m^{3}P). The maximum black disc clarity of 4.65 m was measured in mid-summer under moderately low flow conditions coincident with the very low suspended solids and low turbidity (0.7 NTU) levels.

Maximum mid-morning pH (8.1) occurred under autumn relatively low flow conditions while the median pH (7.8) was equivalent with the median of 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 but one occasion (0.6 g/m^3); 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 (11 and 3 cfu/100 mL, respectively) indicative of minimal impact of upstream developed farmland at this site near mid-catchment. The bacterial numbers from the 14 December 2016 survey, undertaken on the rising stage of a small fresh after a short flow recession, were the highest recorded (18,000 and 1,900 cfu/100 mL, respectively) by a large margin.

River water temperatures varied over a moderate range of 7.7 °C during the period, with a maximum mid-morning temperature of 14.2 °C recorded in autumn (April 2017) under high flow conditions.

Nutrient levels were generally very low in terms of median ammoniacal nitrogen, nitrate-N, and dissolved reactive phosphorus concentrations. Total nitrogen concentration was also relatively low throughout the year. Total phosphorus concentration varied markedly, coincident with suspended solids concentration, ranging from 0.022 to 0.35 g/m^3.

Brief comparison with the previous 1995-2016 period

Water quality measured during the 2016-2017 survey period, in comparison with the previous 21 years' survey results, was poorer aesthetically in terms of median black disc clarity (which was lower by 1.98 m), median turbidity (higher by 2.6 NTU), and suspended solids level which was higher (by >6 g/m^3) than the historical median.

Median bacteriological water quality was slightly poorer in the latest period, although both periods had very high quality with all median faecal coliform and enterococci counts ≤20 cfu/100 mL.

Water temperature range was narrower (by 3.2 °C), mainly due to a lower maximum temperature during 2016-2017, with the median value higher (by 0.8 °C) in the 2016-2017 period than that in the earlier 21-year period. For nutrient species, nitrate was higher than the previous longer period median (by 100%), though still relatively low at 0.04 g/m^3; TN was higher by 50%, while still low at 0.08 g/m^3; and DRP and TP were higher (by 11 and 71%, respectively).

Median sampled flow during the 2016-2017 period was higher (by 0.11 m^3/sec, or 3%) than the median of flows sampled over the previous 21-year period, with a few freshes and no flood events and relatively high low flow periods sampled in 2016-2017. This was reflected in the slightly lower median conductivity value (by 0.3 mS/m at 20°C) recorded in 2016-2017.

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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100mL	cfu/100mL
13 Jul 2016	1115	0.024	0.005	0.000	21	1.16	<0.5	9.5	11.8	100	0.021	5	3
10 Aug 2016	1055	0.028	0.006	0.000	20	1.88	<0.5	9.1	12.2	101	0.012	7	3
14 Sep 2016	1035	0.028	0.008	0.002	16	1.25	<0.5	8.9	10.8	101	0.016	20	7
12 Oct 2016	0950	0.032	0.009	0.002	22	1.54	<0.5	9.2	10.2	101	0.022	42	1
09 Nov 2016	1015	0.045	0.011	0.000	18	1.70	<0.5	8.5	9.9	101	0.016	68	3
14 Dec 2016	0940	0.032	0.008	0.001	24	0.90	<0.5	8.9	10.4	101	0.021	240	52
11 Jan 2017	0945	0.032	0.007	0.001	26	2.63	<0.5	8.9	9.6	102	0.029	91	92
08 Feb 2017	0945	0.043	0.011	0.001	24	1.70	<0.5	9.1	10.1	102	0.025	290	48
08 Mar 2017	0955	0.032	0.006	0.000	26	1.58	<0.5	9.0	10.7	102	0.036	440	460
13 Apr 2017	1045	0.039	0.008	0.000	24	1.34	<0.5	9.1	10.0	101	0.020	68	66
10 May 2017	1045	0.032	0.007	0.001	23	1.50	<0.5	9.1	11.0	102	0.022	37	11
14 Jun 2017	1035	0.065	0.013	0.001	15	0.86	<0.5	7.7	11.6	102	0.022	180	29

Date	Time NZST	FC	Flow	NH4	NO2	NO3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m3/s	g/m3N	g/m3N	g/m3N	pH	g/m3	°C	g/m3N	g/m3N	g/m3P	NTU
13 Jul 2016	1115	5	0.407	0.017	0.001	0.12	7.5	<2	7.4	0.03	0.15	0.030	3.6
10 Aug 2016	1055	7	0.570	0.022	0.001	0.14	7.4	<2	6.6	0.08	0.22	0.020	3.0
14 Sep 2016	1035	20	0.678	0.007	<0.001	0.04	7.6	<2	11.6	0.09	0.13	0.024	4.7
12 Oct 2016	0950	42	0.396	0.012	0.001	0.06	7.6	2	13.2	0.15	0.21	0.030	3.9
09 Nov 2016	1015	68	0.652	0.015	0.001	0.05	7.6	<2	15	0.11	0.16	0.029	2.4
14 Dec 2016	0940	240	0.435	0.013	0.001	0.02	7.6	2	12.5	0.06	0.08	0.035	3.4
11 Jan 2017	0945	93	0.336	0.003	0.001	0.01	7.9	<2	16.9	0.07	0.08	0.040	2.2
08 Feb 2017	0945	290	0.468	0.003	0.001	0.04	7.7	<2	14.9	0.06	0.10	0.037	3.8
08 Mar 2017	0955	440	0.316	0.004	0.001	0.03	7.8	2	11.9	0.07	0.10	0.043	2.6
13 Apr 2017	1045	80	0.413	0.008	0.002	0.08	7.6	<2	14.4	<0.2	0.28	0.058	4.9
10 May 2017	1045	43	0.393	0.011	0.002	0.08	7.7	<2	11.4	0.07	0.15	0.032	4.0
14 Jun 2017	1035	200	0.858	0.039	0.002	0.06	7.4	5	8.6	0.14	0.20	0.040	6.0

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

Table 16 Statistical summary of data from July 2016 to June 2017 Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.024	0.065	0.032	12	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.005	0.013	0.008	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.001	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	15	26	22	12	4
BDISC	Black disc transparency	m	0.86	2.63	1.52	12	0.48
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	<0.5	<0.5	12	0
CONDY	Conductivity @ 20°C	mS/m	7.7	9.5	9.0	12	0.4
DO	Dissolved oxygen	g/m^3	9.6	12.2	10.6	12	0.8
PERSAT	Dissolved oxygen saturation %	%	100	102	101	12	1
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.012	0.036	0.022	12	0.006
ECOL	E.coli bacteria	cfu/100 mL	5	440	68	12	136
ENT	Enterococci bacteria	cfu/100 mL	1	460	20	12	128
FC	Faecal coliforms	cfu/100 mL	5	440	74	12	136
FLOW	Flow	m^3/s	0.316	0.858	0.424	12	0.163
NH_4	Ammoniacal nitrogen	g/m^{3}N	0.003	0.039	0.012	12	0.010
NO_2	Nitrite nitrogen	g/m^{3}N	<0.001	0.002	0.001	12	0.
NO_3	Nitrate nitrogen	g/m^{3}N	0.009	0.139	0.054	12	0.039
pH	pH		7.4	7.9	7.6	12	0.1
SS	Suspended solids	g/m^3	<2	5	<2	12	1
TEMP	Temperature	°C	6.6	16.9	12.2	12	3.2
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.03	<0.20	0.08	12	0.05
TN	Total nitrogen	g/m^{3}N	0.08	0.28	0.15	12	0.06
TP	Total phosphorus	g/m^{3}P	0.020	0.058	0.034	12	0.010
TURBY	Turbidity	NTU	2.2	6.0	3.7	12	1.1

A statistical summary of the 22 years' data collected since 1 July 1995, is presented in Table 17.

Table 17 Statistical summary of data from July 1995 to July 2017: Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.015	0.144	0.032	264	0.023
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.032	0.007	264	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.005	0.000	264	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	6	27	22	264	5
BDISC	Black disc transparency	m	0.08	4.53	1.825	264	0.858
BOD5	Biochemical oxygen demand 5day	g/m3	<0.5	3.0	<0.5	264	0.3
CONDY	Conductivity @ 20°C	mS/m	4.0	10.9	8.6	264	1.2
DO	Dissolved oxygen	g/m3	8.9	12.5	10.4	263	0.8
PERSAT	Dissolved oxygen saturation %	%	87	106	100	263	3
DRP	Dissolved reactive phosphorus	g/m3P	0.007	0.389	0.023	264	0.024
ECOL	E.coli bacteria	cfu/100 mL	3	6100	100	240	791
ENT	Enterococci bacteria	cfu/100 mL	<1	1200	32	264	157
FC	Faecal coliforms	cfu/100 mL	3	6100	115	264	810
FLOW	Flow	m3/s	0.18	12.38	0.436	264	1.073
NH4	Ammoniacal nitrogen	g/m3N	0.002	0.078	0.007	264	0.01
NO2	Nitrite nitrogen	g/m3N	<0.001	0.014	0.001	264	0.001
NO3	Nitrate nitrogen	g/m3N	<0.01	0.28	0.047	264	0.044
pH	pH		6.9	8.3	7.6	264	0.2
SS	Suspended solids	g/m3	<2	160	<2	264	12
TEMP	Temperature	°C	5.0	19.2	11.9	264	3.3
TKN	Total kjeldahl nitrogen	g/m3N	0.01	0.85	0.09	264	0.12
TN	Total nitrogen	g/m3N	<0.05	0.87	0.15	264	0.132
TP	Total phosphorus	g/m3P	0.015	0.413	0.034	264	0.038
TURB	Turbidity (Hach 2100A)	NTU	0.45	29	1.7	245	3.1
TURBY	Turbidity (Cyberscan WTW)	NTU	0.46	28	2.4	145	3.6

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

2016-2017

Although black disc clarity and turbidity results were indicative of relatively good water quality in terms of aesthetic appearance, these values continued to be poorer than might be anticipated for the upper reaches of a ring plain stream, i.e. medians of 1.52 m (black disc) and 3.7 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 (0.86 m) was recorded during a small fresh in June 2017, coincidental with a minor increase in suspended solids concentration (5 g/m^3) and increase in turbidity (6.0 NTU). The highest recorded ammonia concentration (0.039 g/m^3N) occurred during this event. A maximum black disc value of 2.63 m was measured under low flow conditions in mid-summer (January 2017).

The maximum pH (7.9) was also recorded (in mid-morning) in mid-summer, under low flow conditions (336 L/s).

Dissolved oxygen concentrations were consistently high (100 to 102% saturation for the period) and BOD_5 levels were very low and less than 0.5 g/m^3 on all occasions; further indications of generally high water quality.

A moderate median faecal coliform bacterial count for the upper reaches of a ring plain stream (74 cfu/100 mL) indicated some impacts of upstream farmland run-off (and possible stock access) on stream water quality at this site, and represented some 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 a minor and a moderate fresh were sampled during the 2016-2017 period, similar to many previous periods, resulting in a relatively typical median for the latest period.

Water temperatures varied over a relatively wide range (10.3 °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 16.9 °C was recorded in January 2017, relatively high for the upper reaches of a ring plain stream at this time of the day (0945 hrs).

Brief comparison with the previous 1995-2016 period

Stream water quality measured during the 2016-2017 period was significantly poorer in terms of median turbidity (which was higher by 1.3 NTU, or 54%) and median black disc clarity (which was lower by 0.30 m, or 17%) than the previous overall record. Median suspended solids concentration remained low and in the recent year was equivalent with the median of the previous 21-year period. Median dissolved oxygen percentage saturation levels were very similar (within 1%) for the two periods.

Bacteriological water quality was better over the most recent period in terms of median faecal coliform number (by 46 cfu/100 mL) and median number of enterococci (by 13 cfu/100 mL). The relative median nitrogen species concentrations varied between the periods, recent nitrate values being higher, and recent total nitrogen higher. Total and dissolved phosphorus median values in the recent year were similar to those for the long-term record.

The water temperature range was narrower (by 3.9 °C) compared with surveys prior to the latest twelve-month period; with the median flow sampled slightly lower by 12 L/s, or 3%, in the 2016-2017 period.

Median pH values were the same during the two sampling periods but the maximum pH was 0.4 unit lower than the maximum recorded in the previous 21-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 present actual flows gauged at the site at the time of sampling. Previously, data from a NIWA flow recording station elsewhere in the catchment were used by the Council to provide a synthesized flow rate at this site, but the 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/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 cfu/100mL	ENT cfu/100mL
13 Jul 2016	1145	0.024	0.004	0.000	30	1.56	0.6	18.9	11.6	100	0.036	77	36
10 Aug 2016	1125	0.023	0.004	0.000	30	1.28	0.8	21.1	12.1	101	0.040	77	23
14 Sep 2016	1100	0.029	0.007	0.001	32	1.42	1.3	18.6	10.8	101	0.057	1000	250
12 Oct 2016	1020	0.030	0.008	0.000	36	1.13	<0.5	19.8	10.3	102	0.058	2100	2500
09 Nov 2016	1055	0.044	0.008	0.000	31	0.97	1.0	15.2	10.3	101	0.056	560	130
14 Dec 2016	1005	0.042	0.009	0.001	40	0.56	1.0	17.3	10.2	106	0.082	1300	970
11 Jan 2017	1010	0.042	0.009	0.001	40	2.76	0.7	15.5	9.7	102	0.082	480	520
08 Feb 2017	1005	0.045	0.010	0.001	39	1.51	0.7	16.7	9.8	101	0.085	1000	1300
08 Mar 2017	1025	0.038	0.008	0.000	42	1.50	1.1	15.5	10.4	102	0.060	1900	3200
13 Apr 2017	1105	0.039	0.008	0.000	37	1.39	0.7	20.1	9.7	100	0.060	360	870
10 May 2017	1110	0.031	0.006	0.000	39	1.34	0.6	21.9	10.6	100	0.041	130	180
14 Jun 2017	1100	0.054	0.011	0.001	32	0.78	0.6	16.4	11.4	102	0.024	360	270

Date	Time NZST	FC cfu/100mL	Flow m^3/s	NH_4 g/m^{3}N	NO_2 g/m^{3}N	NO_3 g/m^{3}N	pH pH	SS g/m^3	Temp °C	TKN g/m^{3}N	TN g/m^{3}N	TP g/m^{3}P	Turb NTU
13 Jul 2016	1145	77	0.987	0.025	0.006	2.28	7.6	2	8.8	0.45	2.74	0.047	1.8
10 Aug 2016	1125	77	1.695	0.047	0.009	3.76	7.5	3	7.6	0.19	3.96	0.052	2.7
14 Sep 2016	1100	1000	1.596	0.045	0.026	2.09	7.5	12	12.6	0.69	2.81	0.086	4.4
12 Oct 2016	1020	2200	1.281	0.056	0.026	2.52	7.8	4	14.2	0.27	2.82	0.087	3.1
09 Nov 2016	1055	560	1.093	0.058	0.019	1.13	7.7	3	14.6	0.34	1.49	0.085	2.3
14 Dec 2016	1005	1300	0.597	0.026	0.016	0.99	7.7	4	14.8	0.17	1.18	0.108	1.9
11 Jan 2017	1010	500	0.464	0.018	0.009	0.57	7.9	<2	18.0	0.12	0.70	0.116	1.7
08 Feb 2017	1005	1000	0.911	0.034	0.014	0.90	7.8	26	17.0	0.23	1.14	0.103	1.7
08 Mar 2017	1025	1900	0.508	0.010	0.004	0.37	7.8	3	14.4	0.14	0.51	0.082	1.7
13 Apr 2017	1105	360	1.153	0.049	0.015	2.23	7.6	<2	16.4	0.34	2.58	0.082	2.8
10 May 2017	1110	360	1.198	0.050	0.012	2.92	7.7	<2	13.1	0.33	3.26	0.060	2.1
14 Jun 2017	1100	370	1.409	0.017	0.007	1.71	7.6	4	10.3	0.24	1.96	0.045	5.8

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

Table 19 Statistical summary of data from July 2016 to June 2017 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.023	0.054	0.038	12	0.009
A440F	Absorbance @ 440nm Filtered	/cm	0.004	0.011	0.008	12	0.002
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	30	42	36	12	4
BDISC	Black disc transparency	m	0.56	2.76	1.36	12	0.54
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.3	0.7	12	0.2
CONDY	Conductivity @ 20'C	mS/m	15.2	21.9	18.0	12	2.3
DO	Dissolved Oxygen	g/m^3	9.7	12.1	10.4	12	0.8
PERSAT	Dissolved Oxygen Saturation %	%	100	106	101	12	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.024	0.085	0.058	12	0.019
ECOL	E.coli bacteria	cfu/100 mL	77	2100	520	12	692
ENT	Enterococci bacteria	cfu/100 mL	23	3200	395	12	1026
FC	Faecal Coliforms	cfu/100 mL	77	2200	530	12	692
FLOW	Flow	m^3/s	0.464	1.695	1.123	12	0.403
NH_4	Ammoniacal nitrogen	g/m^3N	0.010	0.058	0.040	12	0.017
NO_2	Nitrite nitrogen	g/m^3N	0.004	0.026	0.013	12	0.007
NO_3	Nitrate nitrogen	g/m^3N	0.366	3.761	1.904	12	1.027
PH	pH		7.5	7.9	7.7	12	0.1
SS	Suspended solids	g/m^3	<2	26	3	12	7
TEMP	Temperature	°C	7.6	18.0	14.3	12	3.2
TKN	Total Kjeldahl nitrogen	g/m^3N	0.12	0.69	0.26	12	0.16
TN	Total nitrogen	g/m^3N	0.51	3.96	2.27	12	1.09
TP	Total phosphorus	g/m^3P	0.045	0.116	0.084	12	0.024
TURBY	Turbidity	NTU	1.7	5.8	2.2	12	1.3

A statistical summary of the 22 years' data collected since 1 July 1995, is presented in Table 20.

Table 20 Statistical summary of data from July 1995 to June 2017 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.015	0.115	0.039	264	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.027	0.008	264	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.006	0.000	264	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	10	46	34	264	7
BDISC	Black disc transparency	m	0.055	3.65	1.50	264	0.688
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	8.1	1.0	264	0.9
CONDY	Conductivity @ 20'C	mS/m	5.8	22.9	16.1	264	2.5
DO	Dissolved Oxygen	g/m^3	8.6	12.8	10.4	264	0.8
PERSAT	Dissolved Oxygen Saturation %	%	90	114	100	264	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.013	0.212	0.044	264	0.026
ECOL	E.coli bacteria	cfu/100 mL	48	21000	495	238	2440
ENT	Enterococci bacteria	cfu/100 mL	15	14000	320	263	1505
FC	Faecal Coliforms	cfu/100 mL	51	21000	520	264	2694
FLOW	Flow	m^3/s	0.242	12.3	0.814	264	1.505
NH_4	Ammoniacal nitrogen	g/m^3N	0.004	0.376	0.040	264	0.06
NO_2	Nitrite nitrogen	g/m^3N	0.001	0.110	0.014	264	0.014
NO_3	Nitrate nitrogen	g/m^3N	0.07	3.79	0.96	264	0.74
PH	pH		7.1	8.6	7.7	264	0.2
SS	Suspended solids	g/m^3	<2	220	3	264	20
TEMP	Temperature	°C	5.0	21.0	13.4	264	3.5
TKN	Total Kjeldahl nitrogen	g/m^3N	0.03	1.99	0.32	264	0.26
TN	Total nitrogen	g/m^3N	0.21	4.30	1.40	264	0.83
TP	Total phosphorus	g/m^3P	0.026	0.531	0.079	264	0.06
TURB	Turbidity (Hach 2100A)	NTU	0.8	50	1.9	245	4.9
TURB	Turbidity (Cyberscan WTW)	NTU	0.8	49	2.3	145	6.0

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

2016-2017 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.38 m, this clarity being typical of the lower reaches of developed ringplain catchments. A median suspended solids concentration of 3 g/m^3 and turbidity of 2.2 NTU was also more typical of the lower reaches of a ring plain catchment. Minimum clarities (black disc values of 0.58 and 0.78 m, turbidities of 1.9 and 5.8 NTU, and suspended solids concentrations of 4 and 4 g/m^3) were recorded during a slightly rising flow in December 2016 and a minor fresh in June 2017.

Nitrate concentration and conductivity were elevated in winter and early spring, to the equal highest level recorded (3.8 $g/m^3 NO_3$-N; 21.1 mS/m at 20°C) whereas the highest phosphorus concentrations occurred in summer under lower flows.

pH range was narrow, with the maximum value of 7.9 recorded in January under low flow conditions, but this value was recorded in late morning and would be expected to have reached a higher level later in the day. This values 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 100% saturation), BOD_5 concentrations often indicated low levels of organic enrichment (ie $\geq$1 g/m^3).

The high median bacteriological numbers (395 enterococci and 530 faecal coliform cfu/100 mL) were further indication 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 (360 to 1,900 cfu/100 mL) found during spring to autumn lower flow conditions was 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 10.4 ˚C with a maximum summer (late morning) temperature of 18.0 ˚C recorded in January 2017 and the lowest temperature (7.6 ˚C) recorded in August 2016; the former 3.0 ˚C below the previous maximum temperature and the latter 2.6˚C above the previous minimum temperature.

Brief comparison of upper and lower Punehu Stream sites during the 2016-2017 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 (456 faecal coliforms cfu/100 mL and 375 enterococci cfu/100 mL), and median nutrient concentrations (particularly nitrogen species), with nitrate, total nitrogen, and total phosphorus increasing by factors of about 35, 15 and 2.5 times respectively. These downstream spatial trends may be compared with median 22-year historical data which indicate bacterial increases of 405 cfu/100 mL (faecal coliforms) and 288 cfu/100 mL (enterococci) and increases in nitrate, total nitrogen, and total phosphorus of 20, 9, and 2.3 times respectively. Median turbidity (2016-2017) decreased downstream, coincident with an unusually high median level at the upper site, while there was a significant increase in suspended solids and a decrease in median black disc clarity (10% reduction) between sites, compared with the historical median turbidity decrease of only 0.1 NTU and decrease in median black disc clarity of 0.28 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 165% in the lower reaches of the stream). The downstream water temperature range increased by only 0.1 ˚C while the median increased by only 2.1˚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 1995-2016 period

Similar aesthetic water quality was indicated with a decrease in median turbidity (of 0.1 NTU) recorded during the more recent twelve-month survey period, decrease in median black disc clarity (of 0.18 m), and the same median suspended solids concentration.

In the more recent survey period, a slight deterioration was recorded in median faecal coliform bacterial number (of 10 cfu/100 mL) and a larger increase in median enterococci bacteria number (by 75 cfu/100 mL). Marked deterioration in median nutrient species concentrations was recorded for nitrate N and total nitrogen, which increased by about 104% and 64 % of the long term medians, respectively. There was a deterioration in phosphorus levels, with higher levels of both the dissolved reactive form (by 32 %) and total phosphorus (by 64 %).

Median dissolved oxygen saturation levels were within 1%, while median BOD_5 level was significantly lower, by 30%, for the most recent period.

There was no difference in median pH for 2016-2017, and the maximum pH was 0.7 unit lower in comparison with the previous 21-year period.

Water temperature range was narrower (by 5.6 ˚C); this decrease due to both higher minimum and lower maximum water temperatures (by 2.6 and 3.0˚C) over the recent survey period, with the 2016-2017 median water temperature 1.1 ˚C higher than the median 21-year temperature.

Median sampled flow over the 2016-2017 period was significantly higher than the median sampled (by 320 L/s) flow for the previous 21-year period.

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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100m	cfu/100m
13 Jul 2016	1315	0.013	0.002	0.000	30	1.66	0.5	11.7	11.7	102	0.025	84	16
10 Aug 2016	1250	0.01	0.002	0.000	27	1.14	0.6	11.5	11.6	101	0.016	34	17
14 Sep 2016	1225	0.012	0.002	0.000	29	1.79	0.6	11.4	11.1	104	0.019	80	8
12 Oct 2016	1150	0.012	0.004	0.001	29	1.74	0.8	11.6	10.2	100	0.027	270	42
09 Nov 2016	1220	0.023	0.007	0.001	26	1.23	0.8	10.0	10.2	104	0.034	180	23
14 Dec 2016	1125	0.02	0.005	0.000	31	1.60	0.5	10.7	10.6	106	0.022	230	66
11 Jan 2017	1135	0.022	0.006	0.001	39	2.12	0.8	11.7	10.0	109	0.034	290	440
08 Feb 2017	1130	0.026	0.007	0.001	36	2.19	0.7	10.7	10.0	104	0.035	660	230
08 Mar 2017	1200	0.029	0.006	0.000	42	1.54	1.4	11.9	10.6	108	0.019	1100	1400
13 Apr 2017	1230	0.022	0.005	0.000	29	1.42	0.8	11.3	9.7	100	0.037	900	2900
10 May 2017	1240	0.014	0.004	0.000	32	1.64	0.5	11.9	11.0	106	0.026	250	80
14 Jun 2017	1230	0.015	0.004	0.002	32	1.55	0.5	11.7	11.7	106	0.015	280	90

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
13 Jul 2016	1315	88	1.998	0.008	0.005	1.84	7.7	3	8.5	0.14	1.98	0.038	1.8
10 Aug 2016	1250	34	4.039	0.009	0.004	2.19	7.6	4	8.6	0.05	2.24	0.036	2.2
14 Sep 2016	1225	80	2.536	0.012	0.006	1.58	7.9	3	11.8	0.31	1.90	0.033	1.5
12 Oct 2016	1150	270	3.003	0.019	0.009	1.85	7.7	3	13.0	0.08	1.94	0.044	2.2
09 Nov 2016	1220	180	2.797	0.037	0.012	1.35	7.7	5	15.3	0.2	1.56	0.064	2.2
14 Dec 2016	1125	240	1.309	0.023	0.010	0.95	7.9	<2	14.3	<0.09	1.05	0.036	1.3
11 Jan 2017	1135	300	0.601	0.020	0.009	0.72	8.2	<2	18.7	0.07	0.80	0.054	1.3
08 Feb 2017	1130	670	0.658	0.008	0.008	0.55	8.0	<2	16.8	0.12	0.68	0.049	1.3
08 Mar 2017	1200	1200	0.550	<0.003	0.004	0.33	8.0	2	15.1	0.18	0.51	0.043	1.6
13 Apr 2017	1230	930	2.964	0.028	0.011	1.62	7.6	3	15.4	0.25	1.88	0.066	2.9
10 May 2017	1240	250	1.849	0.013	0.007	1.83	7.9	2	13.3	0.12	1.96	0.043	1.7
14 Jun 2017	1230	280	1.577	0.007	0.005	1.65	7.8	3	9.9	0.09	1.74	0.029	2.4

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

Table 22 Statistical summary of data from July 2016 to June 2017: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.010	0.029	0.018	12	0.006
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.007	0.004	12	0.002
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.002	0.000	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	26	42	30	12	5
BDISC	Black disc transparency	m	1.14	2.19	1.62	12	0.31
BOD_5	Biochemical oxygen demand 5day	g/m^3	0.5	1.4	0.6	12	0.3
CONDY	Conductivity @ 20'C	mS/m	10.0	11.9	11.6	12	0.6
DO	Dissolved Oxygen	g/m^3	9.7	11.7	10.6	12	0.7
PERSAT	Dissolved Oxygen Saturation %	%	100	109	104	12	3
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.015	0.037	0.026	12	0.008
ECOL	E.coli bacteria	cfu/100 mL	34	1100	260	12	340
ENT	Enterococci bacteria	cfu/100 mL	8	2900	73	12	868
FC	Faecal coliforms	cfu/100 mL	34	1200	260	12	364
FLOW	Flow	m^3/s	0.550	4.039	1.924	12	1.11
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.037	0.012	12	0.01
NO_2	Nitrite nitrogen	g/m^{3}N	0.004	0.012	0.008	12	0.003
NO_3	Nitrate nitrogen	g/m^{3}N	0.326	2.186	1.602	12	0.593
PH	pH		7.6	8.2	7.8	12	0.2
SS	Suspended solids	g/m^3	<2	5	3	12	1
TEMP	Temperature	°C	8.5	18.7	13.8	12	3.2
TKN	Total Kjeldahl nitrogen	g/m^{3}N	0.05	0.31	0.12	12	0.08
TN	Total nitrogen	g/m^{3}N	0.51	2.24	1.81	12	0.59
TP	Total phosphorus	g/m^{3}P	0.029	0.066	0.043	12	0.012
TURBY	Turbidity	NTU	1.3	2.9	1.8	12	0.5

A statistical summary of the 22 years' data collected since 1 July 1995, is presented in Table 23.

Table 23 Statistical summary of data from July 1995 to June 2017: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.009	0.100	0.020	264	0.013
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.024	0.005	264	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.003	0.000	264	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	11	49	30	264	7
BDISC	Black disc transparency	m	0.10	4.39	1.685	264	0.787
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	7.3	0.7	264	0.8
CONDY	Conductivity @ 20'C	mS/m	4.6	14.7	11.2	264	1.5
DO	Dissolved Oxygen	g/m^3	9.2	13.0	10.6	265	0.7
PERSAT	Dissolved Oxygen Saturation %	%	92	121	103	265	5
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.003	0.146	0.020	264	0.014
ECOL	E.coli bacteria	cfu/100 mL	6	59000	180	240	3958
ENT	Enterococci bacteria	cfu/100 mL	3	7700	100	264	1009
FC	Faecal coliforms	cfu/100 mL	6	100000	190	264	7250
FLOW	Flow	m^3/s	0.326	28.797	1.636	264	3.207
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	1.72	0.017	264	0.11
NO_2	Nitrite nitrogen	g/m^{3}N	<0.001	0.033	0.007	264	0.005
NO_3	Nitrate nitrogen	g/m^{3}N	0.13	2.31	1.15	264	0.49
PH	pH		7.1	8.6	7.8	264	0.3
SS	Suspended solids	g/m^3	<2	180	3	264	17
TEMP	Temperature	°C	5.6	21.5	12.6	264	3.2
TKN	Total Kjeldahl nitrogen	g/m^{3}N	0.00	2.41	0.19	264	0.29
TN	Total nitrogen	g/m^{3}N	0.21	3.22	1.44	264	0.53
TP	Total phosphorus	g/m^{3}P	0.013	0.829	0.039	264	0.073
TURB	Turbidity (Hach 2100A)	NTU	0.70	36	1.5	245	3.8
TURB	Turbidity (Cyberscan WTW)	NTU	0.62	18	2.0	145	3.0

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.

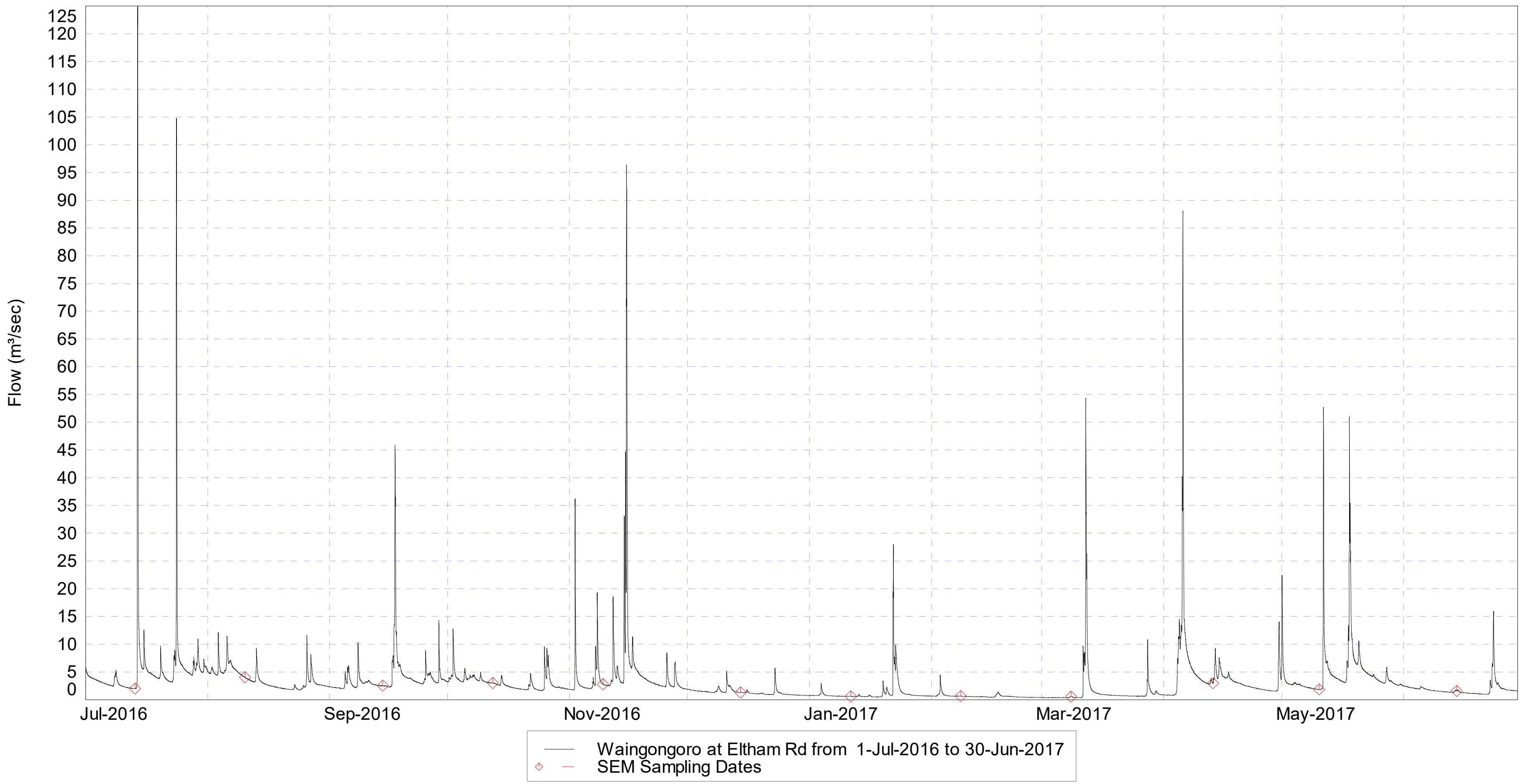


Figure 4 Flow record for the Waingongoro River at Eltham Road

Discussion

2016-2017

Moderate aesthetic water quality (more similar to lower ringplain reaches' aesthetic quality) was indicated by a median black disc clarity of 1.62 m and median turbidity of 1.8 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 2.19 m), 2.20 m lower than the historical maximum, was recorded in late summer during a period of low flow conditions (0.66 m^3/s), while worst black disc clarities (1.14 and 1.23 m) occurred on the falling stages of small to moderate freshes coincident with turbidity of 2.2 NTU and suspended solids concentrations of 4 and 5 g/m^3 sampled in August and November 2016 (Figure 5). Generally, the poorer water quality conditions monitored during freshes (elevated bacterial numbers, some elevated nutrients, discolouration, and decreased clarity) were apparent on several occasions during the 2016-2017 period.

pH reached a maximum of 8.2 in mid-summer coincident with supersaturation (109%) 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 100% saturation recorded in spring) and low BOD_5 levels (median: 0.6 g/m^3). Bacteriological quality was more typical of the mid reaches of developed ring plain catchments, subject to agricultural impacts, with median faecal coliform and enterococci numbers of 260 and 73 cfu/100 mL, respectively. Water temperature varied over a moderate range of 10.2 ˚C with the maximum summer (late morning) river temperature of 18.7 ˚C recorded in January 2017 under low flow conditions (Figure 5).

Brief comparison with previous 1995-2016 period

The latest twelve-month period sampled a narrower range of flow conditions with median sampled flow much higher (by 296 L/s. or 18%) than the median of flows sampled over the previous 21-year period. Aesthetic river water quality was slightly lower in terms of median black disc clarity (which was lower by 0.10 m), and median turbidity level (which was higher by 0.2 NTU), with median suspended solids level the same, during the 2016-2017 period.

In general, some deterioration in faecal coliform bacteriological water quality was recorded in the 2016-2017 period with a higher median number (by 90 cfu/100 mL) but some improvement in median enterococci number (by 23 cfu/100 mL). Some increases were indicated in median nutrient species' concentrations over the 2016-2017 period, particularly nitrate N, total nitrogen, dissolved phosphorus and total phosphorus, which rose by 44%, 27%, 30% and 10%, respectively. Median ammonia N value fell by 17%.

The range in water temperature was narrower (by 4.7 ˚C) over the 2016-2017 period mainly due to both warmer (by 2.0˚C) minimum and cooler maximum (by 2.8°C) water temperatures.

Median pH value was the same, but the maximum pH previously recorded (over 21 years) was 0.4 unit higher than that measured in the 2016-2017 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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/ 100mL	cfu/100mL
13 Jul 2016	1230	0.02	0.003	0.000	35	1.16	1.2	15.9	12.0	101	0.037	80	42
10 Aug 2016	1210	0.015	0.003	0.000	31	0.88	1.2	15.4	11.9	101	0.031	84	17
14 Sep 2016	1145	0.022	0.006	0.002	36	1.76	1.2	16.1	11.0	103	0.035	180	24
12 Oct 2016	1115	0.019	0.004	0.000	36	1.31	1.1	16.0	10.1	100	0.041	190	44
09 Nov 2016	1140	0.048	0.011	0.000	31	0.70	2.1	13.5	10.1	102	0.062	1000	95
14 Dec 2016	1050	0.035	0.007	0.000	41	0.96	0.6	15.9	10.3	105	0.038	220	120
11 Jan 2017	1100	0.033	0.007	0.001	52	2.04	0.8	18.0	10.0	110	0.044	180	1700
08 Feb 2017	1055	0.035	0.008	0.001	49	1.60	0.8	16.5	9.7	103	0.070	380	170
08 Mar 2017	1100	0.036	0.007	0.000	58	1.55	2.5	18.4	10.3	104	0.016	750	550
13 Apr 2017	1140	0.026	0.006	0.000	35	1.55	0.7	15.2	9.7	100	0.054	740	1900
10 May 2017	1150	0.026	0.006	0.000	38	1.38	0.8	16.7	10.8	103	0.043	240	150
14 Jun 2017	1135	0.024	0.004	0.000	41	1.02	1.6	17.9	11.3	102	0.038	230	200

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
13 Jul 2016	1230	80	6.083	0.013	0.011	2.22	7.8	4	8.2	0.25	2.48	0.057	3.2
10 Aug 2016	1210	84	12.994	0.052	0.053	2.70	7.6	8	8.3	0.28	3.03	0.070	5.0
14 Sep 2016	1145	180	7.737	0.026	0.028	2.30	7.7	4	12.6	0.32	2.65	0.054	2.8
12 Oct 2016	1115	190	8.786	0.035	0.016	2.25	7.8	4	14.3	0.08	2.35	0.067	3.4
09 Nov 2016	1140	1000	8.326	0.064	0.035	1.60	7.7	7	15.8	0.55	2.18	0.117	5.0
14 Dec 2016	1050	220	3.785	0.024	0.009	1.56	7.9	3	16.1	0.22	1.79	0.065	2.5
11 Jan 2017	1100	180	1.950	0.024	0.012	1.17	8.2	<2	19.7	0.12	1.30	0.075	2.3
08 Feb 2017	1055	380	1.975	0.020	0.009	0.87	8.0	13	18.6	0.35	1.23	0.087	1.6
08 Mar 2017	1100	750	1.288	<0.003	0.008	0.53	7.9	3	15.8	0.23	0.77	0.057	1.5
13 Apr 2017	1140	760	9.084	0.039	0.018	1.96	7.7	5	16.2	0.35	2.33	0.087	3.4
10 May 2017	1150	240	6.370	0.026	0.015	2.11	7.8	4	13.6	0.38	2.50	0.062	2.6
14 Jun 2017	1135	230	6.591	0.032	0.013	2.65	7.7	11	10.9	0.18	2.84	0.075	5.1

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

Table 25 Statistical summary of data from July 2016 to June 2017: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.015	0.048	0.026	12	0.009
A440F	Absorbance @ 440nm Filtered	/cm	0.003	0.011	0.006	12	0.002
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.002	0.000	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	31	58	37	12	9
BDISC	Black disc transparency	m	0.70	2.04	1.34	12	0.4
BOD_5	Biochemical oxygen demand 5day	g/m3	0.6	2.5	1.2	12	0.6
CONDY	Conductivity @ 20'C	mS/m	13.5	18.4	16	12	1.4
DO	Dissolved Oxygen	g/m3	9.7	12.0	10.3	12	0.8
PERSAT	Dissolved Oxygen Saturation %	%	100	110	102	12	3
DRP	Dissolved reactive phosphorus	g/m3P	0.016	0.070	0.040	12	0.014
ECOL	E.coli bacteria	cfu/100 mL	80	1000	225	12	302
ENT	Enterococci bacteria	cfu/100 mL	17	1900	135	12	663
FC	Faecal Coliforms	cfu/100 mL	80	1000	225	12	305
FLOW	Flow	m3/s	1.288	12.994	6.48	12	3.491
NH_4	Ammoniacal nitrogen	g/m3N	<0.003	0.064	0.026	12	0.016
NO_2	Nitrite nitrogen	g/m3N	0.008	0.053	0.014	12	0.013
NO_3	Nitrate nitrogen	g/m3N	0.53	2.70	2.03	12	0.69
PH	pH		7.6	8.2	7.8	12	0.2
SS	Suspended solids	g/m3	<2	13	4	12	3
TEMP	Temperature	°C	8.2	19.7	15	12	3.7
TKN	Total Kjeldahl nitrogen	g/m3N	0.08	0.55	0.26	12	0.13
TN	Total nitrogen	g/m3N	0.77	3.03	2.34	12	0.70
TP	Total phosphorus	g/m3P	0.054	0.117	0.068	12	0.018
TURBY	Turbidity	NTU	1.5	5.1	3.0	12	1.3

This was the nineteenth 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 2017: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.078	0.032	228	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.019	0.007	228	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	228	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	21	62	39	228	9
BDISC	Black disc transparency	m	0.12	4.34	1.195	228	0.586
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	6.7	1.0	228	0.8
CONDY	Conductivity @ 20˚C	mS/m	9.8	23.2	16.4	228	2.2
DO	Dissolved oxygen	g/m^3	8.4	12.9	10.5	228	0.8
PERSAT	Dissolved oxygen saturation %	%	89	141	102	228	6
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.015	0.223	0.054	228	0.033
ECOL	E.coli bacteria	cfu/100 mL	3	41000	220	227	3147
ENT	Enterococci bacteria	cfu/100 mL	6	5900	150	228	711
FC	Faecal coliforms	cfu/100 mL	3	41000	220	228	3142
FLOW	Flow	m^3/s	0.997	50.341	4.840	228	6.659
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.305	0.032	228	0.040
NO_2	Nitrite nitrogen	g/m^{3}N	0.003	0.132	0.020	228	0.019
NO_3	Nitrate nitrogen	g/m^{3}N	0.48	2.98	1.87	228	0.55
pH	pH		7.2	9.1	7.8	228	0.3
SS	Suspended solids	g/m^3	<2	120	5	228	15
TEMP	Temperature	°C	5.4	22.0	13.8	228	3.7
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.00	1.51	0.38	228	0.24
TN	Total nitrogen	g/m^{3}N	0.55	3.62	2.39	228	0.61
TP	Total phosphorus	g/m^{3}P	0.042	0.325	0.094	228	0.049
TURB	Turbidity (Hach 2100A)	NTU	1.0	36	2.3	209	4.0
TURBY	Turbidity (Cyberscan WTW)	NTU	0.8	56	3.2	145	5.9

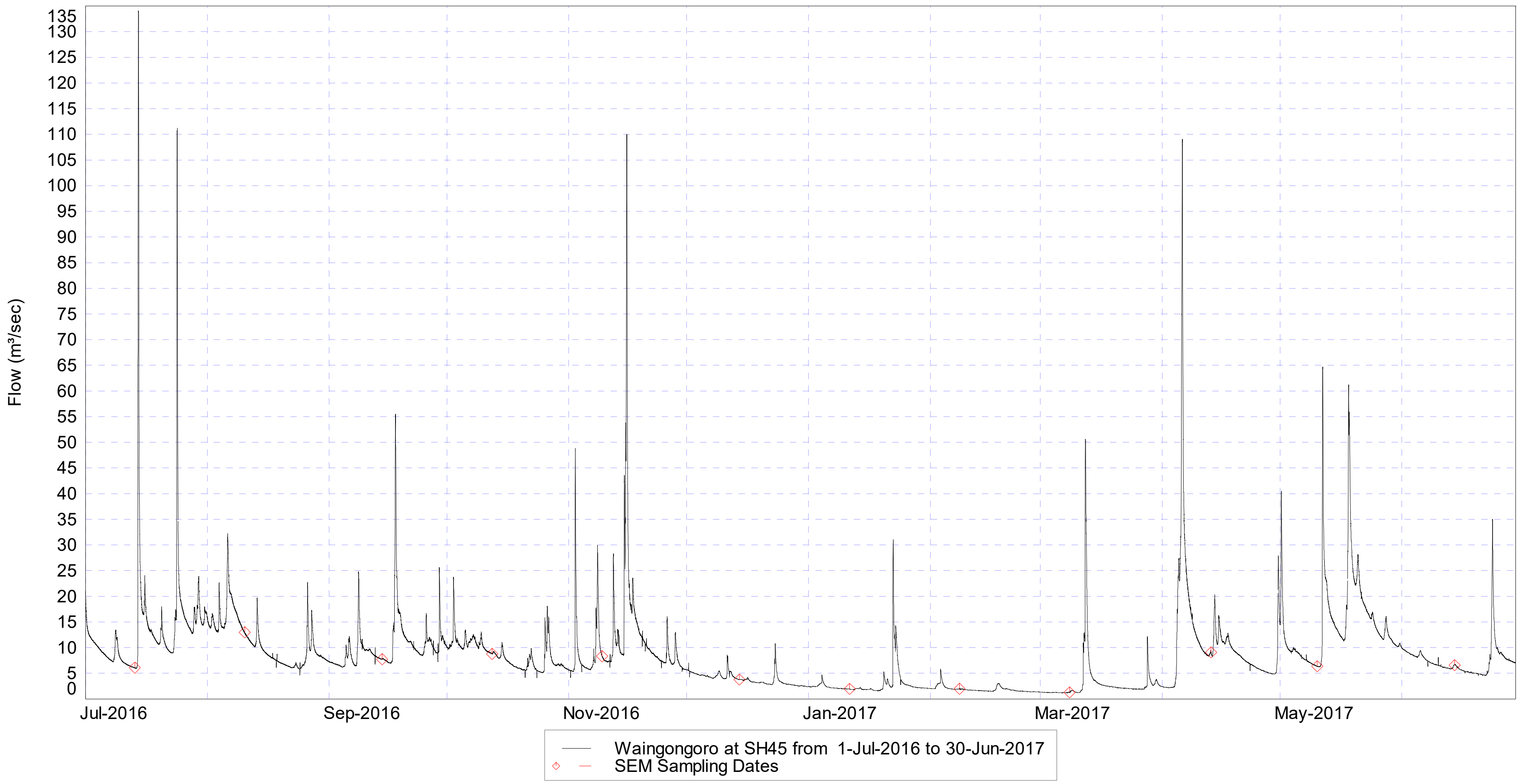


Figure 5 Flow record for the Waingongoro River at SH45

Discussion

2016-2017 period

Relatively poor aesthetic water quality was indicated by a median black disc clarity of 1.34 m and median turbidity of 3.0 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 2.04 m) was recorded in mid-summer during low flow conditions (1.95 m^3/s). The minimum clarity of 0.88 m was recorded during a moderate fresh in August 2016 (Figure 5). Poorest water quality conditions were apparent at times of fresh flows, when elevated bacterial numbers, nutrients, and/or discolouration, and decreased clarity were typical.

pH reached 8.2 in mid-summer under low flow conditions coincidental with highest dissolved oxygen saturation levels (110 %), although it would be expected that pH would have risen further during summer/autumn later in the day (i.e. after 1100 NZST), than values recorded at the earlier sampling times.

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 100% saturation) and moderately low BOD_5 levels (median: 1.2 g/m^3). Bacteriological quality was relatively poor at this site, with numbers typical for the lower reaches of developed ring plain catchments, subject to agricultural impacts, with median faecal coliform and enterococci numbers of 225 and 135 (cfu/100 mL) respectively. These numbers reflected, to some degree, the relative lack of proximity of preceding river freshes on 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 11.5 ˚C with a maximum mid-summer (late morning) river temperature of 19.7 ˚C recorded in January 2017.

Brief comparison of upper and lower Waingongoro River sites during the 2016-2017 period

Downstream deterioration in aspects of water quality over the 40 km length between the mid reaches and the lower reaches of the river was emphasised by more turbid conditions [lower median black disc clarity by 0.28 m (17 % decrease), increased median turbidity level (by 1.2 NTU), and an increase in median suspended solids concentration of 1 g/m^3]. Bacteriological quality, in terms of the median faecal coliform count, remained poor (lower by 25 cfu/100 mL) at the lower river site whereas the median enterococci count deteriorated by 62 cfu/100 mL (compared with historical median deteriorations of 30 cfu/100 mL for faecal coliforms and 50 cfu/100 mL for enterococci). The lower river site's pH range was the same over the 2016-2017 period, as was the median, maximum and minimum recorded pH levels.

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 27 % to 117%) compared with upstream concentrations. Historical (1998-2016) median data also indicate from 58% to 170% increases in nutrient species concentrations in a downstream direction.

Water temperature range was slightly larger (by 1.3 ˚C) at the lower site and median water temperature was 1.2 ˚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 1.1 ˚C and ranges have been wider by 0.7 ˚C. Median flow increased by 237 % at the lower reach site in the 2016-2017 period compared with 202% over the previous eighteen-year period.

Brief comparison with the previous 1998-2016 period

The most recent twelve-month period sampled a narrower range of flow conditions and the median sampled flow was higher by 1,678 L/s, or 35%, than that sampled over the previous eighteen-year period. This was due in part to several freshes.

Water clarity at the time of sampling was improved, with the medians for suspended solids lower by 1 g/m^3, turbidity lower by 0.2 NTU, and black disc clarity higher by 0.16 m in the 2016-2017 period.

Median faecal coliform bacterial number showed a slight deterioration, by 5 cfu/100 mL, but enterococci improved, by 15 cfu/100 mL. While pH median values were the same, a much narrower range (by 1.3 unit) 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 eighteen-year period. Dissolved oxygen saturation median value was the same. Both median phosphorus species nutrient levels reduced (by 26 % to 30 %) in the recent one year period and all of the median nitrogen nutrient species' levels were also lower, by 2 to 24%.

The 2016-2017 range in water temperatures was much narrower (by 5.1 ˚C) due to a higher minimum temperature (by 2.8 ˚C) and lower maximum temperature (by 2.3 ˚C) while the median was 1.3 ˚C higher in the 2016-2017 sampling period than that recorded over the previous eighteen-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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100mL	cfu/100mL
13 Jul 2016	1345	0.011	0.002	0.000	24	2.26	<0.5	6.5	11.5	99	0.024	6	<1
10 Aug 2016	1320	0.009	0.002	0.000	19	3.85	<0.5	5.7	12.3	101	0.013	5	<1
14 Sep 2016	1300	0.01	0.002	0.000	20	4.84	0.5	6.2	11.3	100	0.017	3	3
12 Oct 2016	1215	0.013	0.003	0.000	20	3.05	<0.5	5.9	10.4	100	0.022	23	5
09 Nov 2016	1255	0.024	0.003	0.000	14	2.22	<0.5	4.9	10.2	100	0.013	8	1
14 Dec 2016	1200	0.017	0.004	0.000	19	2.25	<0.5	5.9	10.3	100	0.017	94	25
11 Jan 2017	1205	0.016	0.004	0.001	28	4.08	<0.5	6.5	9.8	100	0.026	16	4
08 Feb 2017	1205	0.017	0.004	0.000	25	4.84	<0.5	6.4	10.2	100	0.024	120	39
08 Mar 2017	1240	0.022	0.005	0.000	27	3.16	<0.5	7.0	10.6	102	0.038	29	40
13 Apr 2017	1315	0.051	0.012	0.001	15	2.50	<0.5	4.6	9.9	100	0.018	1900	1600
10 May 2017	1310	0.012	0.003	0.000	24	5.66	<0.5	6.5	11.0	101	0.026	3	4
14 Jun 2017	1305	0.032	0.008	0.001	16	1.96	<0.5	5.9	11.6	102	0.020	8	3
Date	Time NZST	FC	Flow	NH4	NO2	NO3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m3/s	g/m3N	g/m3N	g/m3N	pH	g/m3	°C	g/m3N	g/m3N	g/m3P	NTU
13 Jul 2016	1345	6	0.204	0.003	<0.001	0.04	7.5	<2	6.4	0.01	0.05	0.026	0.5
10 Aug 2016	1320	5	0.235	0.003	<0.001	0.05	7.4	<2	4.9	0.01	0.06	0.014	0.3
14 Sep 2016	1300	3	0.243	0.003	<0.001	0.02	7.5	<2	7.8	0.04	0.06	0.017	0.5
12 Oct 2016	1215	23	0.235	0.003	<0.001	0.02	7.5	<2	10.4	0.06	0.08	0.022	0.4
09 Nov 2016	1255	8	0.347	0.006	<0.001	0.01	7.4	<2	12.1	0.05	0.06	0.020	0.4
14 Dec 2016	1200	94	0.252	0.006	<0.001	<0.01	7.5	3	11.4	0.04	0.04	0.022	0.6
11 Jan 2017	1205	16	0.153	0.008	<0.001	<0.01	7.7	<2	13.6	0.02	0.02	0.041	0.5
08 Feb 2017	1205	130	0.193	0.003	<0.001	0.02	7.6	7	12.3	0.01	0.05	0.030	0.4
08 Mar 2017	1240	31	0.146	0.003	<0.001	0.01	7.8	<2	10.7	0.04	0.05	0.040	0.5
13 Apr 2017	1315	2100	0.647	0.003	<0.001	0.02	7.3	<2	12.5	0.13	0.15	0.028	1.0
10 May 2017	1310	3	0.194	0.010	<0.001	0.04	7.5	<2	9.2	0.04	0.08	0.026	0.5
14 Jun 2017	1305	8	0.420	0.003	0.001	0.02	7.5	<2	7.4	0.04	0.06	0.029	1.5

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

Table 28 Statistical summary of data from July 2016 to June 2017: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.051	0.016	12	0.012
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.012	0.004	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	14	28	20	12	5
BDISC	Black disc transparency	m	1.96	5.66	3.1	12	1.24
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	<0.5	0.2	12	0
CONDY	Conductivity @ 20˚C	mS/m	4.6	7.0	6	12	0.7
DO	Dissolved oxygen	g/m³	9.8	12.3	10.5	12	0.8
PERSAT	Dissolved oxygen saturation %	%	99	102	100	12	1
DRP	Dissolved reactive phosphorus	g/m³P	0.013	0.038	0.021	12	0.007
ECOL	E.coli bacteria	cfu/100 mL	3	1900	12	12	542
ENT	Enterococci bacteria	cfu/100 mL	<1	1600	4	12	459
FC	Faecal coliforms	cfu/100 mL	3	2100	12	12	599
FLOW	Flow	m³/s	0.146	0.647	0.235	12	0.141
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.010	0.002	12	0.002
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.001	<0.001	12	0
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.05	0.02	12	0.015
pH	pH		7.3	7.8	7.5	12	0.1
SS	Suspended solids	g/m³	<2	7	1	12	1
TEMP	Temperature	°C	4.9	13.6	10.6	12	2.7
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	<0.13	0.04	12	0.03
TN	Total nitrogen	g/m³N	<0.05	0.15	0.06	12	0.03
TP	Total phosphorus	g/m³P	0.014	0.041	0.026	12	0.008
TURBY	Turbidity	NTU	0.29	1.5	0.5	12	0.3

A statistical summary of the 22 years' data collected since 1 July 1995, is presented in Table 29.

Table 29 Statistical summary of data from July 1995 to June 2017: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.006	0.112	0.016	264	0.021
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.024	0.004	264	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	264	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	3	34	22	263	7.1
BDISC	Black disc transparency	m	0.09	10.14	4.34	263	1.812
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	3.7	0.2	264	0.3
CONDY	Conductivity @ 20˚C	mS/m	2.5	8.2	6.2	264	1.3
DO	Dissolved oxygen	g/m³	9.1	12.4	10.6	264	0.7
PERSAT	Dissolved oxygen saturation %	%	90	103	99	264	2
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.042	0.018	264	0.008
ECOL	E.coli bacteria	cfu/100 mL	<1	10000	21	240	715
ENT	Enterococci bacteria	cfu/100 mL	<1	2200	8	264	192
FC	Faecal coliforms	cfu/100 mL	<1	10000	21	264	715
FLOW	Flow	m³/s	0.084	18	0.216	264	1.465
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.057	<0.003	264	0.006
NO_2	Nitrite nitrogen	g/m³N	<0.001	<0.003	<0.001	264	<0.000
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.14	0.02	264	0.017
pH	pH		6.5	8.0	7.5	264	0.2
SS	Suspended solids	g/m³	<2	160	<2	264	11
TEMP	Temperature	°C	3.7	14.9	9.2	264	2.5
TKN	Total kjeldahl nitrogen	g/m³N	0.00	2.70	0.05	264	0.20
TN	Total nitrogen	g/m³N	<0.05	2.72	0.08	264	0.20
TP	Total phosphorus	g/m³P	0.008	0.281	0.024	264	0.022
TURB	Turbidity (Hach 2100A)	NTU	0.3	31	0.6	245	2.2
TURBY	Turbidity (Cyberscan WTW)	NTU	0.2	4.2	0.6	144	0.6

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

2015-2016 period

Aesthetic water quality was high, as emphasised by median black disc and turbidity values of 3.1 m and 0.5 NTU respectively. The lowest black disc clarity (1.96 m) and highest turbidity were recorded in June 2017, coincident with a small rainfall event but no measureable increase in suspended solids, BOD or bacterial levels.

Maximum pH (7.8) at this shaded site was measured under very low flow conditions. pH range however was relatively narrow under all flow conditions (varying by only 0.5 unit) over the period, although measurements were confined to near midday.

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 relatively high (median faecal coliform and enterococci numbers of 12 and 4 cfu/100 mL respectively). There was no 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. Elevated bacterial counts were returned for the April 2017 sampling, during a small fresh, with increase in colour, but no measureable increase in BOD or suspended solids was recorded.

River water temperatures varied over a moderate range (8.7 ˚C) at this relatively shaded site during the period. A maximum mid-day temperature of 13.6 ˚C was recorded under very low flow conditions in January 2017.

Brief comparison with the previous 1995-2016 period

A much narrower range and a lower median of river flows was sampled during the 2016-2017 period, with no significant fresh sampled, in comparison with the previous 21-year period. Median flow for the 2016-2017 sampling occasions was 20 L/s, or 9%, higher than the median of sampled flows over the previous 21-year period. Aesthetic river water quality was slightly lower in terms of median turbidity and median black disc clarity during the 2016-2017 period. Median suspended solids concentrations were very low (below 2 g/m^3) in both periods.

Median nutrient species levels were comparatively similar between the two periods, although there was a small increase in median dissolved reactive phosphorus concentration (of 17%) over the latest twelve-month sampling period. Total nitrogen reduced at low level, possibly related to the higher flows.

Median faecal coliform bacterial number decreased (by 9 cfu/100 mL) and median enterococci number decreased (by 4 cfu/100 mL) over the recent sampling period. Median pH values were the same, while the maximum pH value was only 0.2 unit lower in the 2016-2017 period.

Median water temperature over the past twelve-month period was 1.4 ˚C higher than the median for the previous 21-year period; the maximum temperature was 1.3˚C lower, and the minimum temperature was 1.2 ˚C higher in the latest period. Therefore, a narrower range of temperatures (by 2.5 °C) was recorded in the 2016-2017 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	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
		/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100mL	cfu/100mL
13 Jul 2016	1425	0.015	0.003	0.000	27	1.80	0.5	10.3	11.6	102	0.028	80	32
10 Aug 2016	1425	0.011	0.002	0.000	26	2.26	<0.5	9.8	11.5	101	0.018	200	76
14 Sep 2016	1400	0.016	0.003	0.000	26	2.06	1.0	9.8	11.3	107	0.025	150	28
12 Oct 2016	1305	0.029	0.009	0.000	25	0.68	2.6	9.4	10.0	99	0.034	19000	2400
09 Nov 2016	1335	0.020	0.004	0.000	25	1.69	0.8	8.9	10.0	103	0.036	92	41
14 Dec 2016	1305	0.024	0.005	0.001	28	1.42	0.8	9.3	10.5	108	0.029	220	35
11 Jan 2017	1305	0.027	0.007	0.001	35	2.39	1.3	10.9	10.5	117	0.045	88	21
08 Feb 2017	1320	0.031	0.008	0.001	31	1.79	0.9	9.6	10.6	111	0.046	540	310
08 Mar 2017	1340	0.035	0.008	0.000	33	1.50	1.7	9.8	11.0	112	0.057	1700	1600
13 Apr 2017	1340	0.029	0.007	0.000	27	1.11	1.0	9.9	9.6	100	0.040	2200	1200
10 May 2017	1400	0.011	0.002	0.000	29	2.77	0.9	10.5	10.8	106	0.036	120	88
14 Jun 2017	1400	0.017	0.004	0.000	29	1.74	1.3	10.5	11.9	108	0.033	280	100

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
13 Jul 2016	1425	84	3.566	0.053	0.013	1.21	7.7	<2	8.2	0.13	1.35	0.037	1.6
10 Aug 2016	1425	200	5.716	0.058	0.008	1.37	7.6	<2	8.8	0.02	1.40	0.032	1.4
14 Sep 2016	1400	150	3.858	0.060	0.013	1.05	8.0	<2	12.3	0.15	1.21	0.037	1.6
12 Oct 2016	1305	19000	5.968	0.139	0.022	1.09	7.6	7	13.3	0.55	1.66	0.107	6.8
09 Nov 2016	1335	92	5.260	0.111	0.016	0.97	7.7	5	15.4	0.23	1.22	0.055	1.5
14 Dec 2016	1305	220	2.401	0.045	0.016	0.75	8.0	<2	15.4	0.08	0.85	0.046	1.2
11 Jan 2017	1305	92	1.132	0.016	0.020	0.71	8.4	<2	19.4	0.05	0.78	0.068	1.2
08 Feb 2017	1320	540	1.923	0.020	0.025	0.77	8.2	33	16.7	0.08	0.87	0.073	1.4
08 Mar 2017	1340	1700	1.309	0.010	0.017	0.65	8.5	3	14.8	0.14	0.81	0.088	2.3
13 Apr 2017	1340	2300	4.812	0.080	0.016	1.10	7.5	3	15.6	0.26	1.38	0.072	2.7
10 May 2017	1400	160	3.310	0.038	0.014	1.09	7.8	<2	13.6	0.18	1.28	0.047	1.4
14 Jun 2017	1400	290	2.756	0.087	0.017	1.05	7.7	<2	9.9	0.12	1.19	0.054	2.4

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

.

Table 31 Statistical summary of data from July 2016 to June 2017: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.011	0.035	0.022	12	0.008
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.009	0.004	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	25	35	28	12	3
BDISC	Black disc transparency	m	0.68	2.77	1.76	12	0.57
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	2.6	1.0	12	0.6
CONDY	Conductivity @ 20˚C	mS/m	8.9	10.9	9.8	12	0.6
DO	Dissolved oxygen	g/m^3	9.6	11.9	10.7	12	0.7
PERSAT	Dissolved oxygen saturation %	%	99	117	106	12	5
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.018	0.057	0.035	12	0.010
ECOL	E.coli bacteria	cfu/100 mL	80	19000	210	12	5381
ENT	Enterococci bacteria	cfu/100 mL	21	2400	82	12	795
FC	Faecal coliforms	cfu/100 mL	84	19000	210	12	5380
FLOW	Flow	m^3/s	1.132	5.968	3.438	12	1.669
NH_4	Ammoniacal nitrogen	g/m^{3}N	0.010	0.139	0.056	12	0.039
NO_2	Nitrite nitrogen	g/m^{3}N	0.008	0.025	0.016	12	0.004
NO_3	Nitrate nitrogen	g/m^{3}N	0.653	1.372	1.05	12	0.22
pH	pH		7.5	8.5	7.8	12	0.3
SS	Suspended solids	g/m^3	<2	33	<2	12	9
TEMP	Temperature	°C	8.2	19.4	14.2	12	3.3
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.02	0.55	0.14	12	0.14
TN	Total nitrogen	g/m^{3}N	0.78	1.66	1.22	12	0.28
TP	Total phosphorus	g/m^{3}P	0.032	0.107	0.054	12	0.023
TURB	Turbidity	NTU	1.2	6.8	1.6	12	1.6

A statistical summary of the 22 years' data collected since 1 July 1995 is presented in Table 32.

Table 32 Statistical summary of data from July 1995 to June 2017: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.095	0.023	264	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.023	0.005	264	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	264	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	10	57	28	264	6
BDISC	Black disc transparency	m	0.05	4.68	1.82	264	0.82
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	16	0.9	264	1.4
CONDY	Conductivity @ 20˚C	mS/m	5.0	14.3	9.9	264	1.4
DO	Dissolved oxygen	g/m^3	8.9	12.9	10.6	264	0.7
PERSAT	Dissolved oxygen saturation %	%	87	121	103	264	6
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.010	0.160	0.037	264	0.030
ECOL	E.coli bacteria	cfu/100 mL	2	25000	200	240	3277
ENT	Enterococci bacteria	cfu/100 mL	4	19000	110	264	1683
FC	Faecal coliforms	cfu/100 mL	2	63000	220	264	5043
FLOW	Flow	m^3/s	0.65	77.53	2.940	264	7.316
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.329	0.052	264	0.05
NO_2	Nitrite nitrogen	g/m^{3}N	<0.001	0.051	0.016	264	0.008
NO_3	Nitrate nitrogen	g/m^{3}N	0.21	1.54	0.92	264	0.22
pH	pH		6.9	8.8	7.8	264	0.4
SS	Suspended solids	g/m^3	<2	360	<2	264	27
TEMP	Temperature	°C	5.3	22.3	13.0	264	3.4
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.01	4.07	0.23	264	0.35
TN	Total nitrogen	g/m^{3}N	0.41	4.50	1.23	264	0.34
TP	Total phosphorus	g/m^{3}P	0.022	1.390	0.066	264	0.107
TURB	Turbidity (Hach 2100A)	NTU	0.2	80	1.5	245	6.9
TURBY	Turbidity (Cyberscan WTW)	NTU	0.9	21	1.7	145	3.0

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.

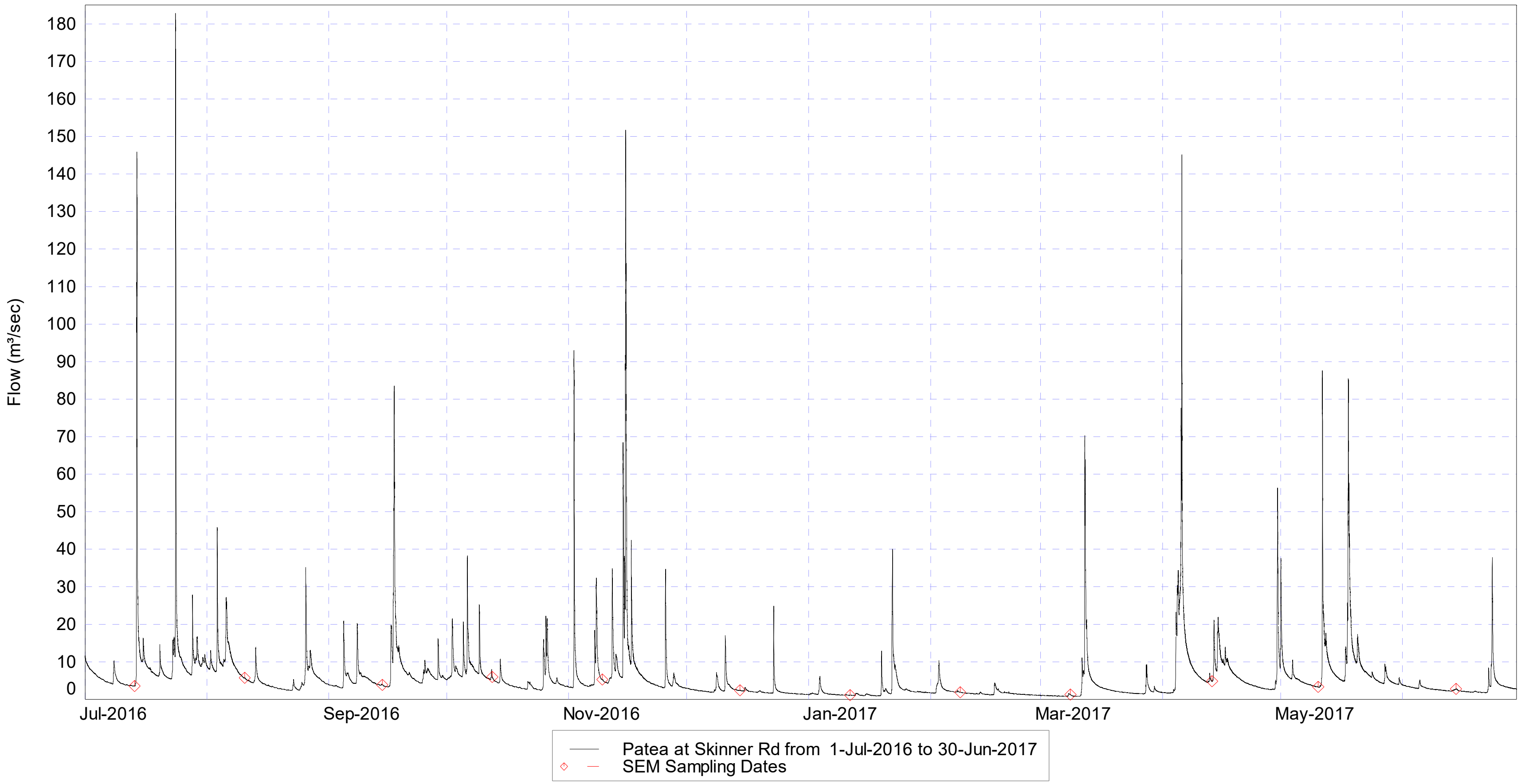


Figure 6 Flow record for the Patea River at Skinner Road

Discussion

2016-2017 period

Moderate median black disc clarity (1.76 m) 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. Minimum clarity (black disc of 0.68 m and turbidity of 6.8 NTU) and small increase in suspended solids concentrations (7 g/m^3) were recorded on the falling stage of a small fresh sampled in October 2016 (Figure 7). Deterioration in water quality during this event was also illustrated by high bacterial numbers.

Early afternoon pH levels reached a maximum of 8.4 units in mid-summer coincident with dissolved oxygen saturation peaking at 117%. Dissolved oxygen levels were consistently high (99% or higher saturation) with supersaturation recorded particularly during early-spring to early autumn low flow conditions coincident with more extensive algal cover and elevated pH levels (≥ 8.0 units). BOD_5 concentrations under normal to low recession flow conditions were generally indicative of moderately low organic contamination (i.e. up to 1.3 g/m^3), with higher oxygen demand during freshes (i.e. up to 2.6 g/m^3).

The moderately poor median bacteriological numbers (210 faecal coliforms and 82 enterococci cfu/100 mL) 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 moderat 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, together with other point source and non-point source discharges.

Water temperatures varied over a moderately wide range of 11.2 °C with a maximum (early afternoon) summer temperature of 19.4 ˚C recorded in January 2017 (coincident with a pH of 8.4 and 117% dissolved oxygen saturation).

Brief comparison of upper and mid Patea River catchment sites during the 2016-2017 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 (17 to 21-fold increases) and increases in median nutrient species concentrations (1.7 to 53-fold) compared with historical (21-year) downstream increase in median bacterial numbers (10 to 14-fold) and nutrient species concentrations (2 to 48 fold). The pH range increased by 0.5 unit at the Skinner Road site with a maximum pH 0.7 unit higher than at the upstream site. A moderate increase in median turbidity levels (1.1 NTU) was measured in mid catchment, almost identical to the historical median increase. Median BOD_5 increased by about 0.5 g/m^3 although maximum BOD_5 was 2.0 g/m^3 higher downstream. A deterioration in black disc clarity (median clarity decreased significantly by 1.34 m and maximum clarity to a larger degree by 2.89 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 a 21-year median black disc deterioration of 2.55 m and maximum clarity deterioration of 5.46 m.

Water temperature range increased (by 2.5 ˚C) at the Skinner Road site, where median water temperature was higher (by 3.6 ˚C) and maximum water temperature was higher (by 5.8 ˚C) than at the Barclay Road site. In comparison, the historical 21-year median and maximum water temperatures have shown downstream increases of 3.7 ˚C and 7.4 ˚C respectively.

Brief comparison with the previous 1995-2016 period

The median of sampled flows in the recent twelve-month period was 545 L/s, or 19%, higher than the median of flows sampled over the 1995-2016 period due largely to more, mostly small, freshes sampled in the 2016-2017 year, though the range of river flows sampled was much narrower in the most recent period. Aesthetic water quality was similar to historical conditions with median black disc clarity lower by 0.07 m, with some reduction in the median suspended solids concentrations (<2 g/m^3) and minimal difference in turbidity (0.1 NTU) between periods.

There was a narrower pH range (by 0.9 pH unit) and lower maximum pH (by 0.3 pH unit) during the 2016-2017 period. Median dissolved oxygen percentage saturation was higher by an insignificant 3% in the 2016-2017 period.

Bacterial water quality was improved for both faecal coliform and enterococci bacteria during the more recent sampling period, with the median numbers decreasing by 15 and 38 cfu/100 mL, respectively. Variability in municipal oxidation ponds' system performance and dairy shed wastes disposal would have been expected to have contributed to any differences in bacterial quality between periods, together with more sampling during or after freshes, when contamination from pasture run-off may occur, in the recent period.

Water temperature range was narrower (by 5.8 ˚C) during the more recent sampling period although the median water temperature was 1.3 ˚C higher than the longer term median. The maximum water temperature was 2.9 °C lower than previously recorded and the minimum water temperature was higher (by 2.9 ˚C) in the latest twelve-month period.

Median BOD_5 was slightly higher during the more recent period (by 0.1 g/m^3), and all median nutrient species showed decreases or no change (ranging from 0% to 18%), except nitrate, which increased (by 15%).

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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100mL	cfu/100mL
13 Jul 2016	1505	0.045	0.008	0.000	40	0.75	<0.5	10.6	12.0	99	0.007	54	15
10 Aug 2016	1500	0.028	0.005	0.000	29	0.54	<0.5	8.6	11.8	99	0.005	80	31
14 Sep 2016	1445	0.036	0.007	0.000	34	1.12	<0.5	9.5	10.9	100	0.005	160	47
12 Oct 2016	1345	0.041	0.011	0.001	30	0.28	0.5	8.5	9.8	97	0.008	790	150
09 Nov 2016	1400	0.067	0.013	0.001	24	0.29	0.8	7.1	9.9	101	0.005	580	140
14 Dec 2016	1340	0.064	0.013	0.001	44	0.84	0.5	11.0	10.1	106	0.004	240	71
11 Jan 2017	1340	0.058	0.013	0.001	54	1.86	0.5	12.8	9.8	111	0.004	200	62
08 Feb 2017	1350	0.064	0.015	0.001	45	1.22	<0.5	10.9	9.5	102	0.003	630	420
08 Mar 2017	1415	0.057	0.011	0.000	56	1.20	1.1	12.7	10.0	106	0.006	630	700
13 Apr 2017	1425	0.050	0.010	0.000	39	0.42	0.6	10.1	9.5	98	0.005	1900	970
10 May 2017	1435	0.048	0.010	0.000	41	1.36	<0.5	10.3	10.9	103	0.006	130	40
14 Jun 2017	1435	0.036	0.007	0.000	42	0.41	<0.5	11.0	11.2	100	0.007	540	670
Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
13 Jul 2016	1505	54	5.252	0.063	0.003	0.22	7.6	4	6.8	0.09	0.31	0.019	5.4
10 Aug 2016	1500	80	14.588	0.022	0.002	0.37	7.4	21	7.5	0.11	0.48	0.038	13
14 Sep 2016	1445	160	14.884	0.017	0.002	0.23	7.4	8	11.1	0.11	0.34	0.020	7.3
12 Oct 2016	1345	820	18.877	0.016	0.002	0.21	7.5	37	13.9	0.25	0.46	0.068	23
09 Nov 2016	1400	580	17.070	0.010	0.002	0.10	7.5	46	16.1	0.30	0.40	0.068	30
14 Dec 2016	1340	240	7.528	0.005	0.002	0.03	8.0	<2	17.6	0.10	0.13	0.012	3.2
11 Jan 2017	1340	200	4.912	0.006	0.002	0.00	8.1	<2	20.4	0.12	0.12	0.014	2.3
08 Feb 2017	1350	640	9.668	0.012	0.002	0.02	7.9	4	18.8	0.12	0.14	0.017	4.3
08 Mar 2017	1415	630	9.592	<0.003	0.001	0.01	8.1	4	17.7	0.14	0.15	0.025	3.8
13 Apr 2017	1425	1900	12.078	0.012	0.002	0.16	7.6	28	15.9	0.18	0.34	0.042	18
10 May 2017	1435	130	7.970	0.009	0.003	0.16	7.7	3	12.6	0.09	0.25	0.188	3.8
14 Jun 2017	1435	550	12.662	0.022	0.004	0.17	7.6	18	10.0	0.11	0.28	0.049	15

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

Table 34 Statistical summary of data from July 2016 to June 2017: Mangaehu River at Raupuha Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.028	0.067	0.049	12	0.013
A440F	Absorbance @ 440nm filtered	/cm	0.005	0.015	0.01	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	24	56	40	12	10
BDISC	Black disc transparency	m	0.28	1.86	0.8	12	0.5
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.1	0.4	12	0.2
CONDY	Conductivity @ 20°C	mS/m	7.1	12.8	10.4	12	1.7
DO	Dissolved oxygen	g/m^3	9.5	12.0	10	12	0.9
PERSAT	Dissolved oxygen saturation %	%	97	111	100	12	4
DRP	Dissolved reactive phosphorus	g/m^3P	0.003	0.008	0.005	12	0.001
ECOL	E.coli bacteria	cfu/100 mL	54	1900	390	12	511
ENT	Enterococci bacteria	cfu/100 mL	15	970	106	12	330
FC	Faecal coliforms	cfu/100 mL	54	1900	395	12	513
FLOW	Flow	m^3/s	4.912	18.877	10.873	12	4.523
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.063	0.012	12	0.016
NO_2	Nitrite nitrogen	g/m^3N	0.001	0.004	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m^3N	0.003	0.368	0.158	12	0.111
pH	pH		7.4	8.1	7.6	12	0.3
SS	Suspended solids	g/m^3	<2	46	6	12	15
TEMP	Temperature	°C	6.8	20.4	14.9	12	4.5
TKN	Total kjeldahl nitrogen	g/m^3N	0.09	0.30	0.11	12	0.07
TN	Total nitrogen	g/m^3N	0.12	0.48	0.3	12	0.13
TP	Total phosphorus	g/m^3P	0.012	0.188	0.032	12	0.049
TURBY	Turbidity	NTU	2.3	30	6.4	12	9.1

A statistical summary of the 22 years' data collected since 1 July 1995 is presented in Table 35.

Table 35 Statistical summary of data from July 1995 to June 2017: Mangaehu River at Raupuha Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.027	0.181	0.054	264	0.018
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.056	0.011	264	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.025	0.000	264	0.002
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	9	79	39	264	13
BDISC	Black disc transparency	m	<0.01	4.04	0.85	264	0.738
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	5.6	0.6	264	0.6
CONDY	Conductivity @ 20°C	mS/m	4.3	16.1	9.9	264	2.3
DO	Dissolved oxygen	g/m^3	7.7	12.9	10	264	0.9
PERSAT	Dissolved oxygen saturation %	%	83	118	100	264	5
DRP	Dissolved reactive phosphorus	g/m^3P	<0.003	0.026	0.006	264	0.003
ECOL	E.coli bacteria	cfu/100 mL	6	16000	220	240	1835
ENT	Enterococci bacteria	cfu/100 mL	1	7200	69	264	834
FC	Faecal coliforms	cfu/100 mL	6	16000	230	264	1959
FLOW	Flow	m^3/s	1.658	111.870	7.062	264	15.390
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.081	0.012	264	0.011
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.016	0.002	264	0.001
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.43	0.10	264	0.09
pH	pH		6.8	8.4	7.7	264	0.3
SS	Suspended solids	g/m^3	<2	1300	4	264	117
TEMP	Temperature	°C	4.3	24.9	13.9	264	4.3
TKN	Total kjeldahl nitrogen	g/m^3N	0.02	2.47	0.16	264	0.29
TN	Total nitrogen	g/m^3N	<0.05	2.72	0.295	264	0.32
TP	Total phosphorus	g/m^3P	<0.003	0.786	0.020	264	0.101
TURB	Turbidity (Hach 2100A)	NTU	1.4	850	3.5	245	63
TURBY	Turbidity (Cyberscan WTW)	NTU	0.8	390	4.3	145	46

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.

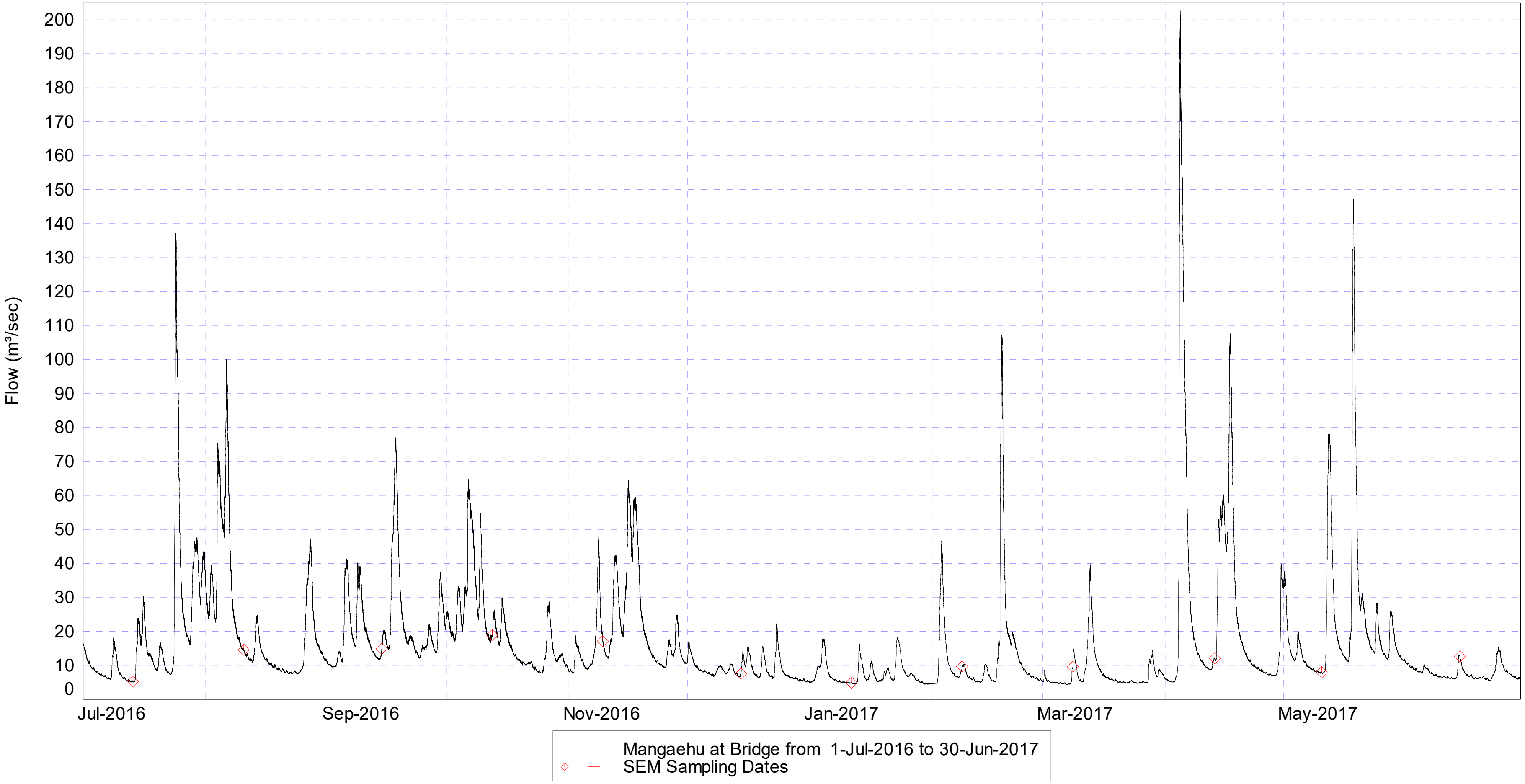


Figure 7 Flow record for the Mangaehu River at Raupuha Road

Discussion

2016-2017 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 0.80 metres with a maximum of 1.86 metres measured under a short receding flow period in January 2017. Clarity was infrequently more than 1.5 metres (on one occasion) due to the presence of very fine, colloidal, suspended particles. The median suspended solids concentration was 6 g/m^3 which was typical for this river. 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 (0.28 and 0.29 m black disc values) were coincident with turbidity levels of 23 and 30 NTU and suspended solids concentrations of 37 and 46 g/m^3, during flood flows of 19 and 17 m^3/s recorded in October and November 2016, 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 August, September, October and November 2016 and April and June 2017; Figure 7).

Maximum mid-afternoon pH values in the summer period (7.9 to 8.1 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. A minimum pH (7.4 units) was found under flood conditions in August and September 2016.

Dissolved oxygen concentrations, were consistently high (median of 10.0 g/m^3) with a median saturation level of 100%. 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 (106 enterococci and 395 faecal coliforms cfu/100 mL) were more reflective 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 wide range of 13.6 ˚C with a maximum (early afternoon) summer temperature of 20.4 ˚C recorded in January 2017 under low flow conditions, at which time dissolved oxygen saturation was 111% and pH was 8.1 units.

Brief comparison with the previous 1995-2016 period

The range of flows sampled during the 2016-2017 period was relatively wide but narrower than the range sampled over the previous 21-year period. The median sampled flow in the 2016-2017 period was significantly higher (by 4,071 L/s, or 60%) than that sampled over the longer term. Median black disc clarity was slightly lower (by 0.06 m) and median turbidity was higher (by 2.4 NTU) in the most recent period, while the median suspended solids concentrations was higher by 2 g/m^3.

For nitrogen nutrient species, median concentrations of nitrate was higher (by 80 %), while ammonia and total nitrogen were similar in the latest period, Dissolved reactive phosphorus was lower (by 17%), while total phosphorus was significantly higher (by 60%) compared to the medians for the previous 21-year period. Median bacterial numbers increased markedly for enterococci (by 39 cfu/100 mL) and faecal coliforms (by 165 cfu/100 mL) in the 2016-2017 period.

Median dissolved oxygen saturation level was identical in the 2016-2017 period while median pH level was 0.1 unit lower in the recent period. Maximum pH was 0.3 unit lower than the maximum previously recorded while minimum pH was 0.6 unit higher than the minimum recorded.

The range of water temperatures was narrower (by 7.0 °C) in the latest twelve-month period than over the previous 21-year period due to a lower maximum temperature (by 4.5 ˚C) and higher minimum temperature (by 2.5 ˚C) in the 2016-2017 sampling year, while median water temperature was 1.0 ˚C higher during 2016-2017.

Whenuakura River at Nicholson Road (site: WNR000450)

Analytical data are presented in Table 36 from the monthly sampling programme. The flow record for the period is illustrated in Figure 8.

Table 36 Analytical results from monthly samples: Whenuakura River at Nicholson Road

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100mL	cfu/100mL
14 Jul 2016	1008	0.072	0.015	0.001	57	0.18	1.5	18.7	11.3	96	0.020	570	380
11 Aug 2016	1000	0.048	0.009	0.000	48	0.29	<0.5	16.5	12.1	96	0.012	23	17
15 Sep 2016	0955	0.051	0.010	0.000	50	0.32	0.7	16.5	10.8	97	0.009	740	200
13 Oct 2016	0845	0.062	0.014	0.001	46	0.10	1.0	14.0	9.9	94	0.017	550	80
10 Nov 2016	0850	0.108	0.025	0.003	33	0.14	1.1	12.9	9.4	94	0.009	750	140
15 Dec 2016	0900	0.066	0.013	0.001	67	0.32	0.8	19.6	9.1	97	0.015	580	150
12 Jan 2017	0850	0.062	0.012	0.001	75	0.96	0.6	21.6	8.6	96	0.012	170	41
09 Feb 2017	0850	0.075	0.017	0.003	62	0.37	<0.5	18.1	9.2	94	0.019	520	260
09 Mar 2017	0830	0.051	0.010	0.000	81	0.44	0.5	22.0	9.2	94	0.014	560	700
13 Apr 2017	1010	0.068	0.014	0.001	56	0.22	0.8	17.5	9.4	94	0.020	1100	770
11 May 2017	1005	0.060	0.012	0.000	59	0.30	0.7	18.6	10.2	96	0.039	200	150
15 Jun 2017	1010	0.052	0.009	0.000	61	0.25	0.7	19.1	11.4	97	0.017	330	140
Date	**Time NZST**	**FC**	**Flow**	**NH_4**	**NO_2**	**NO_3**	**pH**	**SS**	**Temp**	**TKN**	**TN**	**TP**	**Turb**
		cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
14 Jul 2016	1008	570	4.298	0.035	0.004	0.43	7.6	160	8.0	0.38	0.81	0.159	89
11 Aug 2016	1000	23	5.394	0.031	0.004	0.42	7.6	39	6.1	0.11	0.53	0.065	26
15 Sep 2016	0955	760	8.837	0.005	0.003	0.09	7.7	84	11.1	0.32	0.41	0.022	42
13 Oct 2016	0845	600	27.345	0.029	0.002	0.13	7.5	370	12.9	0.57	0.70	0.289	150
10 Nov 2016	0850	750	10.848	0.034	0.006	0.17	7.4	180	15.5	0.46	0.64	0.174	140
15 Dec 2016	0900	580	9.457	0.009	0.006	0.13	7.1	45	17.6	0.38	0.52	0.102	20
12 Jan 2017	0850	170	2.997	0.015	0.002	0.22	7.8	8	20.5	0.13	0.35	0.037	4.9
09 Feb 2017	0850	520	5.453	0.018	0.002	0.18	7.8	29	17.0	0.19	0.37	0.062	21
09 Mar 2017	0830	570	5.654	0.013	0.001	0.16	7.8	37	16.6	0.16	0.32	0.087	19
13 Apr 2017	1010	1200	7.379	0.024	0.006	0.31	7.5	48	15.2	0.33	0.65	0.096	37
11 May 2017	1005	210	6.108	0.028	0.006	0.46	7.6	39	12.8	0.25	0.72	0.057	30
15 Jun 2017	1010	330	8.038	0.028	0.004	0.36	7.6	57	8.8	0.17	0.53	0.110	40

The statistical summary of these data is presented in Table 37.

Table 37 Statistical summary of data from July 2016 to June 2017: Whenuakura River at Nicholson Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.048	0.108	0.062	12	0.016
A440F	Absorbance @ 440nm filtered	/cm	0.009	0.025	0.012	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.003	0.001	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	33	81	58	12	13
BDISC	Black disc transparency	m	0.10	0.96	0.3	12	0.22
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.5	0.7	12	0.3
CONDY	Conductivity @ 20˚C	mS/m	12.9	22.0	18.4	12	2.7
DO	Dissolved oxygen	g/m^3	8.6	12.1	9.6	12	1.1
PERSAT	Dissolved oxygen saturation %	%	94	97	96	12	1
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.009	0.039	0.016	12	0.008
ECOL	E.coli bacteria	nos/100 mL	23	1100	555	12	294
ENT	Enterococci bacteria	nos/100 mL	17	770	150	12	246
FC	Faecal coliforms	nos/100 mL	23	1200	570	12	315
FLOW	Flow	m^3/s	2.997	27.345	6.744	12	6.352
NH_4	Ammoniacal nitrogen	g/m^{3}N	0.005	0.035	0.026	12	0.010
NO_2	Nitrite nitrogen	g/m^{3}N	0.001	0.006	0.004	12	0.002
NO_3	Nitrate nitrogen	g/m^{3}N	0.087	0.464	0.198	12	0.133
pH	pH	pH	7.1	7.8	7.6	12	0.2
SS	Suspended solids	g/m^3	8	370	46	12	102
TEMP	Temperature	°C	6.1	20.5	14	12	4.4
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.11	0.57	0.28	12	0.14
TN	Total nitrogen	g/m^{3}N	0.32	0.81	0.53	12	0.16
TP	Total phosphorus	g/m^{3}P	0.022	0.289	0.092	12	0.073
TURBY	Turbidity	NTU	4.9	150	33.5	12	48

A statistical summary of the 2 years' data collected since 1 July 2015 is presented in Table 38.

Table 38 Statistical summary of data from July 2015 to June 2017: Whenuakura River at Nicholson Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.048	0.139	0.062	24	0.023
A440F	Absorbance @ 440nm filtered	/cm	0.009	0.032	0.012	24	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.006	0.001	24	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	32	94	62	24	17
BDISC	Black disc transparency	m	0.09	0.96	0.30	16	0.21
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.9	0.8	24	0.4
CONDY	Conductivity @ 20˚C	mS/m	11.8	24.6	18.9	24	3.4
DO	Dissolved oxygen	g/m^3	7.8	12.1	9.4	24	1.2
PERSAT	Dissolved oxygen saturation %	%	88	97	94	24	3
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.009	0.039	0.016	24	0.006
ECOL	E.coli bacteria	nos/100 mL	23	2200	470	24	443
ENT	Enterococci bacteria	nos/100 mL	17	1400	150	24	380
FC	Faecal coliforms	nos/100 mL	23	2300	485	24	464
FLOW	Flow	m^3/s	1.929	27.345	5.881	24	5.385
NH_4	Ammoniacal nitrogen	g/m^{3}N	0.005	0.055	0.025	24	0.012
NO_2	Nitrite nitrogen	g/m^{3}N	0.001	0.007	0.004	24	0.002
NO_3	Nitrate nitrogen	g/m^{3}N	0.087	0.525	0.364	24	0.135
pH	pH	pH	7.1	7.9	7.6	24	0.2
SS	Suspended solids	g/m^3	4	980	39	24	211
TEMP	Temperature	°C	6.1	21.9	14.5	24	4.6
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.01	1.27	0.21	24	0.28
TN	Total nitrogen	g/m^{3}N	0.32	1.62	0.60	24	0.28
TP	Total phosphorus	g/m^{3}P	0.022	0.709	0.074	24	0.143
TURBY	Turbidity	NTU	4.9	760	31	24	161

Discussion

2016-2017 period

The relatively poor visual appearance which characterises the mid and lower reaches of this eastern hill-country catchment river was indicated in the low black disc clarity with a range of 0.10 to 0.96 metres, due to the presence of very fine, colloidal, suspended particles. The median suspended solids concentration over this second year of monitoring was high, at 46 g/m^3, with a maximum recorded value of 370 g/m^3 in October 2016, three values ≥160 g/m^3, and a minimum value of 8 g/m^3. Median turbidity level was correspondingly high, at 34 NTU with a range from 5 to 150 NTU. Absorbances (at 340 and 440 nm) were also relatively high (medians of 0.062/cm and 0.013/cm respectively), indicative of slight dissolved colour in the river water (e.g. brown appearance) at this site in the lower reaches of the river. Fresh flows (in excess of 4 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 (i.e. on all sampling occasions except January 2017; Figure 8).

Maximum early/mid-morning pH values in the summer to early autumn period (7.8 units) were moderate for the lower reaches of a Taranaki river, an indication of the limited influence of algal photosynthetic activity on water quality in this reach of the river system where more turbid conditions and silt deposition on the substrate have been typical of the site. A minimum pH (7.1 units) was found under flood conditions in December 2016.

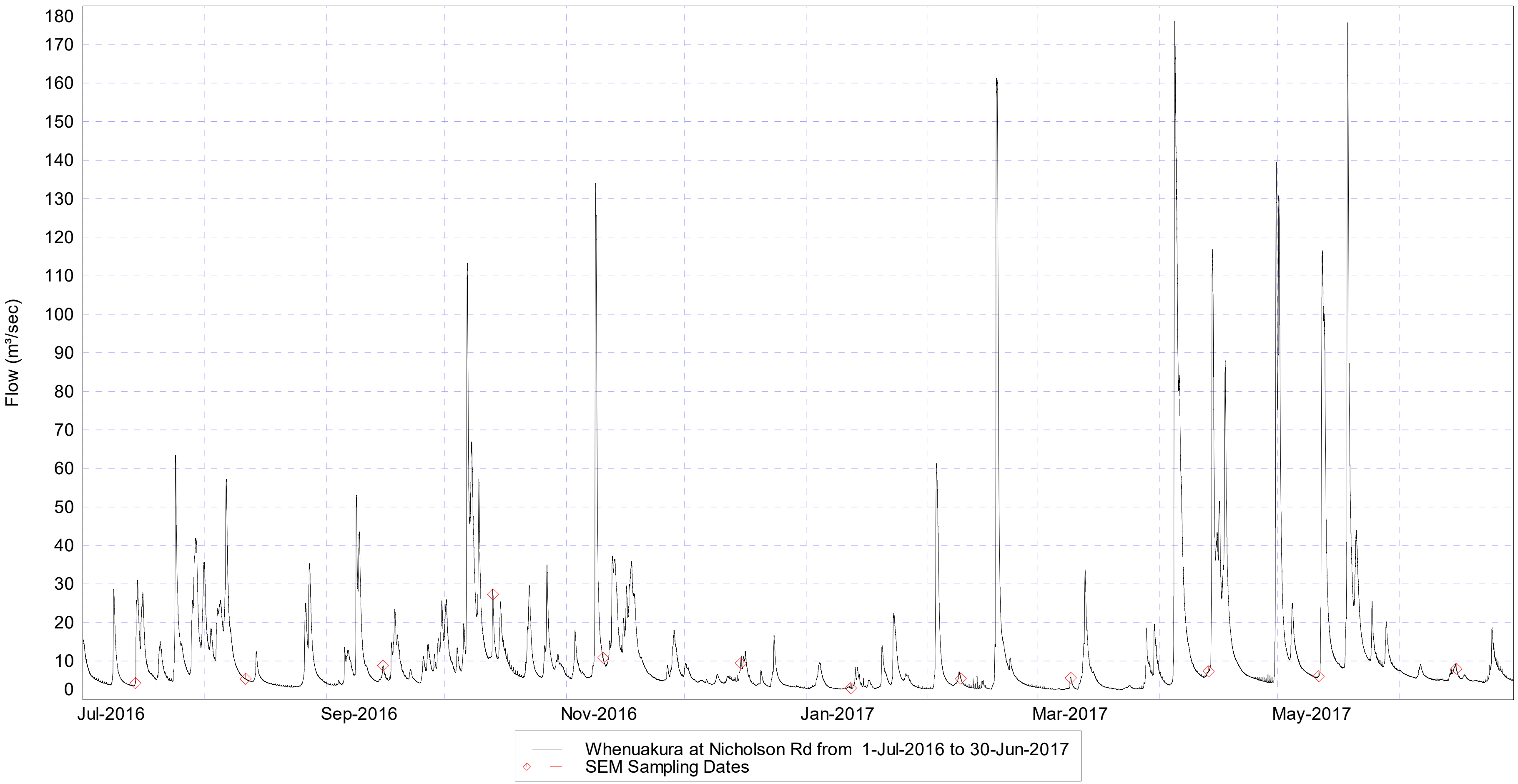


Figure 8 Flow record for the Whenuakura River at Nicholson Road

Dissolved oxygen concentrations (median 9.6 g/m^3) were consistently slightly below saturation level (range 94 to 97%). On the majority of occasions BOD_5 concentrations were indicative of relatively low organic content (i.e. less than 1.0 g/m^3), with values of up to 1.5 g/m^3 recorded. The median bacteriological numbers (570 faecal coliforms and 150 enterococci cfu/100 mL) were more reflective of the impacts of developed farmland run-off and possibly stock access to the lower reaches of this eastern hill country river. The frequent high faecal coliform number indicated a continuous or continual source upstream.

Water temperatures varied over a wide range of 14.4 ˚C with a maximum (early/mid- morning) summer temperature of 20.5 ˚C recorded in January 2017 under low flow conditions.

Brief comparison with the previous 2015-2016 period

The median of sampled flows in the recent twelve-month period was significantly higher (by 3,062 L/s, or 83%) than flows sampled over the previous year, due to a large number of freshes being sampled in the 2016-2017 year. The range of river flows sampled was wider, due to a high maximum flow (of 27.3 m^3/s), though the minimum flow sampled (at 2,997 L/s) was higher.

Median black disc clarity was slightly lower (by 0.07 m) and median turbidity was higher (by 5.5 NTU, or 20%) in the more recent period, while the median suspended solids concentrations was higher by 16 g/m^3, or 53 %.

For nitrogen nutrient species, median concentrations of nitrate and total nitrogen were lower (by 53% and 20%), while ammonia was slightly higher (by 8%) in the later period, Dissolved reactive phosphorus was identical, while total phosphorus was significantly higher (by 31%) compared to the medians for the previous one-year period. Median bacterial numbers decreased markedly for enterococci (by 100 cfu/100 mL) while faecal colif6orms increased markedly (by 205 cfu/100 mL) in the 2016-2017 period.

Median dissolved oxygen saturation level was relatively similar (2% higher) in the 2016-2017 period while median pH level was 0.1 unit lower in the recent period. Maximum pH and minimum pH were both 0.1 unit lower than the respective previously recorded values.

The range of water temperatures was slightly narrower (by 0.2 °C) in the later twelve-month period than over the previous one-year period due to a lower maximum temperature (by 1.4 ˚C) and lower minimum temperature (by 1.2 ˚C) in the 2016-2017 sampling year, while median water temperature was 0.8 ˚C lower during 2016-2017.

Waitara River at Tarata

Analytical data are presented in Table 39 from the monthly sampling programme. The flow record for the period is illustrated in Figure 9.

Table 39 Analytical results from monthly samples: Waitara River at Tarata

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100mL	cfu/100mL
14 Jul 2016	1330	0.053	0.011	0.001	24	0.14	1.7	7.8	11.3	100	0.009	1500	520
11 Aug 2016	1400	0.026	0.006	0.000	23	0.34	<0.5	7.9	11.8	98	0.006	110	8
15 Sep 2016	1340	0.080	0.019	0.002	15	0.04	1.4	6.3	10.3	96	0.014	5100	1100
13 Oct 2016	1245	0.045	0.010	0.001	22	0.36	<0.5	7.2	9.9	97	0.009	320	47
10 Nov 2016	1230	0.081	0.021	0.002	25	0.12	<0.5	7.7	9.4	96	0.010	730	220
15 Dec 2016	1230	0.054	0.012	0.001	35	0.39	0.5	9.9	9.2	99	0.007	580	31
12 Jan 2017	1230	0.052	0.011	0.000	34	1.15	<0.5	9.2	9.0	101	0.005	100	42
09 Feb 2017	1235	0.061	0.013	0.001	25	0.12	0.5	8.0	8.9	96	0.007	1300	300
09 Mar 2017	1215	0.061	0.013	0.001	37	0.72	1.0	9.8	9.3	99	0.006	840	520
13 Apr 2017	1330	0.040	0.009	0.001	27	0.34	<0.5	8.4	9.5	97	0.008	430	160
11 May 2017	1325	0.047	0.010	0.000	29	0.19	0.6	8.5	10.2	98	0.020	970	730
15 Jun 2017	1320	0.063	0.013	0.001	29	0.05	1.1	8.8	11.1	97	0.012	3500	1200
Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
14 Jul 2016	1330	1500	59.320	0.032	0.003	0.30	7.3	280	9.3	0.92	1.22	0.268	150
11 Aug 2016	1400	110	26.743	0.019	0.002	0.49	7.4	20	7.5	0.05	0.54	0.050	21
15 Sep 2016	1340	5300	127.301	0.018	<0.001	0.13	7.1	1080	11.8	0.95	1.08	0.278	640
13 Oct 2016	1245	320	36.072	0.014	0.001	0.27	7.4	24	13.8	0.21	0.48	0.074	20
10 Nov 2016	1230	730	26.262	0.017	0.005	0.15	7.4	60	16.1	0.23	0.38	0.089	70
15 Dec 2016	1230	590	16.026	0.005	0.002	0.14	7.5	12	17.9	0.24	0.38	0.045	15
12 Jan 2017	1230	100	10.249	0.018	0.002	0.11	7.6	4	20.3	0.09	0.20	0.020	4.1
09 Feb 2017	1235	1300	28.499	0.019	0.002	0.12	7.4	73	18.5	0.19	0.31	0.135	65
09 Mar 2017	1215	840	19.441	<0.003	0.002	0.06	7.7	7	18.1	0.19	0.25	0.038	6.4
13 Apr 2017	1330	460	27.167	0.015	0.002	0.30	7.4	21	15.6	0.12	0.42	0.048	22
11 May 2017	1325	1000	22.689	0.014	0.003	0.28	7.5	48	13.1	0.23	0.51	0.052	35
15 Jun 2017	1320	3600	29.591	0.028	0.003	0.18	7.4	410	9.1	0.52	0.70	0.346	410

A statistical summary of these data is presented in Table 40.

Table 40 Statistical summary of data from July 2016 to June 2017: Waitara River at Tarata

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.026	0.081	0.054	12	0.016
A440F	Absorbance @ 440nm filtered	/cm	0.006	0.021	0.012	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.001	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	15	37	26	12	6
BDISC	Black disc transparency	m	0.04	1.15	0.26	12	0.32
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.7	0.5	12	0.4
CONDY	Conductivity @ 20°C	mS/m	6.3	9.9	8.2	12	1.0
DO	Dissolved oxygen	g/m^3	8.9	11.8	9.7	12	1.0
PERSAT	Dissolved oxygen saturation %	%	96	101	98	12	2
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.005	0.020	0.008	12	0.004
ECOL	E.coli bacteria	nos/100 mL	100	5100	785	12	1509
ENT	Enterococci bacteria	nos/100 mL	8	1200	260	12	417
FC	Faecal coliforms	nos/100 mL	100	5300	785	12	1566
FLOW	Flow	m^3/s	10.083	127.301	26.502	12	32.090
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.032	0.018	12	0.008
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	0.058	0.488	0.161	12	0.12
pH	pH		7.1	7.7	7.4	12	0.1
SS	Suspended solids	g/m^3	4	1080	36	12	313
TEMP	Temperature	°C	7.5	20.3	14.7	12	4.2
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.05	0.95	0.22	11	0.31
TN	Total nitrogen	g/m^{3}N	0.20	1.22	0.45	12	0.32
TP	Total phosphorus	g/m^{3}P	0.020	0.346	0.063	12	0.112
TURBY	Turbidity	NTU	4.1	640	28	12	199

A statistical summary of the 2 years' data collected since 1 July 2015 is presented in Table 41.

Table 41 Statistical summary of data from July 2015 to June 2017: Waitara River at Tarata

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.026	0.094	0.053	24	0.019
A440F	Absorbance @ 440nm filtered	/cm	0.006	0.021	0.012	24	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.001	24	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	15	51	30	24	9
BDISC	Black disc transparency	m	0.04	1.28	0.40	24	0.41
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.7	0.6	24	0.3
CONDY	Conductivity @ 20°C	mS/m	6.3	12.5	8.8	24	1.5
DO	Dissolved oxygen	g/m^3	8.4	11.8	9.5	24	1
PERSAT	Dissolved oxygen saturation %	%	94	103	98	24	2
DRP	Dissolved reactive phosphorus	g/m^{3}P	<0.003	0.020	0.007	24	0.004
ECOL	E.coli bacteria	nos/100 mL	43	5100	360	24	1196
ENT	Enterococci bacteria	nos/100 mL	6	1200	59	24	348
FC	Faecal coliforms	nos/100 mL	43	5300	365	24	1236
FLOW	Flow	m^3/s	4.625	127.301	22.039	24	24.926
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.036	0.017	24	0.009
NO_2	Nitrite nitrogen	g/m^{3}N	0.001	0.005	0.002	24	0.001
NO_3	Nitrate nitrogen	g/m^{3}N	0.009	0.488	0.142	24	0.13
pH	pH		7.1	7.9	7.4	24	0.2
SS	Suspended solids	g/m^3	2	1080	17	24	236
TEMP	Temperature	°C	7.5	24.5	15.5	24	4.9
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.04	0.95	0.19	23	0.25
TN	Total nitrogen	g/m^{3}N	0.09	1.22	0.38	24	0.26
TP	Total phosphorus	g/m^{3}P	0.019	0.346	0.040	24	0.091
TURBY	Turbidity	NTU	3.7	640	16.5	24	84

Discussion

2016-2017 period

The relatively poor visual appearance which characterises the mid-reaches of this eastern hill-country catchment river was emphasised by a low median black disc clarity of 0.26 metres with a maximum of 1.15 metres measured under a short receding flow period in January 2017. Clarity was infrequently more than 0.7 metres (on two occasions) due to the presence of very fine, colloidal, suspended particles. The median suspended solids concentration was 36 g/m^3. Absorbances (at 340 and 440 nm) were also relatively high (medians of 0.054/cm and 0.012/cm respectively) at all times, indicative of slight dissolved colour in the river water (e.g. yellow-brown appearance) at this site in the mid reaches of the river. Minimum clarity (0.04 m black disc value) was coincident with turbidity levels of 300 NTU and suspended solids concentration of 640 g/m^3, during flood flow of 127 m^3/s recorded in September 2016. Fresh flows (in excess of 20 m^3/s) were usually coincident with a general deterioration in water quality as emphasised by elevated turbidity, suspended solids, and bacterial counts (e.g. in July, September, October and November 2016, and February, April, May and June 2017; Figure 9).

Maximum mid-afternoon pH values in the mid-summer and early autumn period (7.6 to 7.7 units) were moderate for the mid reaches of a Taranaki river in early afternoon, an indication of the limited influence of algal photosynthetic activity on water quality. A minimum pH (7.1 units) was found under flood conditions in September 2016.

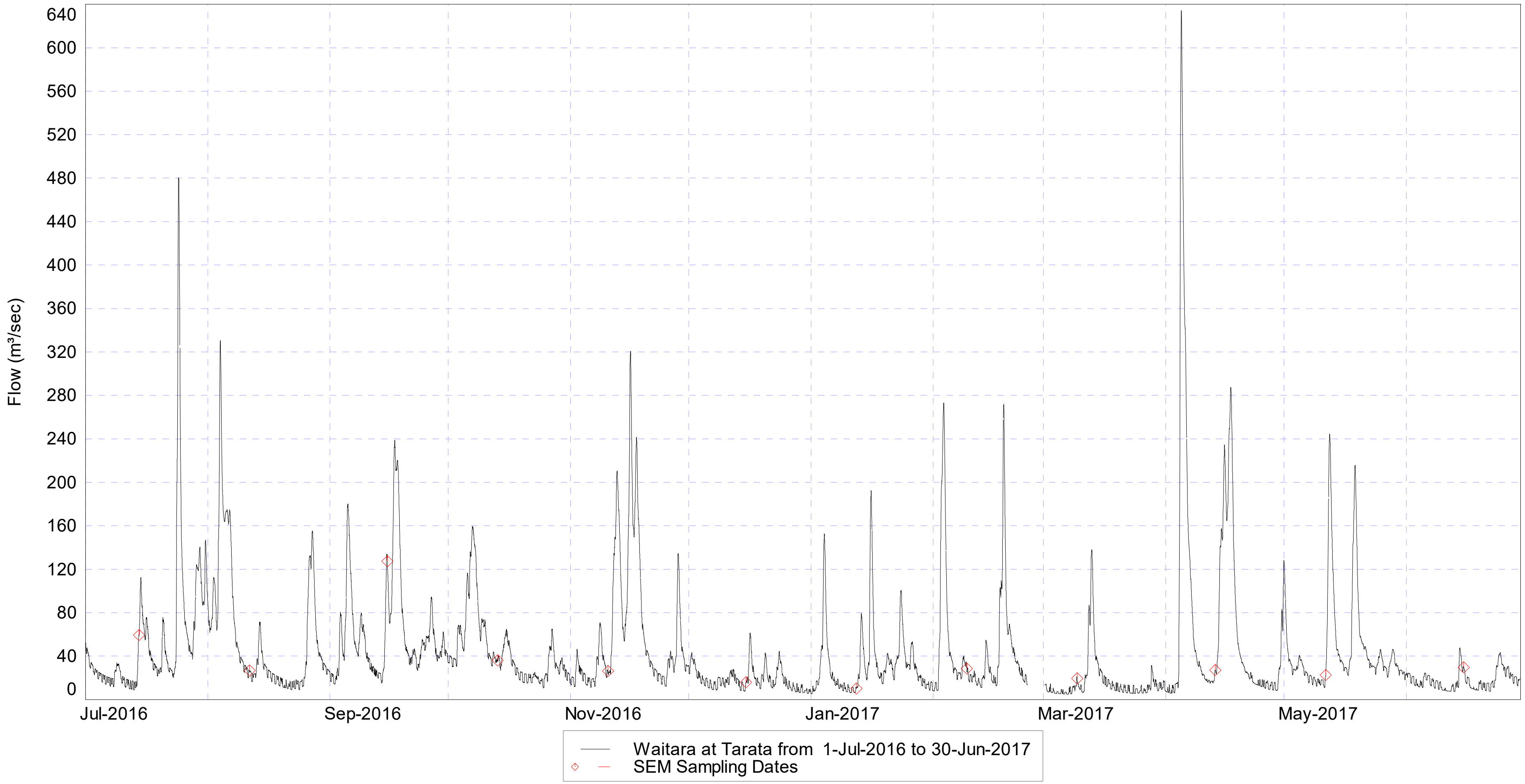


Figure 9 Flow record for the Waitara River at Tarata

Dissolved oxygen concentrations, were consistently high (median of 9.7 g/m^3) with a median saturation level of 98 %. On the majority of occasions BOD_5 concentrations were indicative of relatively low organic content (i.e. less than 1.0 g/m^3). High median bacteriological numbers (785 faecal coliforms and 260 enterococci cfu/100 mL) indicated some impacts of developed farmland run-off and possibly stock access to the lower reaches of this eastern hill country river. Nutrient species concentrations, both nitrogen and phosphorus, were relatively low, over narrow ranges.

Water temperatures varied over a wide range of 12.8 ˚C with a maximum (early afternoon) summer temperature of 20.3 ˚C recorded in January 2017 under low flow conditions, at which time dissolved oxygen saturation was 101% and pH was 7.6 units.

Brief comparison with the previous 2015-2016 period

The median of sampled flows in the recent twelve-month period was significantly higher (by 10,362 L/s, or 64%) than flows sampled over the previous year, due to a large number of freshes being sampled in the 2016-2017 year. The range of river flows sampled was wider, due to a high maximum flow (of 127 m^3/s), though the minimum flow sampled (at 10.1 m^3/s) was much higher. The relatively high number of fresh flows sampled were usually coincident with a general deterioration in water quality, as emphasised by elevated turbidity, suspended solids, all nutrient species (particularly total phosphorus) and bacterial counts.

Median black disc clarity was significantly lower (by 0.44 m, or 63%) and median turbidity was higher (by 20 NTU, or 224%) in the more recent period, while the median suspended solids concentrations was higher by 30 g/m^3, or 500 %.

For nitrogen nutrient species, median concentrations of ammonia, nitrate and total nitrogen were higher (by 20, 22% and 50%) in the later period, while dissolved reactive phosphorus and total phosphorus were higher (by 33 and 186%) compared to the medians for the previous one-year period. Median bacterial numbers increased markedly for enterococci (by 232 cfu/100 mL) while faecal colif6orms increased markedly (by 697 cfu/100 mL) in the 2016-2017 period.

Median dissolved oxygen saturation level was relatively similar (1% lower) in the 2016-2017 period while median pH level was 0.2 unit lower in the recent period. Maximum pH was 0.2 unit lower and minimum pH was 0.1 unit lower than the respective previously recorded values.

The range of water temperatures was narrower (by 3.9 °C) in the later twelve-month period due to a lower maximum temperature (by 4.2 ˚C) and lower minimum temperature (by 0.3 ˚C) in the 2016-2017 sampling year, while median water temperature was 0.8 ˚C lower during 2016-2017.

4.2 Comparative water quality for the twenty two-year (1995-2017) period

4.2.1 TRC data

In addition to the site descriptions of water quality measured during the 2016-2017 monthly sampling programme, a general comparison between the thirteen sites of the Council's programme and also including the two NIWA sites may be made for the 22-year sampling period to date (1995-2017) 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, 35, 38 and 41. Comparative statistics for selected parameters are provided in Table 42 and in the form of the 'box and whisker' plots of Appendix II.

These site comparisons for the summary data over the 22 year record are discussed within groupings of parameters, as follows.

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

The water quality at all but four of the sites has been clean and clear with very low median suspended solids concentrations (3 g/m^3 or lower) and low median turbidity levels (less than 2.5 NTU) except during flood flow conditions. The exceptions have been the three sites in the mid and lower reaches of eastern hill-country rivers and the lower reaches of the Waingongoro River. The eastern hill-country catchment rivers were typically slightly cloudy due to fine colloidal solids and yellow-brown in appearance under most flow conditions. An elevated median suspended solids concentration (39 g/m^3) has been recorded for the Whenuakura River, which was affected by widespread soil erosion after a major flood the month before the monitoring site was established in July 2015; median turbidity level (31 NTU, over two years) is significantly higher for this river than at any other site. The site in the lower reaches of the longest ring plain river (Waingongoro) also has elevated median suspended solids concentration (5 g/m^3) and turbidity (3.2 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 four other sites have achieved a median black disc clarity in excess of 1.5 metres. Due to the elevated turbidity of the eastern hill country rivers, the median clarities in the mid and lower reaches of the rivers were all less than 0.9 metres, while the site in the lower reaches of the Waingongoro River also had a relatively low median black disc value of 1.2 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 22 year period.

Table 42 Some comparative water quality data for the thirteen TRC SEM sites for the twenty two-year period July 1995 to June 2017 (n = 24 to 264 samples)

Site Unit	Black disc m		BOD_5 g/m³	Conductivity @ 20°C mS/m	Faecal coliform bacteria cfu/100mL		Nutrients					pH		Dissolved oxygen saturation %			Suspended solids g/m³	Temperature °C			Turbidity NTU
							Ammonia g/m³N	Nitrate g/m³N	Total N g/m³N	DRP g/m³P	Total P g/m³P										
	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	2.55	<0.5	8.6	50	330	0.010	0.27	0.40	0.024	0.035	7.9	7.6	90	98	13	<2	18.0	11.6	13.2	1.2
Mangaoraka Stream at Corbett Road	4.73	1.80	0.6	14.5	84	800	0.021	0.84	1.10	0.009	0.023	8.1	7.6	83	97	24	2	20.5	13.2	14.7	2.1
Waiwhakaiho River at SH3	8.05	3.06	<0.5	12.2	23	215	0.008	0.11	0.20	0.025	0.035	8.5	7.9	91	101	19	<2	18.3	11.2	13.5	0.7
Stony River at Mangatete Road	13.12	3.16	<0.5	9.7	<1	8	<0.003	0.02	0.06	0.018	0.025	8.2	7.8	87	99	19	<2	16.6	10.8	10.9	1.6
Punehu Stream at Wiremu Road	4.53	1.82	<0.5	8.6	3	115	0.007	0.05	0.15	0.023	0.034	8.3	7.6	87	100	19	<2	19.2	11.9	14.2	2.4
Punehu Stream at SH45	3.65	1.50	1.0	16.1	51	520	0.040	0.96	1.40	0.044	0.079	8.6	7.7	90	100	24	3	21.0	13.4	16.0	2.3
Waingongoro River at Eltham Road	4.39	1.68	0.7	11.2	6	190	0.017	1.15	1.44	0.020	0.039	8.6	7.8	92	103	29	3	21.5	12.6	15.9	2.0
Waingongoro River at SH45 **	4.34	1.20	1.0	16.4	3	220	0.032	1.87	2.29	0.054	0.094	9.1	7.8	89	102	52	5	22.0	13.8	16.6	3.2
Patea River at Barclay Road	10.14	4.34	<0.5	6.2	<1	21	<0.003	0.02	0.08	0.018	0.024	8.0	7.5	90	99	13	<2	14.9	9.2	11.2	0.6
Patea River at Skinner Road	4.68	1.82	0.9	9.9	2	200	0.051	0.92	1.23	0.037	0.066	8.8	7.8	87	103	34	<2	22.3	13.0	17.0	1.7
Mangaehu River at Raupuha Road	4.04	0.85	0.6	9.9	6	230	0.012	0.10	0.30	0.006	0.020	8.4	7.7	83	100	35	4	24.9	13.9	20.6	4.3
Whenuakura River at Nicholson Road***	0.96	0.30	0.8	18.9	23	485	0.025	0.36	0.60	0.016	0.074	7.9	7.6	88	94	9	39	21.9	14.5	15.8	31
Waitara River at Tarata***	1.28	0.40	0.6	8.8	43	360	0.017	0.14	0.38	0.007	0.040	7.9	7.4	94	98	9	17	24.5	15.5	17.0	16

[Notes: * for the period July 2003 to June 2017 (n = 168 samples);
** for the period July 1998 to June 2017 (n = 228 samples);
*** for the period July 2015 to June 2017 (n = 24 samples)]

Turbidity is for the period June 2005 to June 2017.

Absorbances (at 340 nm) have been generally relatively low. They are indicative of slight dissolved colour particularly at the eastern hill country sites, 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 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 (24.9 ˚C), the Whenuakura River (24.5°C), the Waingongoro River (22.0 ˚C), and the smaller Punehu Stream (21.0 ˚C), and in the mid reaches of the Waitara River (24.5°C) and Patea River (22.3 ˚C); these six sites also exhibiting five of the six highest medians (13.9 ˚C, 14.5°C, 13.8 ˚C, 13.4 ˚C, 15.5°C and 13.0 ˚C, respectively) and widest ranges (20.6 ˚C, 15.8°C, 16.6 ˚C, 16.0 ˚C, 17.0°C and 17.0 ˚C, respectively) of water temperatures. Atypically, relatively high median (11.9 ˚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 m asl).

Highest pH values (8.5 to 9.1) have been recorded at the mid and lower ring plain 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 in the ring plain rivers and streams, and from 7.4 to 7.7 in eastern hill-country rivers (Note: diurnal temperature and pH variability is limited by the sampling regime for each site – see below).

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 at 20 °C, except the new site in the lower reaches of the Whenuakura River, at 18.9 mS/m at 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 three eastern hill country sites. Ranges were relatively narrow at most sites (< 30% at ten sites) and median values were 94% 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 ranges (≤13%) were found in the upper reaches of the Patea River, mid reaches of the Maketawa Stream and Waitara River, and lower reaches of the Whenuakura River, with wider saturation ranges (≥19%) recorded at mid and lower catchment sites, and the widest (52%) in the lower reaches of the longest ring plain river where substrate periphyton cover often has been more extensive. (Note: Wider ranges may occur at all sites, but particularly lower reach sites, as the nature of the sampling regime does not provide for diurnal variability; rather sampling is confined to a narrow fixed time window for each site.)

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), Waingongoro River (1.0 g/m^3) and Whenuakura River (0.9 g/m^3), and the mid reaches of the Mangaoraka Stream and 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 830% and 130% in median total nitrogen and total phosphorus respectively over the length of the Punehu Stream; 1500% and 175% respectively from the upper to the mid reaches of the Patea River; and 66% and 140% 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 base flows. 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 ring plain rivers and streams (TCC, 1984 and TRC, 2010). Relatively low dissolved reactive phosphorus (median of <0.01 g/m^{3}P) measured at the sites in the mid reaches of the Waitara River and lower reaches of the Mangaehu River reflect the rivers' eastern hill country catchment source. The high total phosphorus concentrations, largely in particulate form, measured for the lower reaches of the Whenuakura site (median of 0.07 g/m^{3}P) relate to the high sediment loads carried during the first two years of monitoring.

Bacteria

Poor bacteriological water quality (median faecal coliform numbers from 220 to 800 per 100 mL) has been recorded at the sites in the lower reaches of the Maketawa Stream, Punehu Stream, Waingongoro River, Mangaehu River, Whenuakura River and particularly the Mangaoraka Stream. Relatively poor bacteriological quality (medians from 190 to 215 per 100 mLs) in the mid reaches of the Waiwhakaiho, Waingongoro, Patea and Waitara 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 80 faecal coliforms cfu/100 mL, indicative of consistently poor bacteriological quality.

The sites in the mid reaches of the Waiwhakaiho, Waingongoro, Patea and Waitara 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 21 and 8 cfu/100 mL respectively.

The upper site in the Punehu Stream (at Wiremu Road), however, has had an unexpectedly high median faecal coliform count of 115 cfu/100 mL, 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 21 years of data for the two Taranaki region sites included in the NIWA national network (see Figure 1) is presented in Table 43. (A third site, Waingongoro River at SH45, was monitored until December 2015. Refer to TRC 2015 for a summary of comparative data from this site). The Manganui River system draining from Mt Taranaki is a sub-catchment of the Waitara River basin, and thus provides an 'upstream' comparison with the Bertrand Rd site on the lower Waitara River. The Waitara River itself flows from the highly erodible eastern hill country.

Table 43 Some comparative water quality data for the two NIWA SEM sites for the 22-year period July 1995 to June 2017 (n = 264 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	0.43	0.7	8.8	0.012	0.31	0.57	0.006	0.037	8.6	7.7	102	23.9	13.8	17.4	8.6	29.5
Manganui River at SH3	7.7	3.94	<0.5	6.3	0.006	0.09	0.18	0.009	0.015	8.0	7.5	101	18.7	10.7	14.6	0.9	0.95

These data indicate more turbid (cloudier) appearance in the lower reach of the Waitara River (median black disc clarity of 0.43 metres and turbidity of 8.6 NTU) with very clear conditions toward the upper reach of the Manganui River. Lower Waitara River median clarity was the worst of all fifteen 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 and Whenuakura Rivers [Table 42]). Median water temperatures were typical of those found at comparable sites elsewhere in the region (Table 42 and Table 43), 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).

4.2.3 Comparative water quality for the twenty two-year (1995-2017) period

The 22 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 44.

Table 44 Comparison of 1995-2017 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/m³ N•	<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/m³ P	<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	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Whenuakura River at Nicholson Road°	x	✓✓	✓	✓✓	✓	x	x	✓	x	x	✓✓*	✓	✓✓	✓✓	✓✓	✓	✓✓
Waitara River at Autawa Road°	x	✓✓	✓	✓✓	✓✓	x	✓	✓	✓	x	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Manganui River at SH 3	✓	✓✓	✓	✓✓	✓	✓	✓	✓	✓	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Waitara River at Bertrand Road	x	✓✓	✓	✓✓	✓	x	✓	✓	x	x	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Summary of sites (15) in compliance	9	15	14	15	12	5	9	15	4	12	15	10	15	15	15	15	15

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

[Note: ° Whenuakura River at Nicholson Road and Waitara River at Autawa Road data are for the period July 2015 to June 2017 (n = 24 samples).

4.2.3.1 Aesthetics

Most sites met the aesthetic quality guidelines, although the six sites which did not achieve the black disc clarity are all situated in the mid or lower reaches of catchments, three of which (Mangaehu, Waitara and Whenuakura 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 for monitoring recreational bathing, and therefore care should be taken when comparing results against the guidelines. 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, 2017), and on the Council's website (www.trc.govt.nz). However, the sites' data presented in Table 44 are indicative of bacteriological conditions likely to exist at contact recreational sites in the vicinity of the reaches of the streams/rivers monitored, from a year-round, all-flows perspective. The Government's NOF standards apply to data gathered all year round, and are applied to the SEM data further in section 4.2.4.2 below.

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, 2017) occasionally under spring-summer low flow conditions (refer to individual tables of 2016-2017 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 44). 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, TRC, 2014a, TRC, 2016b, and TRC, 2018). 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 cfu/100 mL. 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) cfu/100 mL, 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 three of the nine sites shown in Table 44 as otherwise exceeding the bacteriological guidelines, the 25th 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 two sites under the visibility guideline. The Council has a separate SEM programme that focuses specifically on the macroinvertebrate fauna of 59 sites in the region (including all of the thirteen sites in the physicochemical programme and the two NIWA sites) and none of these communities where monitoring has taken place for the more than 10 years has illustrated significant deterioration, while nine (one upper, three middle and five lower reach) of the 11 sites in the physicochemical programmes have shown significant improvements in stream 'health' trends over the 22 years (1995 to 2017) to date (TRC, 2006c, Stark and Fowles, 2006 and TRC, 2017a).

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.

4.2.4 National Objectives Framework

In 2014, Ministry for the Environment released a 'National Policy Statement for Freshwater Management (NPS-FM)' which sets out objectives and policies that direct local government to manage water in an integrated and sustainable way, while providing for economic growth within set water quantity and quality limits. The national policy statement is a first step to improve freshwater management at a national level.

This national policy statement provides a National Objectives Framework (NOF) that specifies nationally applicable standards for particular water quality parameters, to assist regional councils and communities to more consistently and transparently plan for freshwater objectives. The national policy statement acknowledges iwi and community values by recognising the range of iwi and community interests in fresh water, including environmental, social, economic and cultural values.

The national policy statement sets national bottom lines for two compulsory values – ecosystem health and human health for recreation – and minimum acceptable states for other national values.

Overall freshwater quality within a region must be maintained or improved. The national policy statement allows some variability in terms of freshwater quality, within each Freshwater Management Unit, as long as the overall freshwater quality is still maintained within that FMU.

In September 2015, Ministry for the Environment published a reference document on reporting and calculation NOF values called 'A Draft Guide to Attributes – in Appendix 2 of the NPS-FM, 2014. The purpose of the Guideline is to provide Council staff with guidance on the role and use of attributes involved in the implementation of the NPS-FM.

The NPS-FM identifies 13 national values and uses for freshwater. Two of these are compulsory values that apply to all water bodies: ecosystem health and human health for recreation. For ecosystem health, the NPS-FM specifies attributes to manage long-term exposure to two toxicants, nitrate (NO_3N) and ammoniacal nitrogen (NH_4N). *E. coli* is the attribute used for specifying human health for recreational objectives for freshwater, because it is moderately well correlated with *Campylobacter* bacteria and numeric health risk levels can be calculated (MfE, 2015).

For nitrate and ammoniacal nitrogen attributes, the recommended number of samples to determine the sample statistic for assessing progress towards freshwater objectives is at least 30 samples collected on a monthly basis over three years. Fewer samples can be used, but confidence in sample statistics will be lower. More samples will improve the confidence in estimates of sample statistics, however, the marginal improvements in confidence diminish beyond about 20-40 samples (McBride, 2014).

In March 2018, MfE published an updated document: 'A Draft Guide to Attributes in Appendix 2 of the NPS-FM 2014 (as amended 2017)' focussing on new attribute state recommendations for *E. coli* and planktonic cyanobacteria. A background document for the proposed new changes to *E. coli* was produced earlier (December 2017), titled 'A Draft Guide to Swimming, E. coli and National Targets under the NPS-FM 2014 (as amended 2017)', which provided an overview of 'primary contact' objectives, policies, approach to monitoring and reporting for regional councils to follow.

A major change for *E. coli* was presented, with five attribute states A, B, C, D and E (previously four: A, B, C and D) and four criteria or 'statistical tests' to satisfy each attribute state. The overall grading to be assigned to a river is to be the worst of the four. The rigorous criteria were developed to determine the infection risk profiles relating to *E. coli* levels and the proportion of population at risk of *Campylobacter* infection for activities likely to involve full immersion such as swimming or white water rafting (McBride, Ministry for the Environment and Ministry of Health, 2003). Additionally, the attribute state for *E. coli* is determined by using a minimum of 60 samples over a maximum of five years, collected on a regular basis regardless of weather and flow condition.

Thus, there are now five grades, but no 'bottom line', for *E coli*. Councils are to identify by the end of 2018 what their target is for water quality as defined by *E coli*. The Government has stated that, as a whole, 80% of the country's waterways should be within the top 3 categories by 2030, and 90% by 2040. It should be noted that these percentages do not necessarily apply at the regional level. For the purpose of comparisons, this report uses the five-step categories, with rivers in either of the bottom two categories being deemed unacceptable for recreational purposes.

The following sections present the results of the NOF analysis at 13 sites monitored as part of the Taranaki physico-chemical programme. This includes Whenuakura River at Nicholson Road and Waitara River at Autawa Road, that were added to the programme in July 2015 (24 samples were collected and used for the analysis). Two of NIWA's national monitoring sites were also included in the analysis, i.e., Waitara River and Bertrand Road and Manganui River at State Highway 3.

4.2.4.1 Ecosystem health

The national policy statement specifies attributes to manage long term exposure for two toxicants, nitrate and ammoniacal nitrogen. These toxicants can cause both lethal and sub-lethal (e.g. reducing growth rates or reproductive success) effects to aquatic species. It is recommended for councils to set freshwater objectives in the A or B attribute states when sensitive species are present that may be at risk of lethal effects.

All sites met the NOF standard set for toxicants nitrate and ammoniacal nitrogen (Figure 10, Table 45). More than four-fifths of the sites (87%) achieved 'A' grade for both attributes in terms of their annual medians.

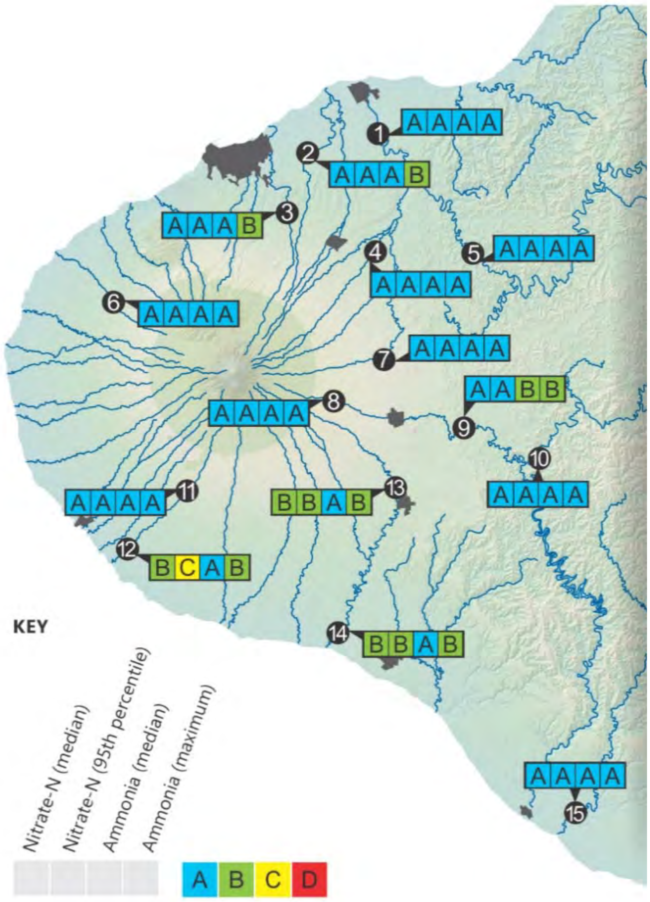


Figure 10 NOF results for ecosystem health at 13 SEM sites and two NIWA sites in Taranaki

Table 45 Summary result for water quality data from 2014-2017 for ecosystem health (n=24 to 36 samples).

SiteNo	Value	Ecosystem health				No. samples
	Attribute	Nitrate-N (g/m^3)		Ammoniacal-N		
		Annual median	Annual 95th percentile	Annual median	Annual maximum	
1	Waitara River at Bertrand Rd*	A	A	A	A	24
2	Mangaoraka Stream at Corbett Rd	A	A	A	B	36
3	Waiwhakaiho River at SH3	A	A	A	B	36
4	Maketawa Stream at Tarata Rd	A	A	A	A	36
5	Waitara River at Autawa Rd	A	A	A	A	36
6	Stony River at Mangatete Rd	A	A	A	A	36
7	Manganui River at SH3	A	A	A	A	36
8	Patea River at Barclay Rd	A	A	A	A	36
9	Patea River at Skinner Rd	A	A	B	B	36
10	Mangaehu River at Raupuha Rd	A	A	A	A	36
11	Punehu Stream at Wiremu Rd	A	A	A	A	36
12	Punehu Stream at SH45	B	C	A	B	36
13	Waingongoro River at Eltham Rd	B	B	A	B	36
14	Waingongoro River at SH45	B	B	A	B	36
15	Whenuakura River at Nicholson Rd*	A	A	A	A	24

Note: *for period July 2015 to June 2017 (n = 24 samples)

4.2.4.2 Human health

The definition of primary contact sites in the Freshwater NPS is:

a. Any part of specified river or lake that a regional council considers is used, or would be used, but for existing freshwater quality, for primary contact; and

b. Any other site in any other river or lake that regional council has determined should be managed for primary contact.

According to the updated Draft Guide to Attributes (as amended 2017), the *E. coli* attribute describes different statistical measures of the distribution of *E. coli* concentrations, and the associated risk of *Campylobacter* infection through ingestion of water during recreation activities (McBride, 2012): Ministry for the Environment and Ministry of Health, 2003). The four individual statistical measures are:

- Percentage of exceedances greater than 540 cfu/100mL: this measure indicates how often the level of *E.* coli exceeds the acceptable threshold for swimming
- Percentage of exceedances greater than 260 cfu/100mL: This measure indicates how often the level of *E. coli* exceeds the point where additional monitoring is required
- Median: the mid-point of E. coli levels
- 95th percentile: an indication of the top range of *E. coli* levels within the distribution.

All four criteria are necessary to establish an attribute state. If one or more criteria can't be satisfied, a lower attribute state must apply. Higher attribute states provide lower levels of infection risk for each activity type.

Overall, three sites (20%) met all four of the new NOF standards set for *E. coli* (11, Table 46), if compliance is assumed to require at least a 'C' grade. The sites located in the upper river catchments showed better results compared to the sites in the middle and lower catchments, i.e. Patea River at Barclay Road (grade A), Punehu Stream at Wiremu Road (grade B), and Stony River at Mangatete Road (grade B).

The majority of the sites (77%) received 'D' grade for the 95th percentile criterion, and hence fail to satisfy the Government's target.

Five sites met the requirement of acceptable threshold for swimming (less than 20% of the time recording exceedances greater than 540 cfu/100 mL), the national threshold applied within the summer recreational bathing survey. However, it is important to note that most of the SEM sites in the programme are not considered contact recreational sites; the streams are too shallow, cold and/or small for recreational bathing activities.

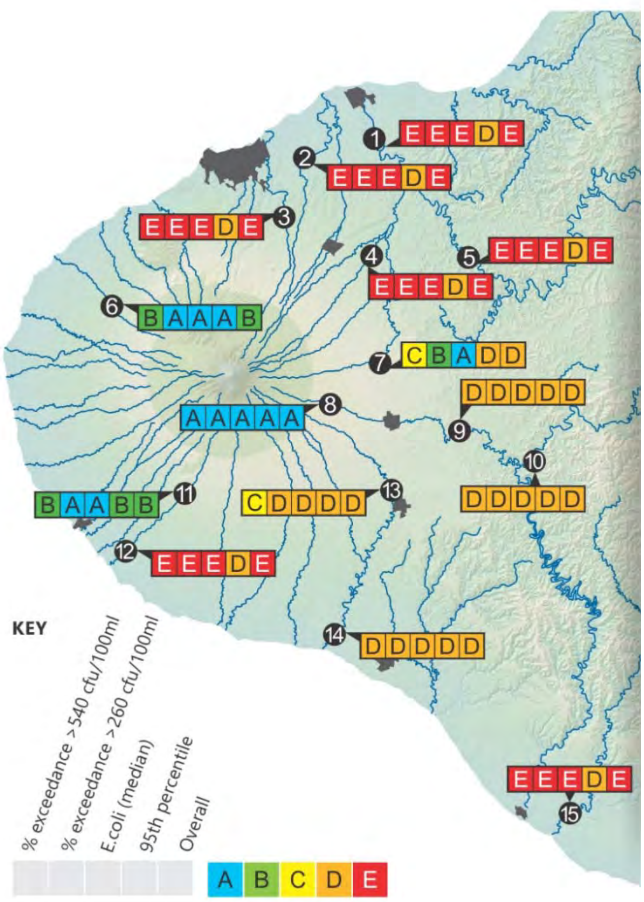


Figure 11 NOF results for human health for recreation at 13 SEM sites and two NIWA sites in Taranaki

Table 46 Results for NOF attribute states for 13 SEM sites in Taranaki

Site No	Value / Attribute	Human health for recreation – Escherichia coli (*E.coli*/100mL): % exceedances over 540 cfu/100mL	% exceedances over 260 cfu/100mL	Median concentration cfu/100mL	95th percentile of *E. coli*/100mL	Overall
1	Waitara River at Bertrand Rd	E	E	E	D	E
2	Mangaoraka Stream at Corbett Rd	E	E	E	D	E
3	Waiwhakaiho River at SH3	E	E	E	D	E
4	Maketawa Stream at Tarata Rd	E	E	E	D	E
5	Waitara River at Autawa Rd	E	E	E	D	E
6	Stony River at Mangatete Rd	B	A	A	A	B
7	Manganui River at SH3	C	B	A	D	D
8	Patea River at Barclay Rd	A	A	A	A	A
9	Patea River at Skinner Rd	D	D	D	D	D
10	Mangaehu River at Raupuha Rd	D	D	D	D	D
11	Punehu Stream at Wiremu Rd	B	A	A	B	B
12	Punehu Stream at SH45	E	E	E	D	E
13	Waingongoro River at Eltham Rd	C	D	D	D	D
14	Waingongoro River at SH45	D	D	D	D	D
15	Whenuakura River at Nicholson Rd	E	E	E	D	E

4.3 Trends in physicochemical water quality data from 1995 to 2017

4.3.1 Introduction

Twenty two years of physicochemical water quality data have been collected up to 30 June 2017. These data have been analysed for trends each year since 10 years of data became available. Previous trend analysis has been reported in TRC (2006, 2009, 2009a, 2010, 2011, 2012, 2013, 2014, 2015a and 2016).

An update of the trends including data from the 2016-2017 monitoring year is provided. It does not include a detailed interpretation of the results. This will be provided at least prior to each five-yearly State of the Environment Report, if not before.

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 (following 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)).

[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.

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 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 long term trend analysis

Table 47 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 are sufficient data. Trend analysis will be performed on the two sites that were established in 2015-2016, on the Whenuakura River at Nicholson Road and the Waitara River at Tarata, when 10 years of data have been gathered.

Of the nutrients, DRP, and to a lesser extent total phosphorus, have shown a significantly deteriorating trend (ie concentrations are increasing) at a number of sites, including the upper and middle catchments which would be less subject to anthropogenic pressures. Seven and four out of eleven sites have shown a significant deterioration in DRP and total phosphorus, respectively, and another two sites come close to the significant trend definition for deterioration in total phosphorus. On the other hand, the lower Waingongoro River site shows significant reductions in both forms of phosphorus.

Total nitrogen improved significantly at four of the eleven sites monitored, and otherwise generally showed no significant trend. These improvements are in the upper (Patea River at Barclay Road and Punehu Stream at Wiremu Road), middle (Stony River at Mangatete Road) and lower (Mangaehu River at Raupuha Road) catchment. Nitrate showed significant deteriorating trends at only two of the eleven sites, in middle (Waiwhakaiho at SH3) and lower (Punehu Stream at SH45) catchments where more land use intensification occurs. While ammonia-N showed generally stable trends throughout all catchment levels, with the exception of the Punehu Stream at Wiremu Road (upper catchment), Maketawa Stream at Tarata Road, and Waiwhakaiho River at SH3 (both mid catchment), where significant trends of deterioration are apparent.

Generally, mid catchment and lower catchment sites appear to be showing the most deterioration in nutrients. There is notable improvement in the Waingongoro River at SH45 (for DRP and total phosphorus), and in the Mangaehu River at Raupuha Road (total nitrogen). This is a positive aspect as the lower catchment would be under the most pressure from land use intensification and upstream influences. The Punehu Stream at SH45 and the Waiwhakaiho River at SH3 have the greatest number of deteriorating trends in relation to nutrients (three of five nutrients). All other sites had 2 or less of 5 nutrients increasing (Table 47).

The Waingongoro River at SH45 is showing a very significant improving trend in dissolved reactive phosphorus and total phosphorus (Figure 12), with two other parameters, nitrate and total nitrogen, improving at slightly less than the rate defined as a significant trend. It is probable that this is due to the reduction in meatworks' discharges to the river at Eltham (between 2001 and 2008) and the elimination of all Eltham WWTP municipal discharges in the catchment (since mid-2010). However, a significant increasing trend was detected for BOD at this site, together with an indication of an increase in ammonia at a low level of significance.

Faecal coliforms and enterococci bacteria generally showed little statistically significant change over the 22 year period, although Mangaoraka Stream at Corbett Rd indicated a very significant deteriorating trend in faecal coliforms and enterococci. There is also a very significant increase in faecal coliforms at Waiwhakaiho River at SH3 (but not for enterococci), and in enterococci at Punehu Stream at SH45 (but not for faecal coliforms). Two sites showed significant improvement in faecal coliforms: Punehu Stream at Wiremu Road, an upper catchment site, and Mangaehu River at Raupuha Road, a lower catchment site.

Traditional indicators of pollution, organic matter (BOD), suspended solids, clarity (black disc), conductivity (dissolved matter) generally show no apparent trends at most sites over the 22 year period. However, the Stony River shows 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 indicates periods of erosion and recovery over time. Deterioration in clarity has also been significant at the Mangaoraka Stream (Corbett Road), where steady declines throughout the period are apparent (Figure 12), with Waiwhakaiho River (SH3) just outside the defined significantly changing definition. There is no longer a significant improvement in clarity at the Waingongoro SH45 site, or in suspended solids at Punehu Stream SH 45. There has been a continued deterioration trend in BOD at Waingongoro SH45 since the 2014 year, and at Maketawa Stream at Tarata Road since the 2016 year. Mangaoraka Stream at Corbett Road showed no significant long-term deterioration in BOD when the latest year is included in the analysis, being just less than the 1% per year criterion. Some significant trends in water temperature and pH have been noted (Table 48), with almost all sites showing a negative trend for both parameters, however, the rates of change per year in all of these cases are less than 1% and are not 'meaningful' changes.

Figure 12 shows the trends graphically for a selected number of sites and parameters where significant trends were recorded.

Table 47 'Meaningful' trends in surface water quality at 11 State of the Environment Monitoring sites in Taranaki- 1995-2017 (p<5% and RSKSE (%change/yr) >1%)

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	⚪	⚪	⚪	🔴	🟢	🟩	⚪	⚪	⚪	⚪	⚪	⚪	⚪	2	10	1
Middle	Stony River Mangatete Road	🔴	🔴	⚪	⚪	🟢	⚪	⚪	⚪	🔴	🔴	⚪	⚪	⚪	1	8	4
Middle	Maketawa Stream Tarata Road*	🔴	🟠	⚪	🔴	⚪	⚪	⚪	⚪	⚪	⚪	⚪	🟠	⚪	0	9	4
Middle	Patea River Skinner Rd	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	0	13	0
Middle	Waiwhakaiho R. SH3	🔴	⚪	🔴	🔴	⚪	🔴	⚪	⚪	⚪	⚪	⚪	⚪	⚪	0	9	4
Middle	Waingongoro R. Eltham Rd	🔴	🔴	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	0	11	2
Lower	Mangaoraka Stream Corbett Rd	🔴	🔴	⚪	⚪	⚪	🔴	🔴	⚪	🔴	⚪	⚪	⚪	⚪	0	8	5
Lower	Waingongoro R. SH45**	🟢	🟢	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	🔴	⚪	2	10	1
Lower	Punehu Stream SH45	🔴	🟠	🔴	⚪	🔴	⚪	🔴	⚪	⚪	⚪	⚪	⚪	⚪	0	7	5
Lower	Mangaehu River Raupuha Rd	⚪	⚪	⚪	⚪	🟢	🟩	⚪	⚪	⚪	⚪	⚪	⚪	⚪	2	11	0
Total no. sites:	Improvement	1	1	0	0	4	2	0	0	0	0	0	0	0			
	No change	3	5	9	8	6	7	9	11	9	10	11	9	11			
	Deterioration	7	5	2	3	1	2	2	0	2	1	0	2	0			

Key:

*Maketawa Tarata Road: Data for this site only for the past 14 years: 2003-2017
**Waingongoro SH45: Data for this site only for the past 19 years: 1998 – 2017

- 🟢 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 48 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**	0.01	1.12	14.07	0.34	0.44	-0.45	94.16	-0.02	0.00	-3.11	100.00	0.01	17.92	1.71
Upper/ Middle	**Punehu Stream Wiremu Rd**	59.67	0.15	85.15	0.06	5.47	1.31	0.08	2.54	0.00	-1.75	1.14	-2.10	94.16	-0.15
Middle	**Stony River Mangatete Road**	0.00	1.07	0.01	1.61	20.71	0.73	14.96	-0.16	0.00	-2.92	64.27	-0.65	22.52	1.14
Middle	**Maketawa Stream Tarata Road**	0.00	2.57	0.21	1.96	81.26	0.19	0.47	3.07	83.72	-0.12	7.41	2.66	5.19	2.96
Middle	**Patea River Skinner Rd**	1.43	-0.77	7.73	-0.63	20.71	0.22	66.62	0.21	47.88	-0.11	33.27	-1.05	77.57	0.30
Middle	**Waiwhakaiho SH3**	0.00	1.22	0.01	0.91	0.02	1.98	0.16	2.49	18.46	-0.52	0.01	4.22	8.01	1.71
Middle	**Waingongoro Eltham Rd**	0.00	3.51	0.00	2.38	0.86	0.68	53.08	0.38	13.21	0.38	53.08	-0.69	56.33	-0.81
Lower	**Mangaoraka Stream Corbett Rd**	0.00	2.51	0.17	1.43	63.10	-0.11	20.13	0.79	6.95	-0.37	0.07	2.70	0.00	6.09
Lower	**Waingongoro SH45***	0.00	-2.85	0.00	-2.41	0.02	-0.91	7.06	1.27	0.00	-0.87	97.58	0.05	92.76	0.16
Lower	**Punehu Stream SH45**	0.00	1.97	0.82	0.93	0.00	2.19	40.18	-0.56	0.03	1.19	69.00	-0.39	0.00	4.04
Lower	**Mangaehu River Raupuha Rd**	69.00	0.14	75.09	0.14	80.08	0.11	71.41	-0.14	0.33	-1.01	4.44	-1.80	76.33	0.42
	Total no. sites: Improvement	1		1		0		0		4		2		0	
	No change	3		6		9		8		6		7		9	
	Deterioration	7		4		2		3		1		2		2	

Table 48 (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	16.64	-0.10	33.42	-0.28	85.14	0.00	56.33	-0.10	81.90	0.00	29.36	-0.02
Upper/ Middle	Punehu Stream Wiremu Rd	0.00	0.29	14.07	-0.51	92.22	-0.01	7.33	-0.32	8.88	-0.10	0.00	-0.08
Middle	Stony River Mangatete Road	28.63	0.08	0.00	-3.37	0.00	14.43	49.93	-0.08	67.67	0.00	8.01	-0.03
Middle	Maketawa Stream Tarata Road	15.04	0.16	36.77	-0.68	66.96	0.08	42.03	0.32	1.09	2.05	40.23	0.02
Middle	Patea River Skinner Rd	95.46	0.00	23.79	-0.42	54.15	-0.13	94.16	0.01	9.20	0.79	44.90	-0.02
Middle	Waiwhakaiho SH3	50.97	-0.06	0.09	-0.93	23.15	0.12	12.39	-0.25	15.91	0.37	0.10	-0.07
Middle	Waingongoro Eltham Rd	95.46	0.01	14.51	-0.48	86.43	0.03	8.29	-0.19	8.01	0.84	1.25	-0.05
Lower	Mangaoraka Stream Corbett Rd	0.47	0.23	0.00	-1.65	48.39	0.31	43.93	-0.12	4.44	0.95	8.74	-0.03
Lower	Waingongoro SH45*	49.86	0.08	2.56	0.87	16.96	-0.72	12.73	-0.25	0.08	2.17	0.00	-0.12
Lower	Punehu Stream SH45	0.33	0.31	87.71	0.04	5.79	-1.14	9.84	-0.24	88.35	0.04	0.00	-0.10
Lower	Mangaehu River Raupuha Rd	90.28	0.01	19.00	-0.63	60.81	-0.28	9.52	-0.24	4.79	-0.50	38.38	0.02
	Total no. sites: Improvement	0		0		0		0		0		0	
	No change	11		9		10		11		9		11	
	Deterioration	0		2		1		0		2		0	

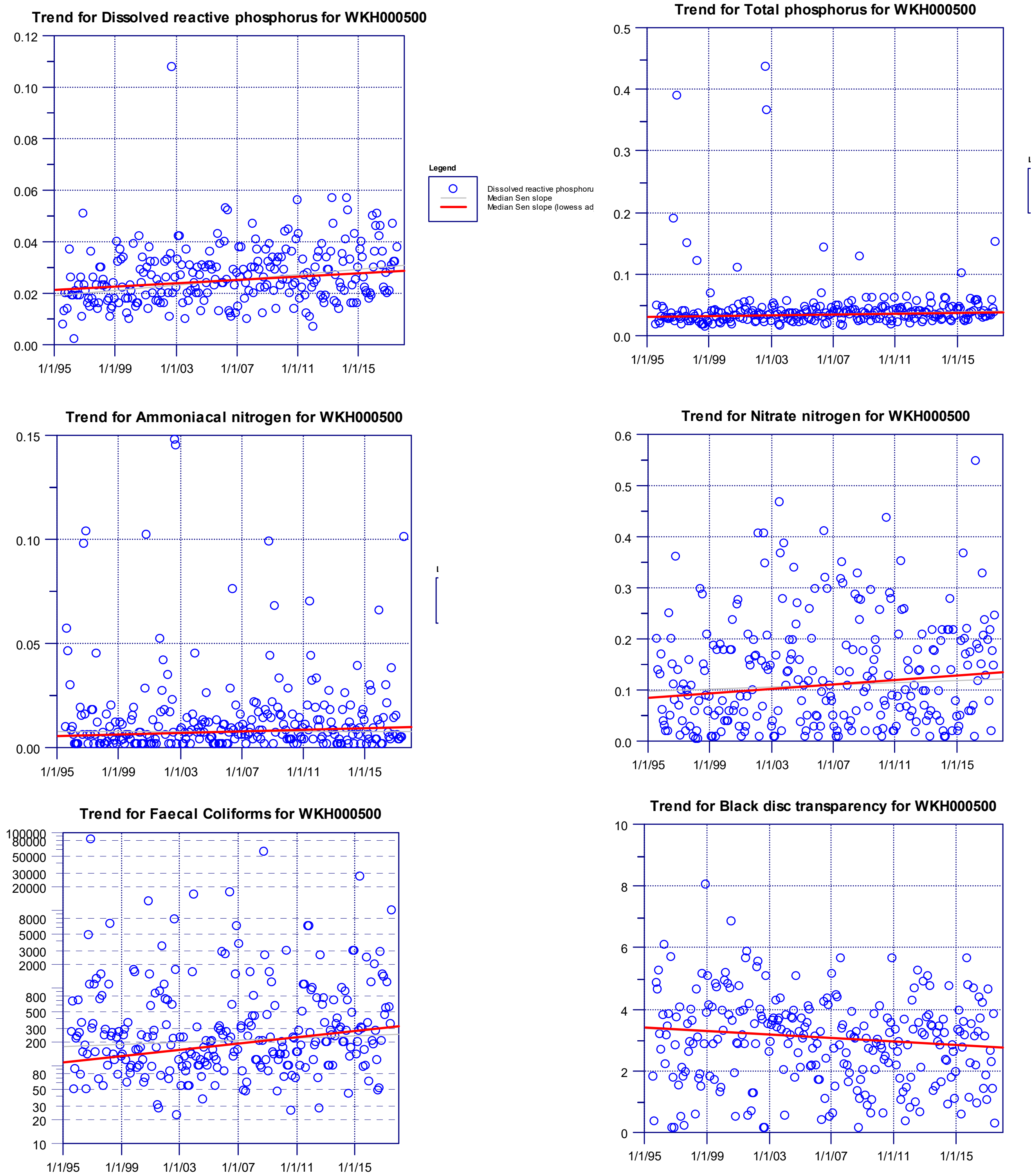


Figure 12 Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

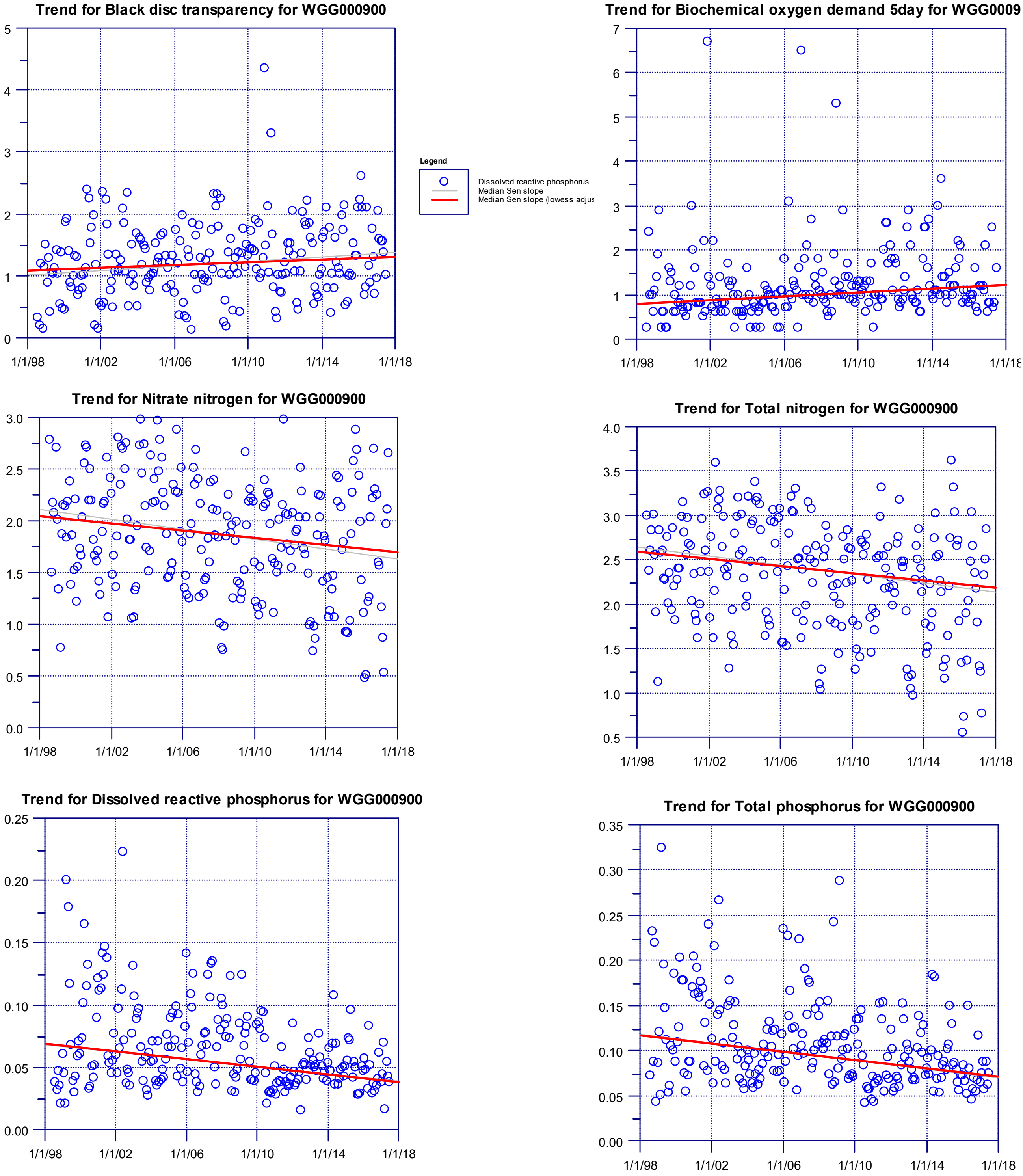


Figure 12 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

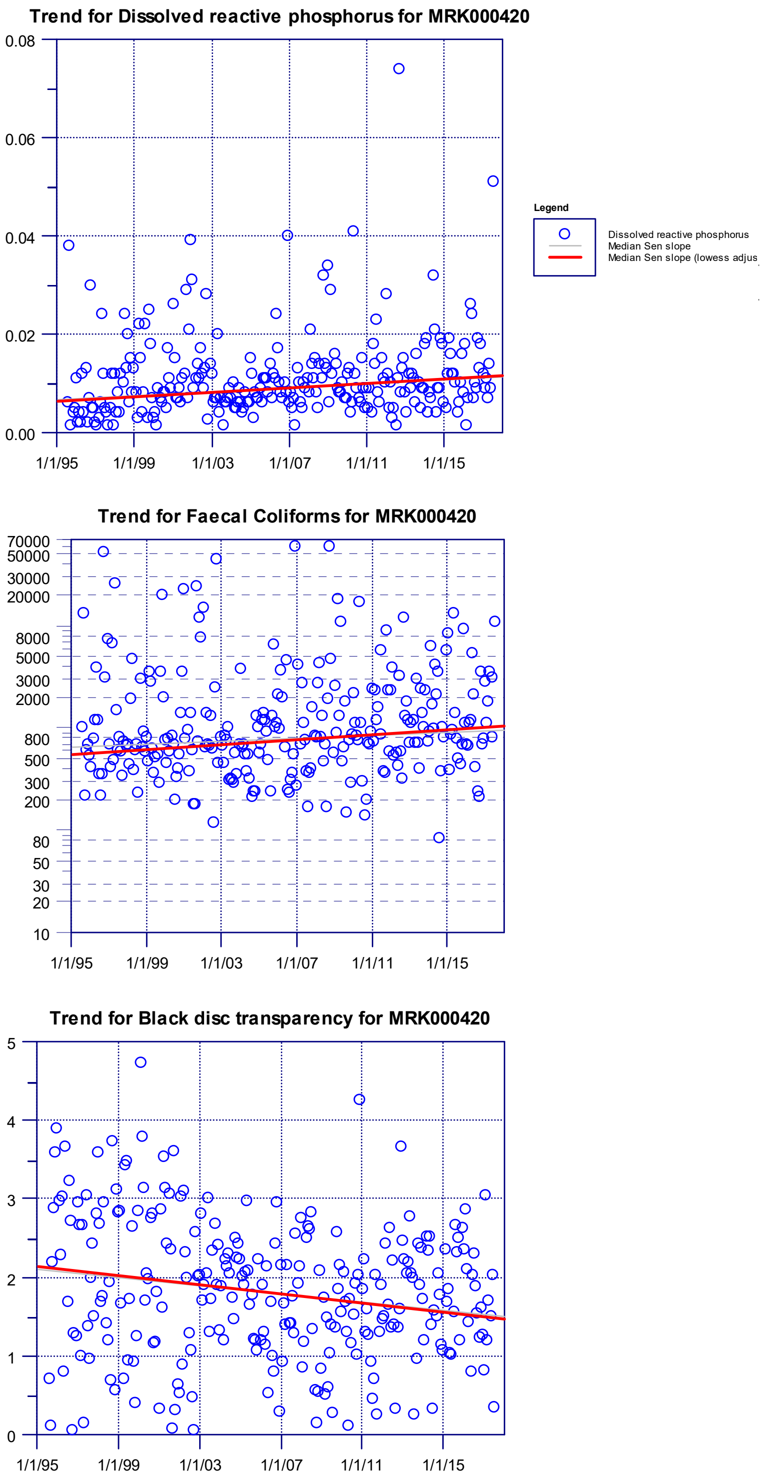


Figure 12 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

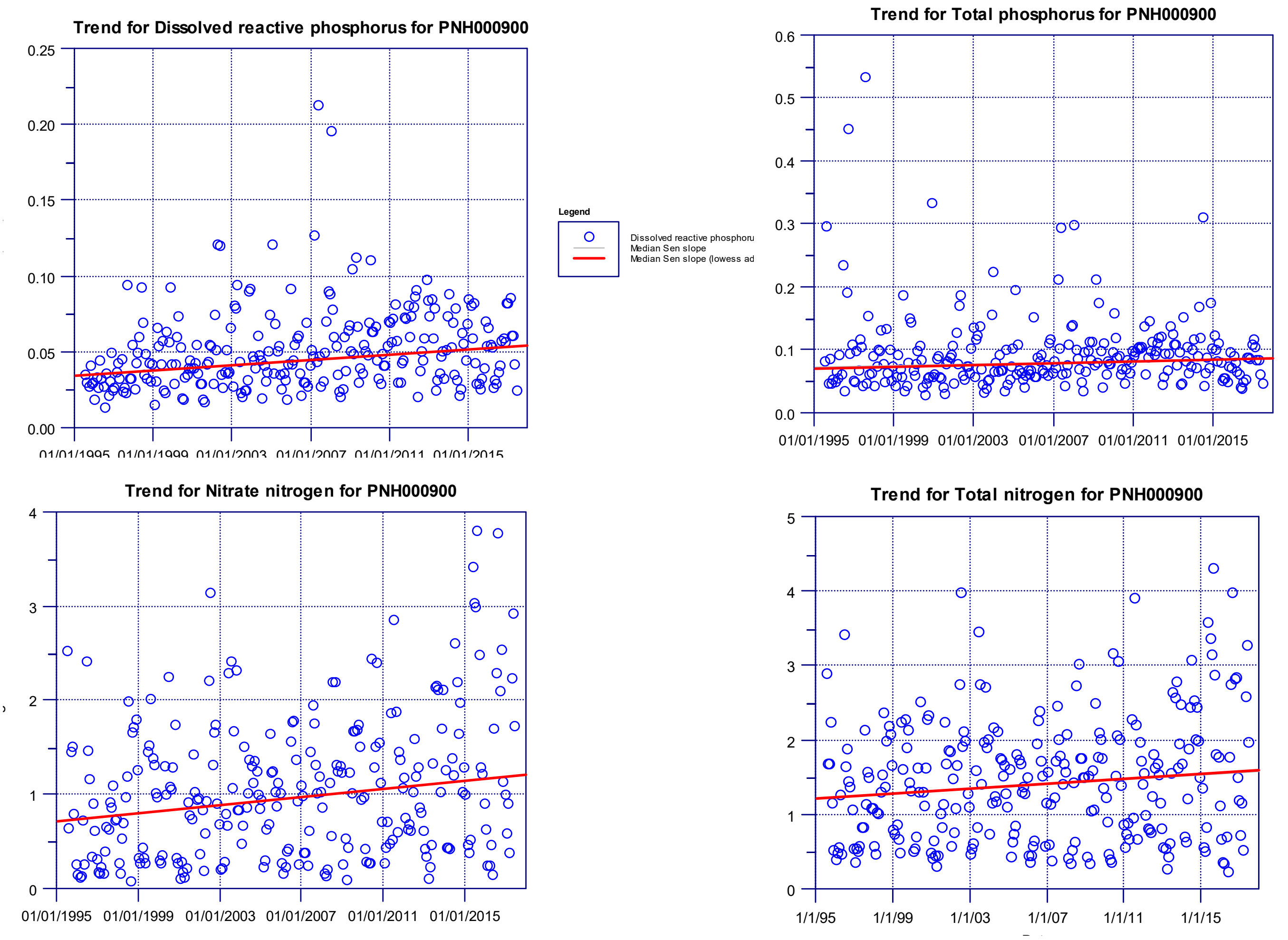


Figure 12 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

4.4 Trends in physicochemical water quality data from 2010 to 2017

4.4.1 Introduction

Data from State of the Environment physicochemical water quality monitoring programme (11 sites) for the most recent 7-year period (July 2010 – June 2017) were trended using the same methodology as for the full record (1995-2017, section 4.3.2) to observe if there were any changes in trends in recent years. The latter is the more meaningful feedback for effectiveness of current policies and interventions.

Physicochemical data from two NIWA sites were also assessed over a 7-year (July 2010 – June 2017) and the full record (January 1989 – June 2017). Starting from January 2016, Waingongoro site at SH45 is no longer monitored for water quality by NIWA. This is part of a NIWA plan to disestablish many of the pre-existing NRWQN sites and eventually replace with a lesser number of 'benchmark' sites that will include newly created sites and some selected NRWQN sites. Hence, there will be no further trending of NIWA information at this site and comparison with TRC data will not be discussed. (For previous analysis, refer to TRC, 2015)

Only significant 'real' trends are shown i.e., those significant trends where there was greater than 1% change per year for physicochemical parameters were considered 'real' trends with a change of a magnitude which could be ecologically significant as well.

An overall summary for the physicochemical water quality monitoring programme comparing the long term and short term trend is provided, together with a summary for each catchment.

4.4.2 Results of trend analysis

Overall, there were some differences between the long term and short term record, in the relative number of measures showing improvement, no significant change or deterioration (Table 49). There are more measures showing no significant trend in the short term record compared to the long term record. This is the result of fewer measures showing either improving or deteriorating trends in nutrients, organics and aesthetics, indicating wider stability in the recent trends. For bacteria, the number of measures showing deterioration is larger in the short term record, although the number of those trends that are very significant ($p<0.01$) is less.

Table 49 Summary of physicochemical trends between 22 years and 7 years of data

Statistical level	Total number of trends	
	21 years	7 years
Improvement ($p<0.01$)	7	0
Improvement ($p<0.05$)	1	0
Being maintained	75	92
Deterioration ($p<0.05$)	3	8
Deterioration ($p<0.01$)	24	10
Total	110	110

Comparison of long term trends 1995-2017 (22 years) and 2010-2017 (7 years) analysis.

Nutrients

- 37 of 55 measures of the nutrients (67%) showed maintenance (56%) or improvement (11%) in the long term trend.
- 41 of 55 measures of the nutrients (75%) showed maintenance in the recent 7 year trend.

Bacteria

- 18 of 22 measures of bacterial levels (82%) showed maintenance (73%) or improvement (9%) in the long term trend.
- 18 of the 22 measures of the bacterial levels (82%) showed maintenance in the recent 7 year trend.

Organics

- 9 of 11 measures (82%) of organics contamination showed maintenance in the long term trend.
- All measures of organics (100%) showed maintenance in the recent 7 year trend.

Aesthetics

- 19 of 22 measures (86%) of aesthetics showed maintenance or improvement in the long-term trend.
- All measures of aesthetics (100%) showed maintenance in the recent 7 year trends

Specific changes in trends for nutrients, bacteria, organics and aesthetics are shown in Figure 13.

Key:

Site 1: Patea River at Barclay Road

Site 2: Punehu Stream at Wiremu Road

Site 3: Stony River at Mangatete Road

Site 4: Patea River at Skinner Road

Site 5: Waiwhakaiho River at SH45

Site 6: Waingongoro River at Eltham Road

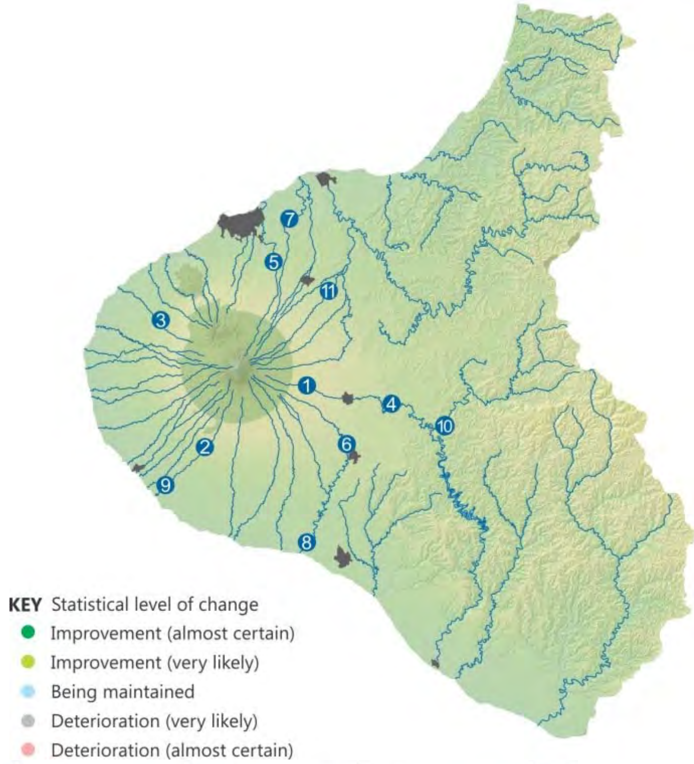
Site 7: Mangaoraka Stream at Corbett Road

Site 8: Waingongoro River at SH45 (19 y data)

Site 9: Punehu Stream at SH45

Site 10: Mangaehu River at Raupuha Road

Site 11: Maketawa Stream at Tarata Road (14 years data)



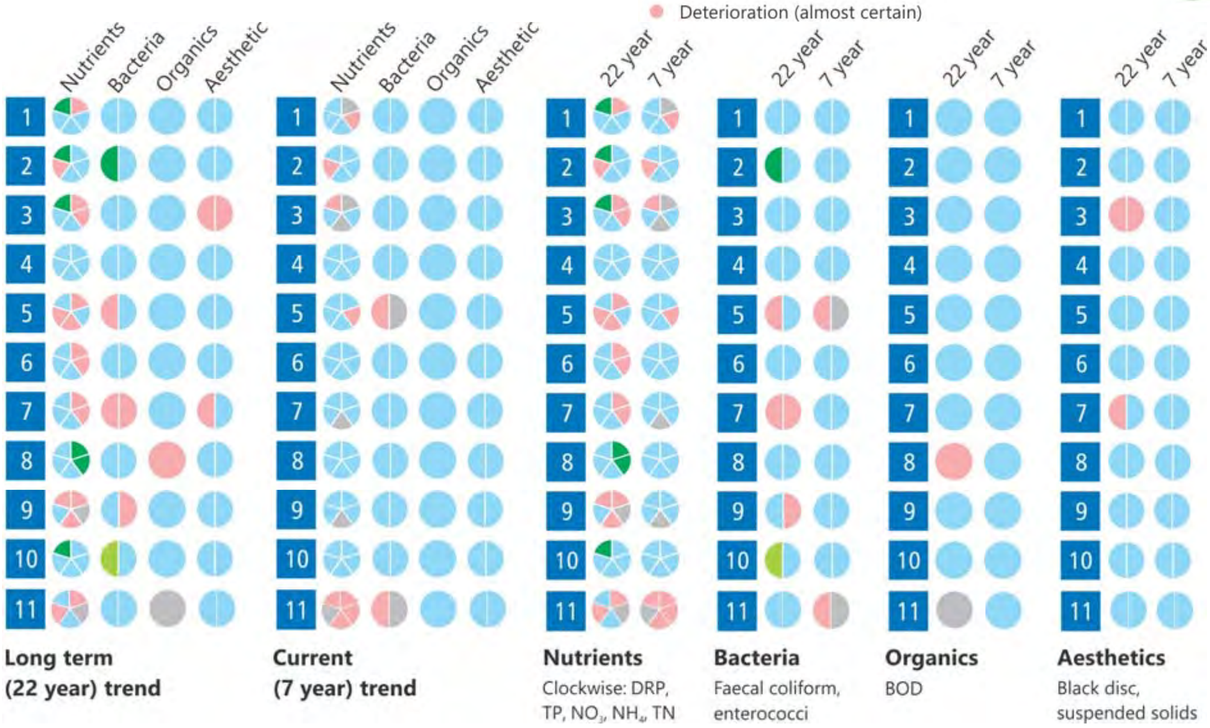


Figure 13 Specific changes in trend for nutrients, bacteria, organics and aesthetic parameters in the long term (22 years) and current (7 years) trend

4.4.2.1 Patea River catchment

- At the upper site Barclay Road, significant long term deterioration in DRP continued in the 7 year trend. Significant improvement in TN has tapered off in the 7 year trend.
- At the middle site Skinner Road, long term and recent trends are not changing significantly for all parameters measured.
- The Mangaehu River has shown improvement over the long term for total nitrogen and faecal coliforms, which have tapered off in the 7 year trend.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Patea River at Barclay Road (upper catchment)	22 year trend	1
	7 year trend	1
Patea River at Skinner Road (middle catchment)	22 year trend	4
	7 year trend	4
Mangaehu River at Raupuha Road (lower catchment)	22 year trend	10
	7 year trend	10

Key: Nutrients: Clockwise: DRP, TP, NO_3, NH_4, TN
Bacteria: Faecal coliform, enterococci
Organics: Biological oxygen demand
Aesthetics: Black disc, suspended solids

4.4.2.2 Punehu Stream catchment

- At the upper site Wiremu Road, significant long term improvement in TN did not continue in the short term trend. NH4 deterioration showed in both the long and short term trends. Other parameters are not changing significantly.
- At the lower site SH45, the long term deteriorating trends in DRP, TP, NO3 and TN have been tapered off in the 7 year trend. Significant long term improvement in suspended solids has also tapered off in the 7 year trend.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Punehu Stream at Wiremu Road (upper catchment)	22 year trend	2
	7 year trend	2
Punehu Stream at SH 45 (lower catchment)	22 year trend	9
	7 year trend	9

4.4.2.3 Stony River catchment

- Significant improvement recorded in the long term trend for TN had reversed in the recent 7 year period, with significant deterioration recorded. However, significant deterioration in TP, clarity and suspended solids was recorded in the long term trend have tapered off in the recent trend.
- DRP continued to show deterioration from the long term to the recent trend, with NH4 and enterococci showing significant deterioration in the 7 year trend.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Stony River at Mangatete Road (middle catchment)	22 year trend	3
	7 year trend	3

Key: Nutrients: Clockwise: DRP, TP, NO_3, NH_4, TN
Bacteria: Faecal coliform, enterococci
Organics: Biological oxygen demand
Aesthetics: Black disc, suspended solids

4.4.2.4 Maketawa River catchment

- Significant long term deterioration in DRP, TP and NH4 continued in the 7 year trend. However, deterioration in organics has tapered off in the 7 year trend.
- The 7-year trend showed deterioration for all nutrient species and both bacteria.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Maketawa River at Tarata Road (middle catchment)	22 year trend	11
	7 year trend	11

4.4.2.5 Waiwhakaiho River

- Significant long term deterioration was recorded for DRP, NO3, NH_4 and faecal coliforms at this mid catchment site.
- TP recorded significant deterioration in the 7 year trend. Deterioration for DRP, NO3 and NH4 tapered off in the recent 7 year trend. Faecal coliforms and enterococci continued to show a deteriorating trend. Other parameters are not changing significantly.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Waiwhakaiho River at SH45 (middle catchment)	22 year trend	5
	7 year trend	5

4.4.2.6 Mangaoraka Stream (Waiongana Stream catchment)

- Significant long term deteriorations were recorded for DRP, TP, faecal coliforms, enterococci and black disc.
- The 7 year trend showed deterioration in nitrate, while other parameters are not changing significantly.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Mangaoraka Stream at Corbett Road	22 year trend	
	7 year trend	

Key: Nutrients: Clockwise: DRP, TP, NO_3, NH_4, TN
Bacteria: Faecal coliform, enterococci
Organics: Biological oxygen demand
Aesthetics: Black disc, suspended solids

4.4.2.7 Waingongoro River catchment

- At the upper site Eltham Road, significant long term deterioration in DRP and TP tapered off in the 7 year trend. Other parameters are not changing significantly.
- At the lower site SH45, significant improvements in DRP and TP were recorded in the long-term trend. BOD showed deterioration in the long-term trend. These trends tapered off in the recent 7 year trend. Other parameters are not changing significantly.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Waingongoro River at River Road	22 year trend	
	7 year trend	
Waingongoro River at SH45	22 year trend	
	7 year trend	

4.4.3 NIWA State of the Environment sites

Physicochemical data from two NIWA sites in the Taranaki region were also assessed over a 7 year (July 2010 – June 2017) and the full record spanning from January 1989 to June 2017 (Table 50). In order to accurately compare the TRC and NIWA data, a 22-year trend has been compiled (TRC data spans from 1995).

Summary of trend results for NIWA sites is as follows:

- In the Waitara River, long term deterioration for the nutrients, except TP, (DRP, NO_3, and TN) have tapered off and appear to be stable in the last 7 years. TP has deteriorated in the last 7 years, affecting the most recent longer term trends also. Black disk showed improvement in the most recent 7 year trend.
- In the Manganui River, recent significant deteriorations for DRP, TP and conductivity were recorded in the 7 year trend.
- Note that suspended solids and BOD are not recorded by NIWA, and bacteria had been recorded only since 2005; as such these parameters are not included in the tables below.

Table 50 Meaningful' trends in surface water quality at NIWA's monitoring sites in Taranaki

Site	Record (years)	Dissolved Reactive P	Total Phosphorus	Nitrate	Ammonia-N	Total Nitrogen	Conductivity	Black Disc	Temp˚C	pH	Total no sites:	Improvement	No change	Deterioration
Waitara River at Bertrand Rd Bridge	28	🔴	⚫	🔴	🔵	🔴	🔵	🔵	🔵	🔵		0	5	4
	22	🔵	⚫	🔴	🔴	🔴	🔵	🔵	🔵	🔵		0	5	4
	7	🔵	🔴	🔵	🔵	🔵	🔵	🟩	🔵	🔵		1	7	1
Manganui River at SH3	28	🔵	🔵	🔵	🔵	🔵	🔵	🔵	🔵	🔵		0	9	0
	22	🔵	🔵	🔵	⚫	🔵	🔵	🔵	🔵	🔵		0	8	1
	7	🔴	🔴	🔵	🔵	🔵	⚫	🔵	🔵	🔵		0	6	3

Key:

🟢 statistically significant **improvement** P<0.01
🟩 statistically significant **improvement** P<0.05
🔵 no statistically significant change
⚫ statistically significant **deterioration** P<0.05
🔴 statistically significant **deterioration** P<0.01

4.5 Addition of new water quality sites for NPS-FW monitoring purposes

The RMA requires [Section 35 (2)(a)] the Council to:

'*monitor the state of* ***the whole or any part of*** *the environment of its region…. .****to the extent that is appropriate*** *to enable the local authority to effectively carry out its functions under this Act;…*'.

The Council has had SEM of fresh water in place since 1995, through a number of specific programmes. These have been audited by the Office of the Auditor-General, as well as by other independent experts, and found each time to be fit for purpose. The programmes have targeted areas with the greatest pressures upon or changes in the water resources of the region, to determine how and why water quality might be changing and the effectiveness of the Council's interventions.

However, the NPS-FW now requires, in addition, that the Council *'identifies a site or sites at which monitoring will be undertaken that are* ***representative for each freshwater management unit'*** [Policy CB1 (b)]. All freshwater in every region must be incorporated into a Freshwater Management Unit (FMU) as defined within the NPS.

This Council has identified four FMUs for the Taranaki region: water bodies of outstanding value; the ring plain; the northern and southern coastal terraces; and the eastern hill country. In terms of the distribution of the current SEM sites for monitoring fresh water, Council staff determined that two more sites within the eastern hill country were needed for the purpose of representativeness of FMUs. Accordingly, since July 2015 Council staff have been undertaking sampling for water quality monitoring purposes at two new sites: Waitara River near Tarata in the northern hill country, and the Whenuakura River at SH 3, on the southern borders of the hill country. Results from these sites are reported for the second time herein.

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 2016 through to June 2017. 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. Sites in the mid-reaches of the Waitara River and lower reaches of the Whenuakura River were added in July 2015, and thus 2016-2017 was the second full year of sampling. Sampling in the year under review coincided randomly with a narrow range of flow conditions in the 2016-2017 period (in comparison with the previous 21 year period), ranging from moderate freshes through to relatively low flow conditions but was characterised by more fresh events than typical during previous years. 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 21 years' data. It also provides an up-to-date statistical summary of the 22 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 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 sites in the mid and lower reaches were characterised by some dissolved colour, relatively high turbidity, poorer clarity, and slightly to moderately 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 planting has been performed in this reach.

Flows in 2016-2017

During the 2016-2017 period, median flows sampled were almost all higher than typical of those sampled during the previous 21-year period. For the eleven sites monitored over at least 10 years, median flows were higher over the latest period (by 3 to 60%) at ten sites, and lower (by 3%) at one site, compared with the long-term median of sampled flow records (Table 51).

Table 51 Comparison of 2016-2017 water quality with previous long-term (1995-2016) 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/s)	Flow (%)
						Ammonia-N	Nitrate-N	Total N	DRP	Total P							
Maketawa Stream at Tarata Road	X	=	=	XX	=	XX	XX	X	X	=	=	=	=	=	X	293	15↑
Mangaoraka Stream at Corbett Road	=	=	=	XX	XX	=	X	=	X	=	=	=	=	=	=	327	28↑
Waiwhakaiho River at SH3	=	=	=	XX	XX	✓	XX	=	X	=	=	=	=	=	=	1,601	43↑
Stony River at Mangatete Road	XX	=	=	X	✓	=	XX	X	=	XX	=	=	XX	=	XX	112	3↑
Punehu Stream at Wiremu Road	=	=	=	✓	✓	XX	XX	=	=	=	=	=	=	=	XX	-12	3↓
Punehu Stream at SH45	=	=	✓	=	X	=	XX	XX	X	=	=	=	=	=	=	395	41↑
Waingongoro River at Eltham Road	=	=	=	X	X	✓	X	X	X	=	=	=	=	=	=	296	18↑
Waingongoro River at SH45	=	=	=	=	=	✓	=	=	✓	✓	=	=	✓	=	=	1,678	35↑
Patea River at Barclay Road	X	=	=	X	XX	=	=	=	=	✓	=	=	=	=	=	20	9↑
Patea River at Skinner Road	=	=	=	=	✓	=	=	=	=	=	=	=	✓	=	=	945	19↑
Mangaehu River at Raupuha Road	=	=	✓	XX	XX	XX	=	=	=	=	=	=	=	=	XX	4,071	60↑
Whenuakura River at Nicholson Road	=	=	✓	XX	X	=	✓✓	=	=	X	=	=	XX	=	=	2,882	83↑
Waitara River at Autawa Road	XX	=	=	XX	XX	=	X	XX	X	XX	=	=	XX	=	XX	10,362	64↑

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

[Notes: Whenuakura River and Waitara River data collection commenced in mid 2015; Maketawa Stream data collection commenced in mid 2003; Waingongoro River at SH45 data collection commenced in mid 1998]

Aesthetic and physical parameters in 2016-2017

Generally, for the sites monitored at least 10 years, water quality in the 2016-2017 period (Table 51) showed similar or poorer **black disc clarity and turbidity** levels, and similar or slightly better **suspended solids** levels, compared with the long-term monitoring record. The Stony River showed continuing deterioration in all three measures following a flood event in February 2017, and turbidity deteriorated at the eastern hill country site on the Mangaehu River). Median water **temperatures** were higher at all of the eleven long-term monitored sites in the year under review, and narrower temperature ranges were measured, mainly due to lower maximum temperatures (in comparison with the longer period).

Median **dissolved oxygen saturation and pH** showed no significant differences in the latest period (Table 51). **BOD_5 concentration** decreased at two lower reach sites, one on the ring plain (Punehu Stream) and one in the eastern hill country (Mangaehu River).

Nutrients in 2016-2017

A majority of sites' median nutrient levels remained similar in the 2016-2017 period to those over the longer period. A few improvements in median nutrient species (ammonia N at three sites and phosphorus species at one site) were recorded. Deterioration was found in median nitrate N (at seven of eleven sites, five by more than 50%), ammonia N (at two sites), total nitrogen (at four sites), dissolved reactive phosphorus (at four sites) and total phosphorus (at one site) (Table 51). On an overall view, nitrate, total nitrogen and dissolved reactive phosphorus levels showed more increases, with no clear pattern for either ammonia or total phosphorus.

Bacteria in 2016-2017

Overall, there was a deterioration in bacteriological water quality, with the number of worsening sites exceeding markedly the number of sites showing improvement. Bacteria numbers showed improvement at three sites in terms of median enterococci numbers but there was deterioration at four sites during the 2016-2017 period. One site showed improvement in median faecal coliform bacteria numbers while six sites showed deterioration. This general trend of deterioration in bacteriological water quality during 2016-2017 probably in part reflected an increased proportional frequency of sampling of freshes during the 2016-2107 period compared with that over the longer period.

Trends

This TRC programme is complemented by the two 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.

A trend assessment has been performed upon eleven TRC sites over the 1995-2017 period (including one site for the 1998-2017 period and one site for the 2003-2017 period) and summarised in this Annual Report. Trend analysis has also been performed on the two NIWA sites. This complements earlier trend analyses.

In conclusion, long term (22-year) physicochemical trends have indicated significant deterioration for some parameters at some sites, especially for nutrients mainly in the middle and lower catchments, alongside stability in most measures and some improvements. Overall, between two-thirds and three-quarters (depending on the parameter) of results show either maintenance or improvement in water quality.

A significant improvement in aspects of temporal water quality (mainly nutrients) has been found at the site in the lower Waingongoro River, coincident with the relatively more recent reductions in waste loadings discharged by industry and/or the township to the river in mid catchment at Eltham (TRC, 2015a). 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 trends for these three sites have 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 four of the eleven sites monitored, with the lower Punehu being the only site showing any degree of deterioration in total nitrogen over the long term (a trend which has disappeared in recent years).

One mid-reach site, the Maketawa Stream at Tarata Road, and one lower reach site, the Waingongoro River at SH45, have shown significant long term deterioration in BOD_5 although concentrations have remained consistently below the recognised criterion of 2g/m^3 at this site.

Faecal coliforms and enterococci trends generally have not altered significantly over the 22-year period at the majority of sites. However, two sites of the eleven have shown significant deterioration, one in each of the lower or mid reaches, and two sites, one in each of the upper and lower reaches, have shown improvement.

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 Mangaoraka Stream at Corbett Road. All sites have had insignificant trends for conductivity, temperature, and pH.

Over the long term, the Waiwhakaiho River (mid catchment) and Mangaoraka Stream (lower catchment) show the greatest degree of deterioration; both sites show much less or no deterioration at all in recent years.

On a site specific basis comparing the 2016-2017 period with the previous 21-year historical record, the mid-reach site on the Stony River showed the most variability in water quality, with eight of the fifteen parameters recording either lower or higher quality, mainly due to an ongoing erosion event. The Maketawa Stream (mid-reach), which is representative of developed farmland catchments, showed deterioration in seven parameters: clarity and turbidity, bacteria number and nutrient species. Another five sites had at least five parameters showing different from usual quality, which may be related to the greater proportion of higher flows sampled. Main differences were found for ammoniacal and nitrate nitrogen, dissolved reactive phosphorus and bacterial species. Least differences in comparative water quality were found at the Patea River (mid-reach) site, whereas the highest number of parameters that were better than usual were found at the Waingongoro River (lower reach) site.

Overall, during the 2016-2017 period water quality parameters' medians differed by more than 20% from 21-year medians for 33% of comparisons (24% deterioration; 9% improvement), and by more than 50% from historical medians for 14% of comparisons (14% deterioration, 0% improvement). This was coincident with higher median flows (3 to 60%) sampled at ten of the eleven sites over the 2016-2017 period.

6 Recommendations

1. THAT the existing freshwater physicochemical component of the SEM programme continue in a similar format for the 2017-2018 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 1995-2017 period (provided in the current report), be updated for the 1995-2018 period at the conclusion of the 2017-2018 year.

7 Acknowledgements

This programme's Job Manager was James Kitto (Science Advisor) who was the principal author of the Annual Report. Statistical analyses were provided by Fiza Hafiz (Scientific Officers) with the majority of the field sample collection performed by Ray Harris, Rae West, David Olson and Katie Blakemore (Technical Officers). Hydrological data were provided by Fiona Jansma (Scientific Officer) with field gaugings performed by Warrick Johnston, Craig Pickford and Regan Diggelmann (Hydrology Officers). Graham Bryers and Mike Crump (NIWA) assisted with the provision of National network data for two Taranaki sites and with the inter-laboratory comparison exercise. All water quality analytical work was performed by the Taranaki Regional Council ISO-9000 accredited laboratory under the supervision of John Williams.

Bibliography

ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Ballantine, DJ and RJ Davies-Colley, 2009: Water quality trends at national river water quality network sites for 1989-2007. Prepared by NIWA for Ministry for the Environment.

Connolly, A, 2011. Trends in regional physicochemical water quality data for Taranaki: a comparison of 1995-2010 (15 year data set) with 2002-2010 (8 year data set). TRC Internal Memorandum.

Connolly, A, 2012. Trends in regional physicochemical water quality data for Taranaki: 2004-2011. TRC Internal Memorandum.

Connolly, A, 2012. Trends in regional physicochemical water quality data for Taranaki: 1995-2012. TRC Internal Memorandum.

Hope, KJ, 2009. Physicochemical trend software comparison. TRC Internal memorandum.

Hope, KJ, 2009a. Physicochemical water quality trend report 1995-2009. TRC Internal memorandum.

McBride, G, 1996: 'Trends at the Taranaki sites of the New Zealand National River Water Quality Network'. NIWA Consultancy Report TRC302.

MfE, 2003: Microbiological water quality guidelines for marine and freshwater recreational areas. Ministry for the Environment publication.

Scarsbrook and McBride, 2007: Best practice guidelines for the statistical analysis of freshwater quality data, version 1. Prepared by NIWA for Ministry for the Environment.

Smith, D G; McBride, G.B; Bryers, G.G; Davies-Colley, R.J; Quinn, J.M; Vant, W.N; 1989. A National Water Quality Network for New Zealand. Consultancy Report 80`5/1. Prepared for the Manager, Water Resources Survey, DSIR.

Stark, J D, 2003: 'The water quality and biological condition of the Maketawa catchment'. Cawthron Report No. 742 70 pp.

Stark, JD and Fowles, CR, 2006: An approach to the evaluation of temporal trends in Taranaki state of the environment macroinvertebrate data. Cawthron Institute Report No 113 88pp.

TCC, 1984: 'Taranaki Ring Plain Water Resources Survey: Water Quality. Taranaki Catchment Commission report.

TRC, 1996a: 'Statement of the Environment: Taranaki Region'. TRC Publication.

TRC, 1997: 'Annual SEM Report 1995-96: Freshwater Biological Monitoring Programme'. TRC Report 97-96.

TRC, 1998: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 1995-96. TRC Technical Report 97-105.

TRC, 1998: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 1996-97. TRC Technical Report 98-19.

TRC, 1999: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 1997-98. TRC Technical Report 98-90.

TRC, 2000: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 1998-99. TRC Technical Report 99-91.

TRC, 2001: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 1999-2000. TRC Technical Report 2000-52.

TRC, 2002: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2000-2001. TRC Technical Report 2001-85.

TRC, 2002: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2001-2002. TRC Technical Report 2002-41.

TRC, 2003: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2002-2003. TRC Technical Report 2003-56.

TRC, 2003: Taranaki - our place, our future, Report on the state of the environment of the Taranaki region - 2003. TRC 206 pp.

TRC, 2004: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2003-2004. TRC Technical Report 2004-54.

TRC, 2004a: 'State of the Environment: Regional Water Quality Monitoring for Taranaki. Physicochemical sampling techniques for freshwater rivers and streams: TRC Internal Report

TRC, 2005: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2004-2005. TRC Technical Report 2005-68.

TRC, 2006: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2005-2006. TRC Technical Report 2006-74.

TRC 2006a: Trends in the quality of the surface waters of Taranaki. TRC Internal Report.

TRC 2006b: Freshwater nuisance periphyton monitoring programme. State of the environment monitoring report 2002-2006. TRC Technical Report 2006-69.

TRC 2006c: An interpretation of the reasons for statistically significant temporal trends in macroinvertebrate (MCI) SEM data in the Taranaki region 1995-2005. TRC internal report.

TRC, 2007: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2006-2007. TRC Technical Report 2007-69.

TRC, 2008: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2007-2008. TRC Technical Report 2008-100.

TRC, 2009: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2008-2009. TRC Technical Report 2009-54.

TRC, 2009a: Taranaki Where We Stand. State of the Environment Report 2009. Taranaki Regional Council ,284p.

TRC, 2010: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2009-2010. TRC Technical Report 2010-15.

TRC, 2011: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2010-2011. TRC Technical Report 2011-47.

TRC, 2011a: An evaluation of dairy shed wastes discharge consent compliance - a comparison of visual inspection and field physicochemical sampling methods 2010-2011. TRC internal Report 56pp.

TRC, 2012: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2011-2012. TRC Technical Report 2012-27.

TRC, 2013: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2012-2013. TRC Technical Report 2013-49.

TRC, 2014: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2013-2014. TRC Technical Report 2014-23.

TRC 2015: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2014-2015. TRC Technical Report 2015-51.

TRC 2015a: Taranaki As One. State of the Environment Report 2015. Taranaki Regional Council, 268p.

TRC 2016: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2015-2016. TRC Technical Report 2016-27.

TRC, 2016a: Freshwater periphyton monitoring programme. (Periphyton monitoring in relation to amenity values). State of the environment monitoring report 2014-2016. TRC Technical Report 2016-34.

TRC 2017: Freshwater contact recreational monitoring programme. State of the environment monitoring report 2016-2017. TRC Technical Report 2017-01.

TRC, 2017a: Freshwater macroinvertebrate fauna biological monitoring programme. State of the Environment Monitoring Annual Report 2016-2017. TRC Technical Report 2017-89.

TRC, 2018: Freshwater periphyton monitoring programme. (Periphyton monitoring in relation to amenity values). State of the environment monitoring report 2016-2018. TRC Technical Report 2018-7.

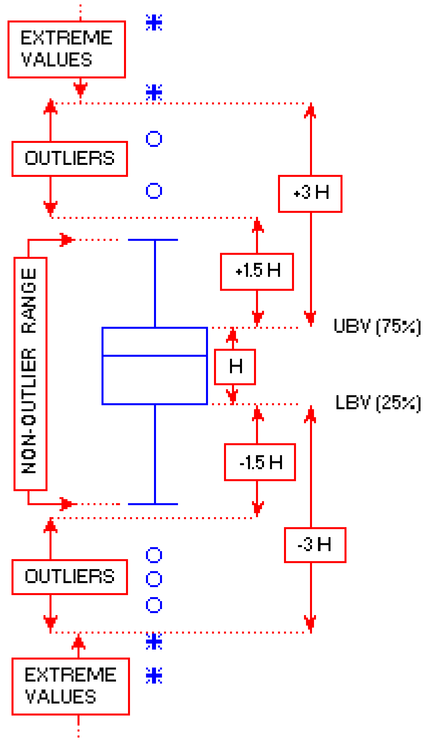
Ward, R C; and McBride, G B, 1986: 'Design of water quality monitoring systems in New Zealand'. Water Quality Centre, MOW&D, Hamilton Publication No 8.

Appendix I

Statistical 'Box & Whisker' Plots of 1995-2017 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:

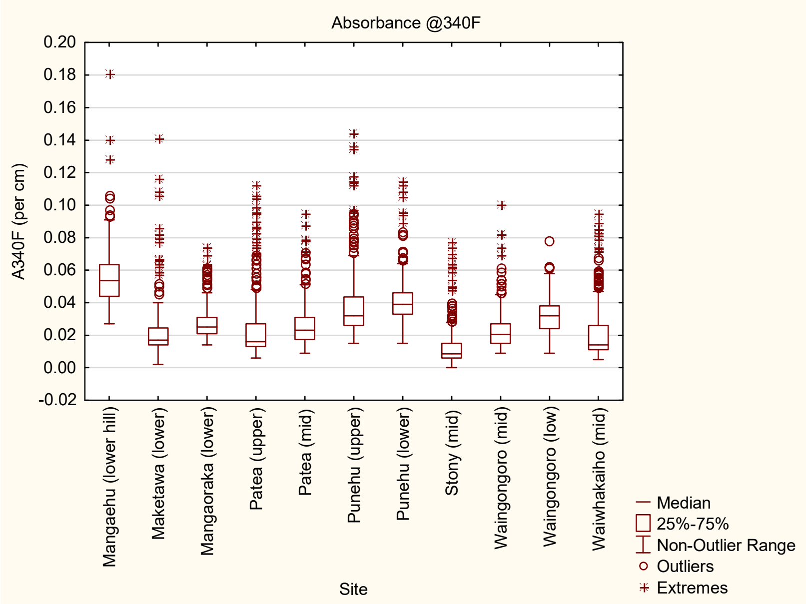
Lower fence = lower hinge – (3 x Hspread)
Upper fence = upper hinge + (3 x Hspread)

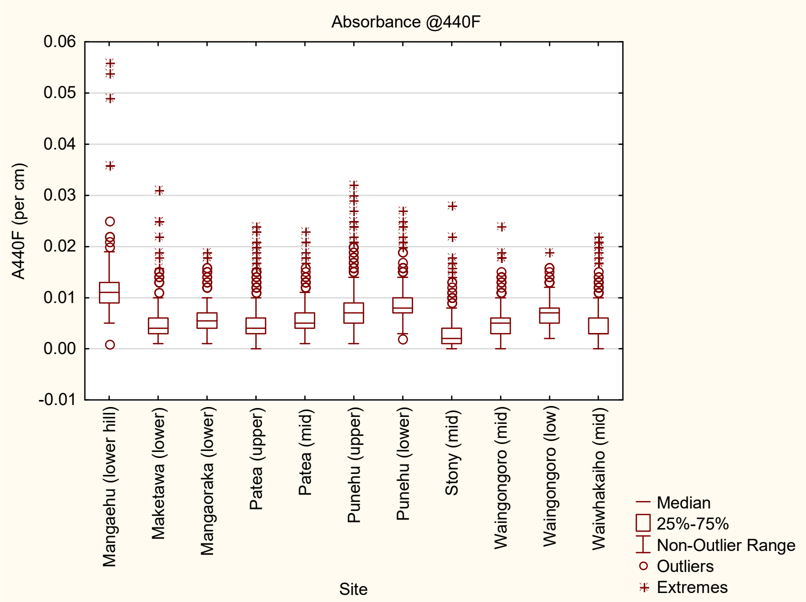
The whiskers show the range of values that lie within the inner fences. Values outside the inner fence are plotted as open circles (o). Values outside the outer fence are plotted as asterisks (*).

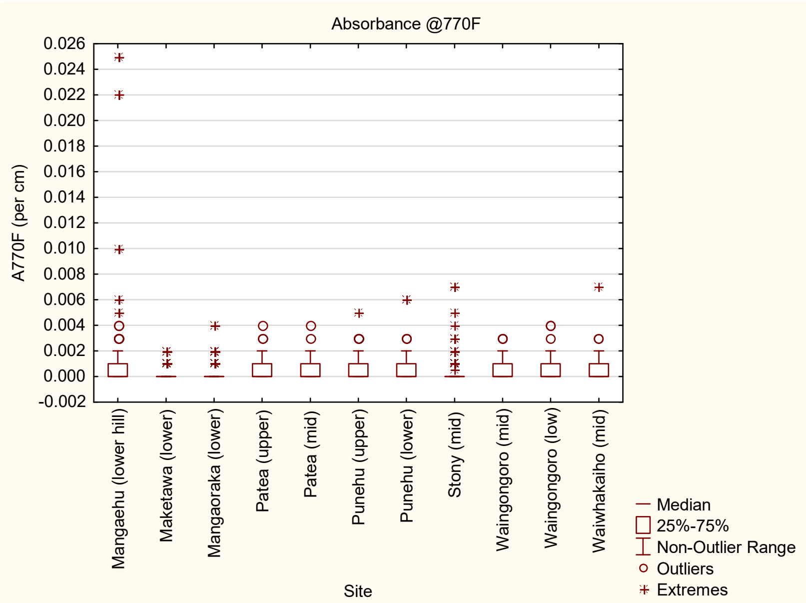
Site locations

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
Waitara River	at Tarata
Waiwhakaiho River	at SH3
Whenuakura River	at Nicholson Road

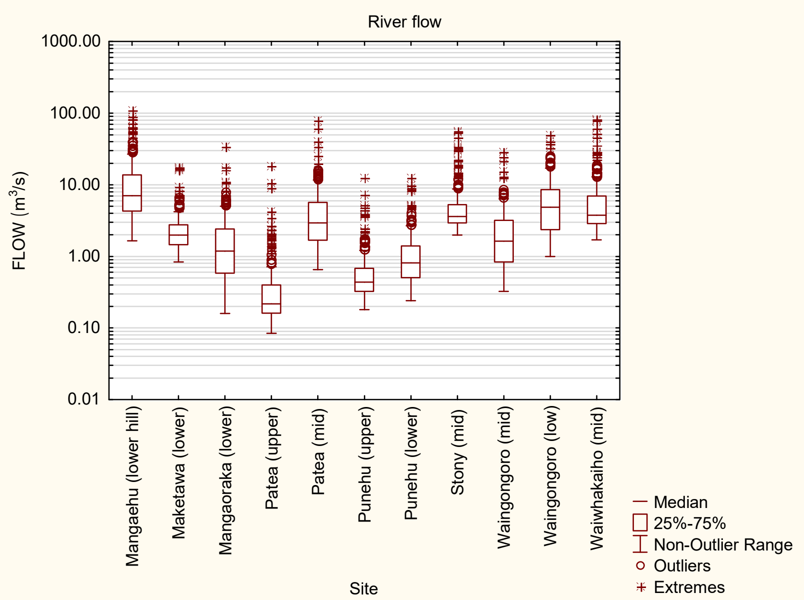
Absorbance (1cm)

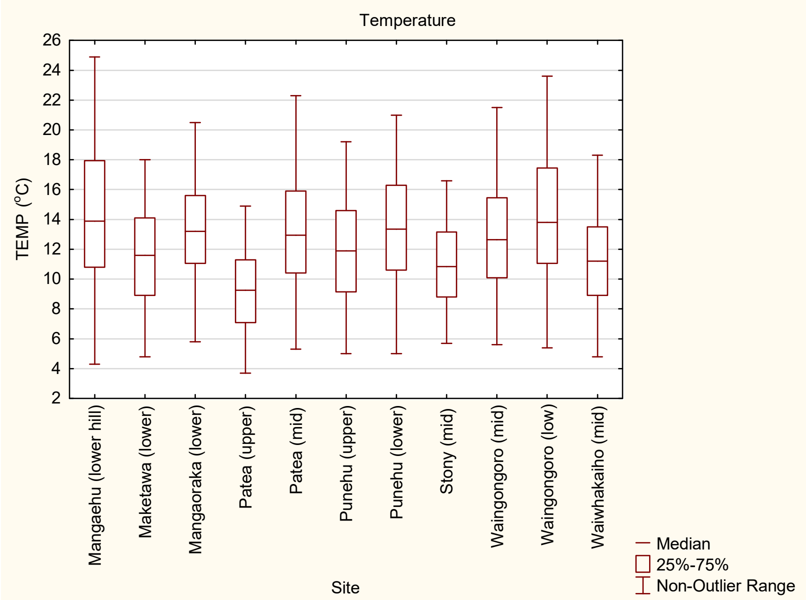


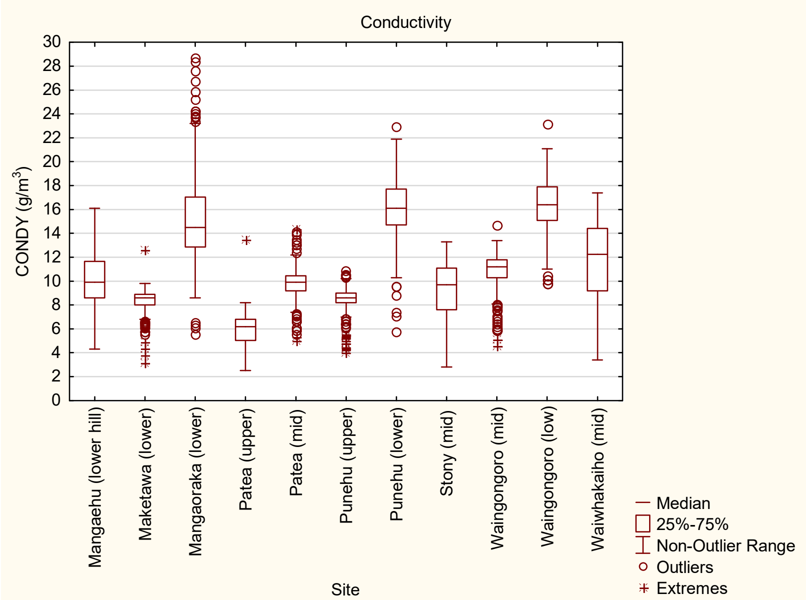


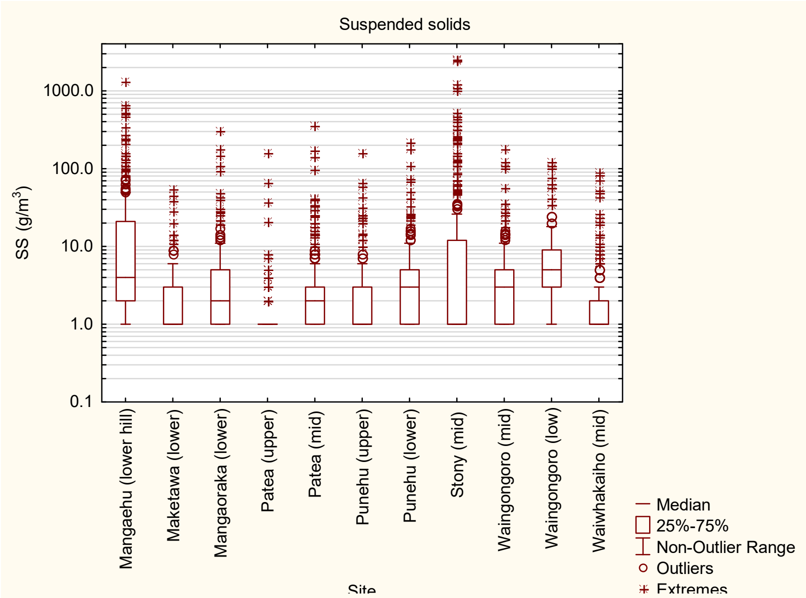


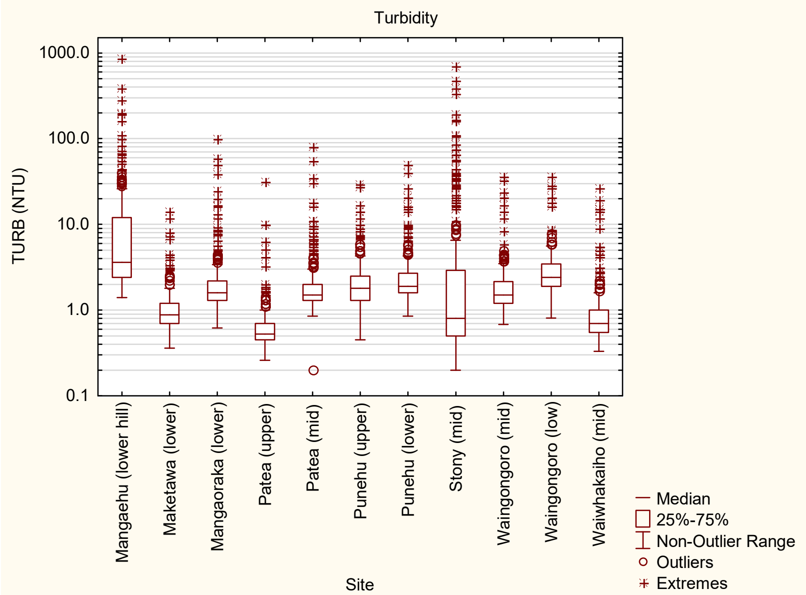
Physical Quality

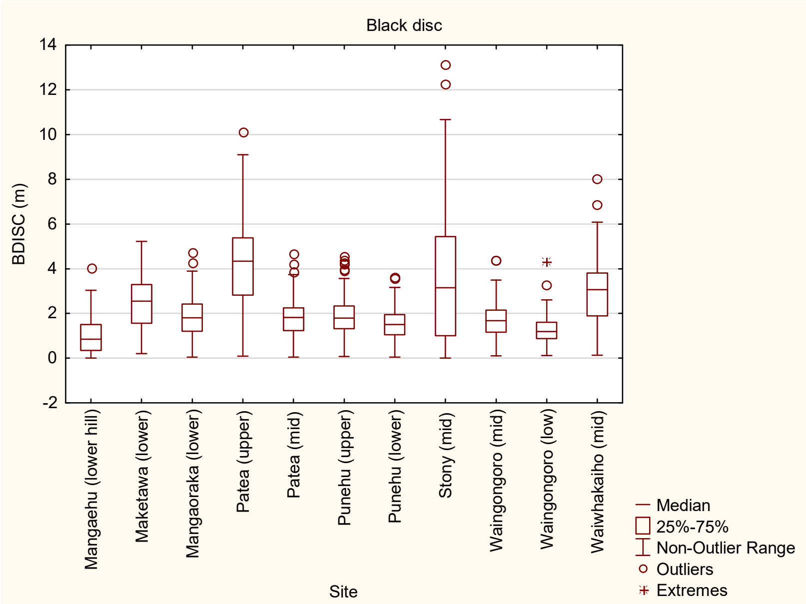


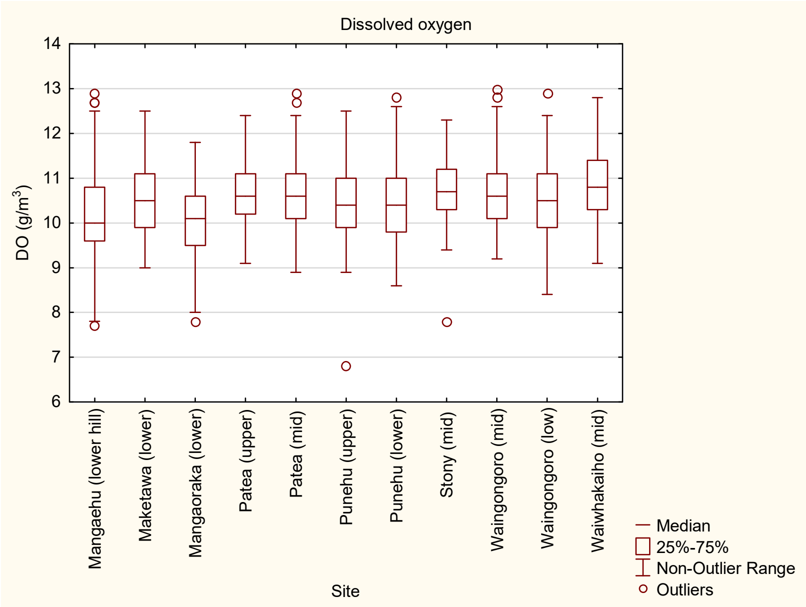


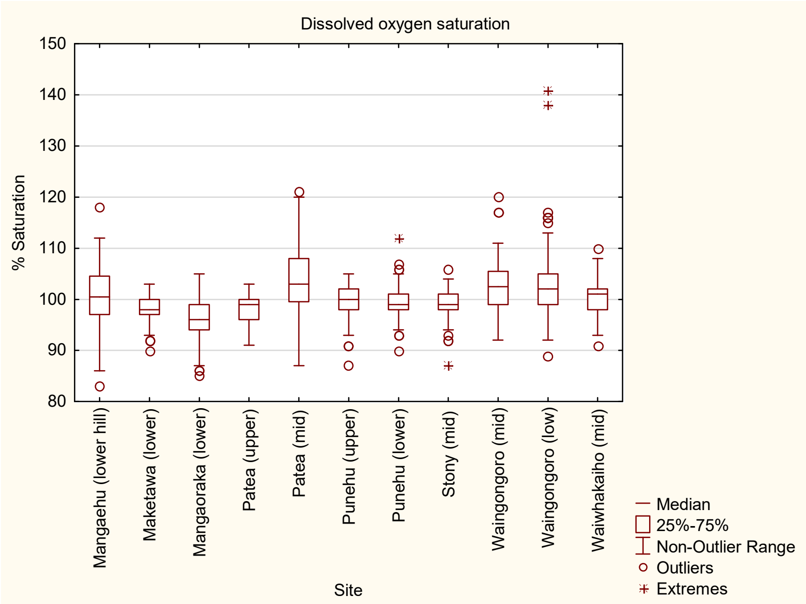


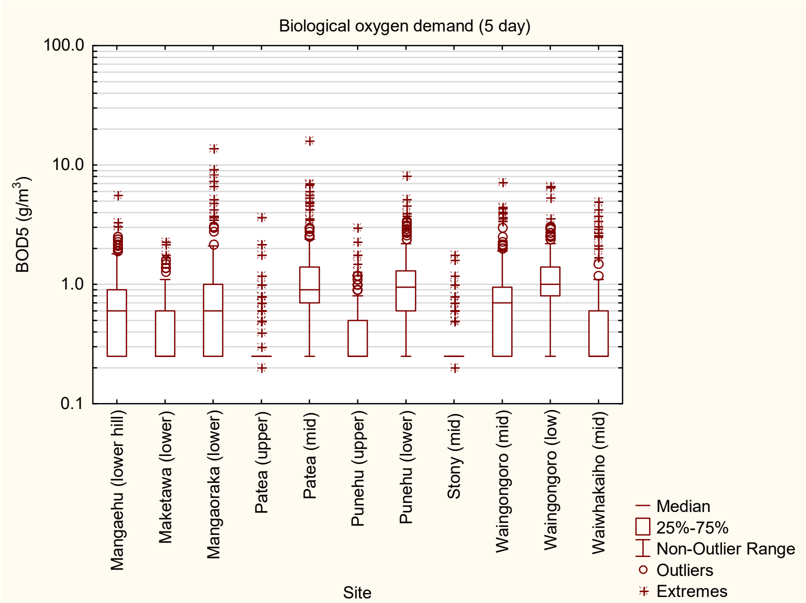

Suspended solids
SS (g/m3)
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

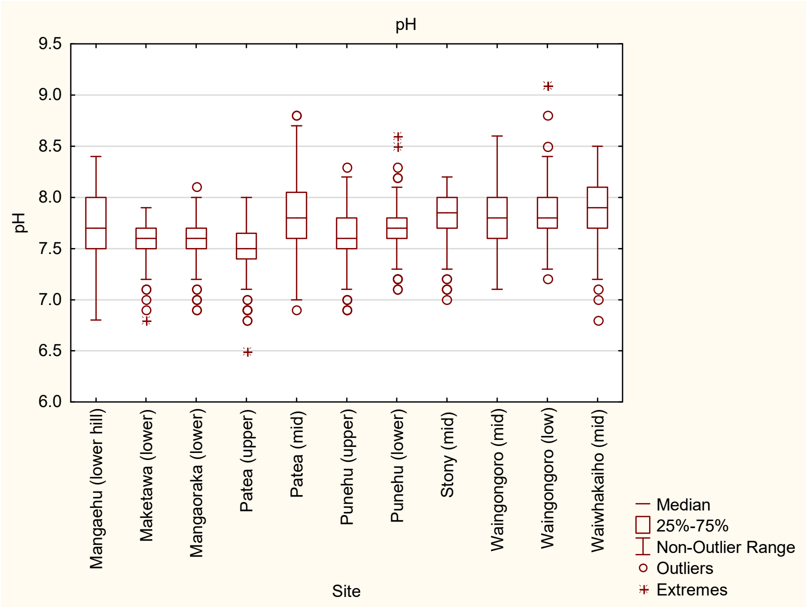

Turbidity
TURB (NTU)
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

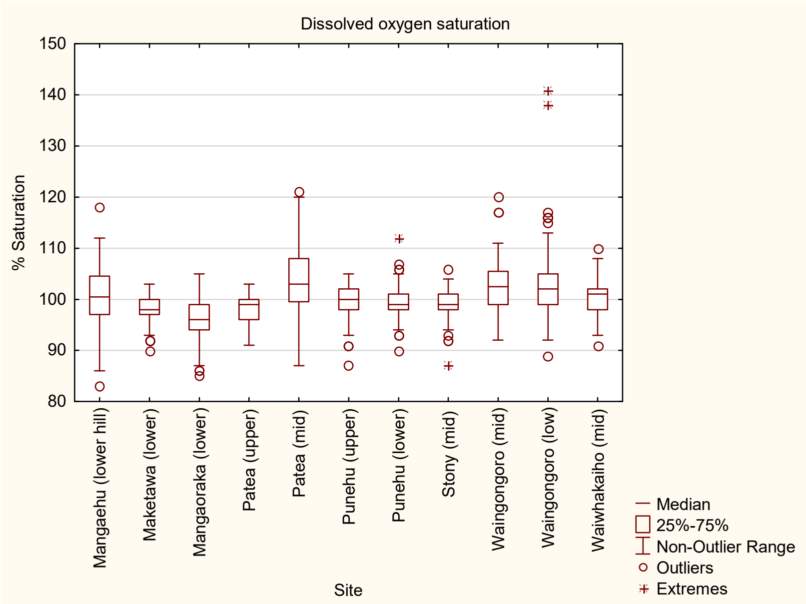

Black disc
BDISC (m)
14
12
10
8
6
4
2
0
-2
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


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

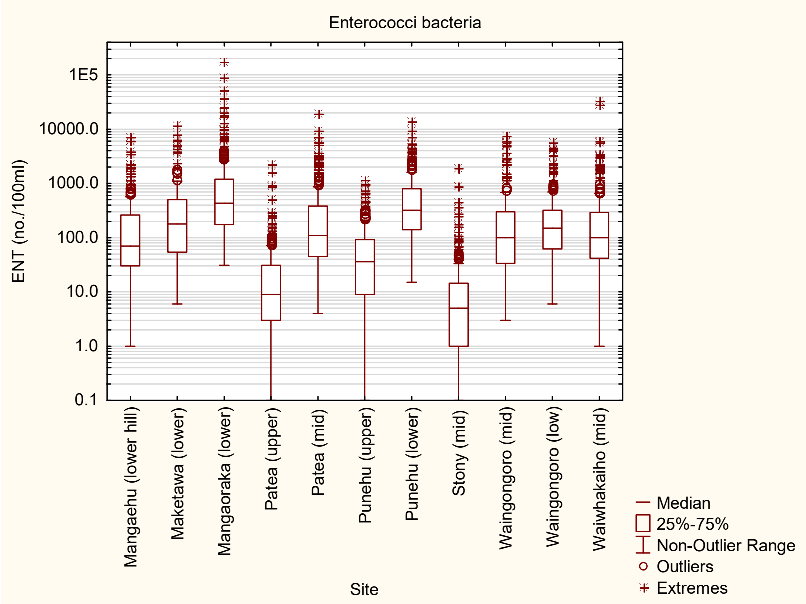

Dissolved oxygen saturation
% Saturation
150
140
130
120
110
100
90
80
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


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

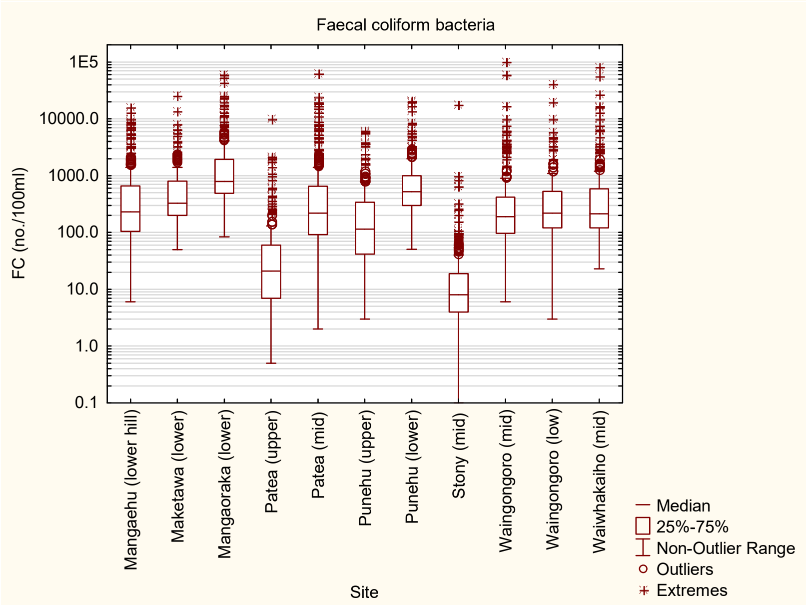

pH
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
pH
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Dissolved oxygen saturation
150
140
130
120
110
100
90
80
% Saturation
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

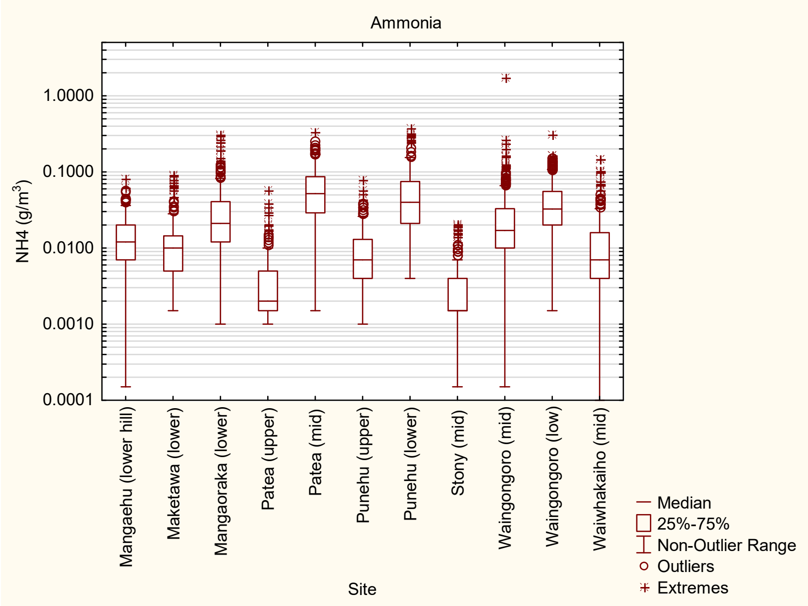


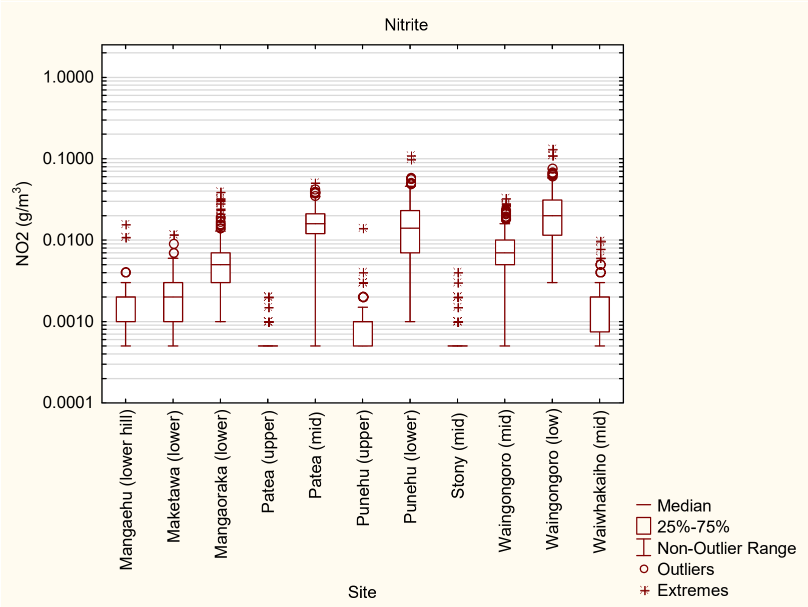
Enterococci bacteria
ENT (no./100ml)
1E5
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers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

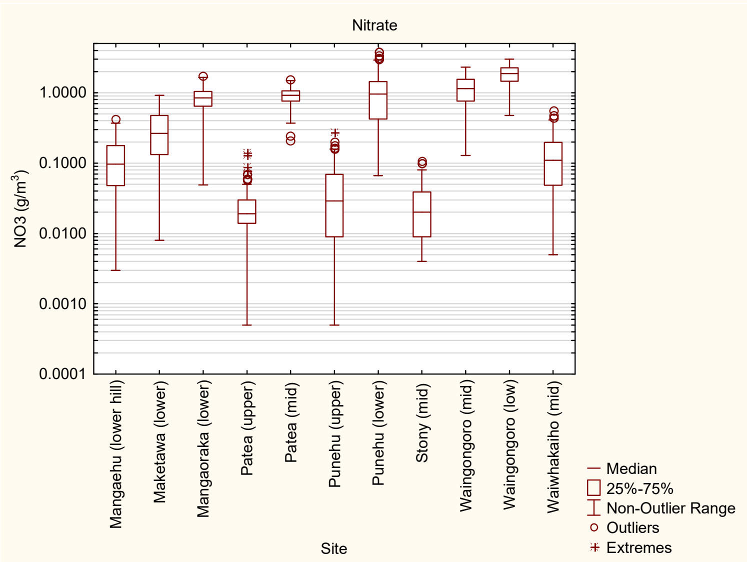


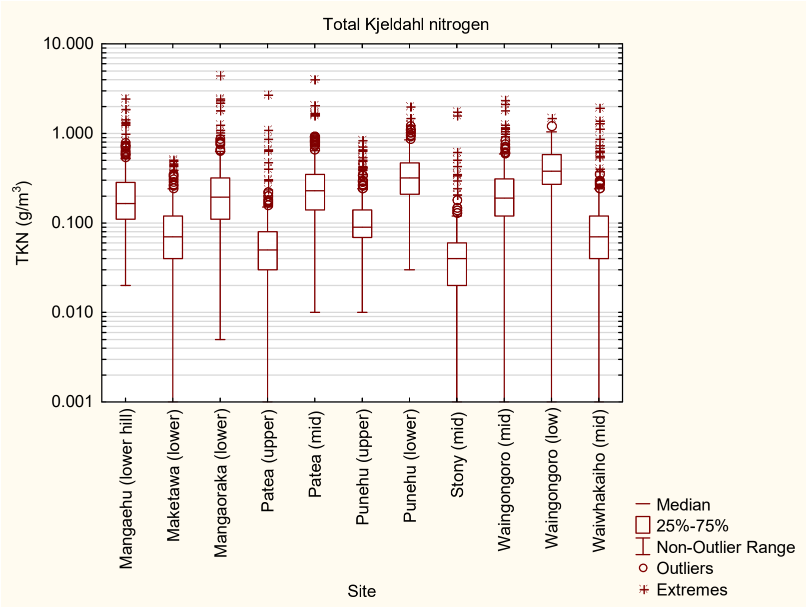
Faecal coliform bacteria
FC (no./100ml)
1E5
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers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

Nutrients

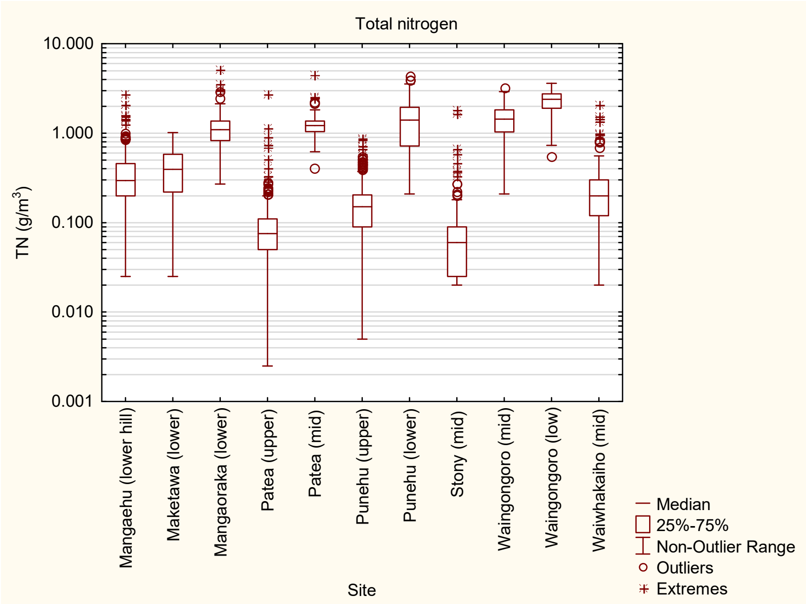

Ammonia
NH4 (g/m3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


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

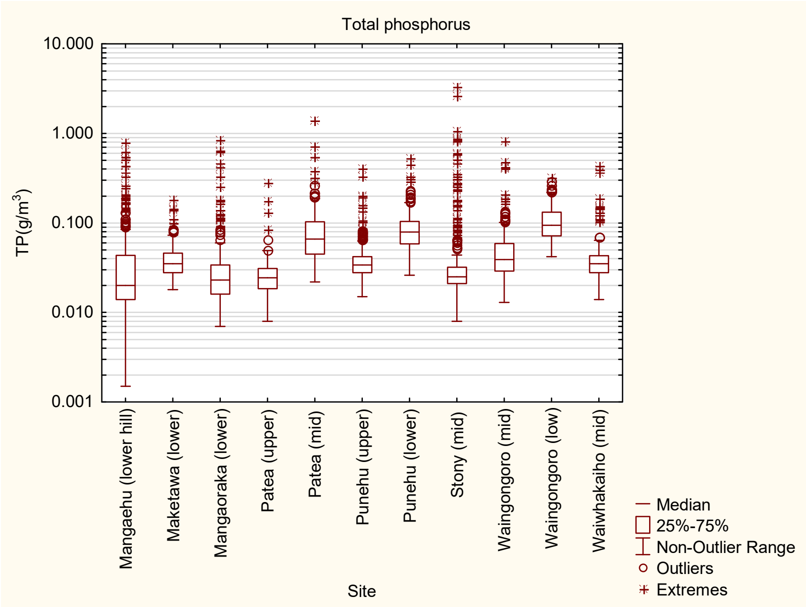

Nitrate
NO3 (g/m3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

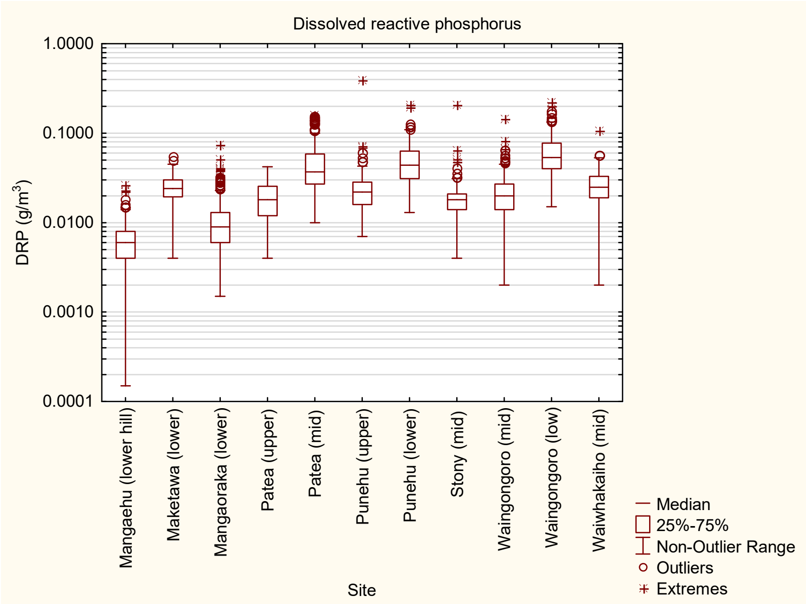


Total Kjeldahl nitrogen
TKN (g/m^3)
10.000
1.000
0.100
0.010
0.001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



Total nitrogen
TN (g/m^3)
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

Section 6.2 of the Regional Policy Statement for Taranaki 2010

Maintaining and enhancing the quality of water in our rivers, streams, lakes, and wetlands

Background to the issue

Water use is important to economic growth and sustainability in the region. Use of water is a fundamental requirement of most rural based industry and agricultural activities and is appropriate where effects on water quality can be avoided, remedied or mitigated. Water quality refers to the physical, chemical and biological characteristics of water that affect its ability to sustain environmental values and uses. Good surface water quality is important, not only in terms of maintaining healthy rivers and streams but also in terms of water supply purposes, meeting the consumptive demands of Taranaki's agricultural and industrial sectors and protecting the natural character and amenity values associated with particular surface water bodies.

Taranaki's water bodies have generally good to excellent water quality on most physical, chemical and biological measures and comparisons. However, surface water quality is lost or reduced through land or water use activities resulting in point or diffuse source discharges of contaminants to surface water or onto land in circumstances where the discharge may enter water.

Point source discharges (ie: waste discharges from a pipe) commonly occur from a wide range of activities such as industries, urban wastewater treatment systems and farming operations etc. Most are treated and discharged in a manner that ensures that adverse effects on water quality are not significant or are no more than minor. However, multiple point source discharges to the same water body can have a cumulative adverse effect on water quality and point source discharges can contribute to the decline in water quality that occurs down the length of ring plain catchments.The Taranaki Regional Council closely monitors point source discharges and this will need to continue.

The cumulative effects of diffuse (widespread) or non-point source discharges to water, such as runoff from land of leachate of agricultural wastes, nutrients or sediments, are the principal cause of reduced water quality in most catchments in the region. Diffuse source contamination is often attributable to poor land use practices such as the excessive use of fertilisers and agrichemicals to land, grazing of river and stream margins, the direct entry of stock to water, and inappropriate land use on erosion prone land. The effects of diffuse source contamination are also exacerbated by the loss or modification of riparian vegetation along the banks of waterways. The adverse effects of point source discharges are not always significant and some are no more than minor.

The significant issues in relation to maintaining or enhancing surface water quality are:

WQU ISS 1	**Managing adverse effects on water quality arising from point source discharges to water bodies.**
WQU ISS 2	**Managing adverse effects on water quality arising from diffuse source discharges to water bodies.**
WQU ISS 3	**Managing the cumulative adverse effects on water quality arising from both multiple point source discharges and diffuse source discharges to water bodies.**

OBJECTIVE

WQU OBJECTIVE 1

To maintain and enhance surface water quality in Taranaki's rivers, streams, lakes and wetlands by avoiding, remedying or mitigating any adverse effects of point source and diffuse source discharges to water.

POLICIES

Sustainable land management practices

WQU POLICY 1

Sustainable land management practices and techniques that avoid, remedy or mitigate adverse effects on surface water quality will be encouraged, including:

(a) the retention and restoration of effective riparian buffer zones;

(b) the careful application of the correct types and quantity of fertiliser and agrichemicals;

(c) the careful application of the appropriate quantities of farm dairy effluent having regard to topography, land area, weather and soil conditions;

(d) the development, recontouring and restoration of disturbed land to reduce diffuse source discharges of contaminants to water;

(e) farm management practices that avoid, remedy or mitigate the effects of stock entry to rivers and streams, trampling and pugging by stock, overgrazing, and accelerated erosion from inappropriate land use on erosion prone land; and

(f) other land management practices, including the discharge of contaminants to land and the diversion of stormwater runoff to land, which avoid or reduce contamination of surface water.

Riparian management

WQU POLICY 2

The retirement and planting of riparian margins throughout the Taranaki region will be promoted, with a particular focus on ring plain catchments.

Protection of water quality in areas of high natural character

WQU POLICY 3

The water quality of the Stony (Hangatahua) River catchment and other rivers, streams, lakes and wetlands with high natural character, ecological and amenity values such as the Maketawa Stream catchment and parts of the Manganui River catchment will be maintained and enhanced as far as practicable.

Domestic and community water supplies

WQU POLICY 4

The importance of maintaining or enhancing water quality in catchments which are used for domestic and community water supplies will be recognised.

Point source discharges to surface water

WQU POLICY 5

Waste reduction and waste treatment and disposal practices, which avoid, remedy or mitigate the adverse environmental effects of the point source discharge of contaminants into water or onto or into land will be required. This includes the cumulative adverse effects of multiple point source discharges to the same waterbody.

In considering policies in regional plans or resource consent proposals to discharge contaminants or water to land or water, matters to be considered by the Taranaki Regional Council will include:

(a) the actual or potential effects of the discharge on the natural character, ecological and amenity values of the water body, including

indigenous biodiversity values, fishery values and the habitat of trout;

(b) the relationship of tangata whenua with the water body;

(c) the use of water for domestic and community water supply purposes;

(d) the actual or potential risks to human and animal health from the discharge;

(e) the significance of any historic heritage values associated with the waterbody;

(f) the degree to which the needs of other resource users might be compromised;

(g) the allowance for reasonable mixing zones and sufficient dilution (determined in accordance with (a) to (o) of this Policy);

(h) the potential for cumulative effects;

(i) measures to reduce the volume and toxicity of the contaminant;

(j) off set mitigation of the effects of the contaminants;

(k) measures to reduce the risk of unintended discharges of contaminants;

(l) the necessity of the discharge and the use of the best practicable option for the treatment and disposal of contaminants;

(m) the availability and effectiveness of alternative means of disposing of the contaminant;

(n) relevant national guidelines and national environmental standards on catchment management; and

(o) the sensitivity of the receiving environment.

Restoration of water quality

WQU POLICY 6

Where the life-supporting capacity of rivers, streams, lakes or wetlands is under pressure as a result of point or diffuse discharges to surface water, improvements in the biological health and quality of water will be promoted.

For the purposes of this policy, in determining the desired life supporting capacity, the matters to be considered will include:

(a) the existing status of water quality according to a selection of chemical parameters and its consequences for life-supporting capacity;

(b) the existing habitat quality, including the need to maintain and enhance aquatic ecosystems and species;

(c) the degree to which cultural and spiritual values of or customary uses by tangata whenua are affected by existing water quality; and

(d) the natural character, ecological and amenity values of the water body, including indigenous biodiversity values, fishery values and the habitat of trout and the potential for enhancement of those values.

Explanation of the policies

Policy 1 outlines management practices to be encouraged that will contribute to maintaining and enhancing water quality by reducing diffuse source discharges of contaminants.

Policy 2 recognises the significant water quality benefits that can be achieved by maintaining and enhancing existing riparian vegetation and promoting the restoration of riparian margins. Riparian margins help mitigate adverse effects of diffuse source discharges of contaminants by providing buffering capacity and preventing direct entry of stock into waterways. Policy 2 applies throughout Taranaki. However, the focus will be on ring plain catchments, which includes Taranaki's most intensively farmed land and where pressures associated with diffuse source contamination are most significant.

Policy 3 recognises that some rivers, streams, lakes and wetlands are highly valued for their natural character, and ecological and amenity values. Through this policy, the Council seeks to maintain or enhance the quality of water in systems recognised as having high natural character and in-stream values (refer Appendix I).

Policy 4 recognises the importance to people and communities and their health and safety, of maintaining or enhancing water quality in catchments used for domestic or community water supplies. However, nutrients or other contaminants will always be present in water, either from natural sources or from the effects of land use or discharging activities, even if these activities are managed to best practice standards. Investment in appropriate water treatment systems and processes will therefore also be required to ensure the community has suitable potable water.

Policy *5* recognises that there are existing discharges to surface water and that discharges to surface water will be necessary in future. Policy 5 sets out a framework to assess proposals or policy on point source discharges to surface water. It requires waste reduction or treatment practices that avoid, remedy or mitigate adverse environmental effects arising from the discharge of contaminants to land or water from point sources. The policy also states the matters that will be considered by the Taranaki Regional Council including catchment specific values and uses, the degree to which other resource users (both consumptive and non-consumptive) may be affected, the adoption of measures to avoid, remedy or mitigate adverse effects, including off set mitigation measures such as riparian plantings, and any national guidelines.

Where multiple point source discharges occur to the same water body there may be cumulative adverse effects on water quality. These effects are also to be avoided, remedied or mitigated under Policy 5.

Policy *6* relating to life supporting capacity is to establish an overall policy intention to generally upgrade the receiving water environment in those waters in which the life supporting capacity is under pressure. Parameters that may be used to measure life supporting capacity include biological oxygen demand, suspended sediment, dissolved reactive phosphate, nitrate and ammonia levels, pH, temperature, macro-invertebrate community index, the presence of pathogenic micro-organisms, and nuisance algae. The necessity of the discharge itself will be considered under Policy 5.

Related policies

All policies relating to **Section 5.1** [Soil erosion]; Policy 1 of **Section 5.2** [Soil health], **Section 6.1** [Sustainable water allocation], **Section 6.2** [Surface water quality], **Section 6.4** [Wetlands], **Section 6.5** [Land drainage and other associated diversions], and **Section 6.6** [Use of river and lake beds]; Policy 1 of **Section 8.1** [Preservation of the natural character of the coastal environment]; all policies relating to **Section 9** [Indigenous biodiversity], **Section 10.1** [Outstanding natural features and landscapes]; **Section 10.3** [Amenity values]; and **Section 13** [Minerals]; Policy 1 of **Section 15.2** [Regionally significant infrastructure]; and all policies relating to **Section 16** [Issues of significance to iwi].

METHODS OF IMPLEMENTATION

The Taranaki Regional Council will:

WQU METH 1 Maintain a **regional plan or plans** with objectives, policies and methods of implementation to ensure that any adverse effects of point and diffuse source discharges to land and water are avoided, remedied, or mitigated, and that water quality is maintained and enhanced, particularly in water bodies that have high natural character, ecological and amenity values and in those that have relatively poor water quality.

WQU METH 2 Apply regional rules to allow, regulate, and in some instances prohibit the following point source discharges to land and water:

(a) point source discharges of water;

(b) point source discharges of stormwater;

(c) point source discharges from closed landfills;

(d) point source discharges from industrial and trade premises;

(e) point source agricultural discharges;

(f) point source discharges from hydrocarbon exploration; and

(g) other point source discharges.

WQU METH 3 Participate and support the dairy farming industry in the preparation and implementation of a regional action plan under the **Dairying and Clean Streams Accord** and include in that Plan targets for excluding stock from water bodies, farm dairy effluent discharge compliance with resource consents, the protection of regionally significant wetlands, and nutrient management.

WQU METH 4

Implement the **Sustainable Land Management Programme** to promote sustainable land use practices that will avoid, remedy or mitigate the adverse effects of diffuse source discharges.

WQU METH 5

Implement the **Riparian Management Programme** to promote the retirement and planting of riparian margins by:

(a) liaising and consulting with interested land users;

(b) preparing property plans in conjunction with landowners containing property-specific advice on riparian management actions and programmes; and

(c) providing on-going technical advice, information and other assistance to plan holders, promoting riparian management.

WQU METH 6

Consider the use of **financial incentives**, such as the provision of plant material at low cost to landowners, for riparian management purposes.

WQU METH 7

Provide **advice and information** including guidelines**,** to landowners, resource users and the public:

(a) to generally promote awareness of water quality issues;

(b) to encourage the adoption of riparian management principles and practices that avoid, remedy or mitigate adverse effects of diffuse source discharges on water quality; and

(c) on systems, siting, design, installation, operation and maintenance procedures for industrial and agricultural waste treatment and disposal systems.

(d) promote where appropriate the adoption of waste disposal systems that reduce the potential for cumulative adverse effects on water quality.

WQU METH 8

Advocate, as appropriate:

(a) to manufacturers and suppliers of agrichemicals, fertilisers and other agricultural compounds, the strengthening of the education and information provision role they play with a view to minimising the likelihood and potential effects of agrichemical and fertiliser application on water quality;

(b) to industrial and agricultural users to adopt waste minimisation or reduction practices and cleaner production technologies to reduce the quantity of contaminants being discharged to the environment;

(c) to industry to prepare and adopt codes of practice and guidelines aimed at reducing the effects of point and diffuse source discharges;

(d) to territorial authorities to construct and upgrade stormwater reticulation systems and wastewater treatment systems where urban developments make such an upgrade desirable; and

(e) to territorial authorities, the Department of Conservation, and other appropriate organisations such as the Queen Elizabeth II National Trust and the Taranaki Tree Trust, that they protect or retire riparian margins.

WQU METH 9	Promote the application and use of relevant **industry codes of practice.**
WQU METH 10	**Liaise or consult** as appropriate with territorial authorities regarding resource consent applications upstream of community water supply abstraction points.
WQU METH 11	Participate in the development and implementation of any **national environmental standards or national policy statements** on water quality or human drinking water standards.
WQU METH 12	**Support**, as and when appropriate, actions by the dairy industry under the Dairy Industry Strategy for Sustainable Environmental Management.
WQU METH 13	**Require** the preparation of **contingency plans** to reduce the risk of a spill that may have significant adverse effects on water quality.
WQU METH 14	**Monitor and gather information** on the state of water quality, pressures on water quality, and responses to management.
WQU METH 15	**Support**, as and when appropriate, **research and investigations** into water quality management including waste treatment options and the cumulative effects of point source discharges on water quality.

Territorial authorities may wish to consider the following methods:

WQU METH 16	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.
WQU METH 17	Include in **district plans** and **resource consents,** provisions or conditions for fencing and the retention or planting of riparian vegetation, including rules for the creation of esplanade reserves and esplanade strips when land is subdivided.
WQU METH 18	Consider the use of **financial incentives** such as land purchase or compensation, fencing grants, providing plants, rates relief and other funds.
WQU METH 19	**Plant**, where appropriate, riparian margins on land owned by the territorial authority.

Principal reasons for adopting the objective, policies and methods

The objective, policies and methods of implementation establish a policy framework for water quality issues in the Taranaki region. Their aim is to maintain Taranaki's generally high to excellent water quality and to enhance that water quality by addressing the effects of water contamination from diffuse and point sources.

The objective sets a broad direction for water quality management that seeks to maintain and enhance overall surface water quality in Taranaki's rivers, streams, lakes and wetlands. The objective states that this is to be done by avoiding, remedying or mitigating the adverse effects of point and diffuse source discharges to water through the policies and methods set out. The terms. 'maintain' and 'enhance' as used in the objective are not mutually exclusive terms that require both to be given effect to in all cases. The objective has been adopted to establish a broad region-wide goal but the extent to which surface water quality is maintained and enhanced will be determined on a case by case basis by reference to the policies and methods in the RPS. In some situations it will be appropriate that water quality be maintained and enhanced. In other situations for example where a new or increased discharge to water is proposed, it may not always be practicable to enhance water quality, but a range of matters and considerations have been set out in the Regional Policy Statement by which any adverse effects can be avoided, remedied or mitigated.

In respect of point source discharges of contaminants, the policies and methods focus on regulatory methods (complemented by a mix of non-regulatory methods). Regulation is a simple, efficient and effective method of controlling the adverse effects of these discharges, including their cumulative adverse effects on water quality.

Through rules and other provisions in a regional plan, appropriate levels of control are applied that address point source discharges to fresh water and which also protect water quality in rivers and streams that have high natural character, ecological and amenity values.

In respect of diffuse source discharges – the most significant source of contaminants entering waterways – non-regulatory methods such as advice and information and, in particular, the implementation of the Riparian Management Programme and the Sustainable Land Management Programme are considered appropriate. These programmes have proven to be successful to date in terms of public acceptance, the adoption of sustainable land management practices and the achievement of desired environmental outcomes. Other non-regulatory methods also contribute towards achieving the desired environmental outcomes. Financial incentives will aid in landowner acceptance and co-operation with regard to retiring land, particularly where these incentives support a voluntary approach to land use and management. The approaches for point and diffuse source discharges are considered appropriate having regard to their efficiency and effectiveness and their benefits and costs.

Environmental results anticipated

WQU ER 1

All significant point source discharges to surface water consented and monitored.

WQU ER 2

Any adverse environmental effects of point source discharges to surface water are avoided, remedied or mitigated.

WQU ER 3

Increased planting and fencing along the margins of rivers, streams lakes and wetlands with:

- *90% of dairy farms having riparian management plans by 2016; and*
- *90% of riparian management plans implemented by 2016.*

WQU ER 4

Maintain or enhance surface water quality and the life-supporting capacity of freshwater against a range of physical, chemical and biological measures.

The resource consents process and compliance monitoring

The Taranaki Regional Council's regulatory activities, particularly in the area of resource consent processing and administration and compliance monitoring, is one of the core activities of Council. The level of activity in this area fluctuates from year-to-year depending on the level of economic activity and other factors, but the Council anticipates it will process some 3,000 applications for resource consents (covering coastal, discharge, land use or water permits) over the next ten years.

In relation to water quality, all significant point source discharges to fresh water have a resource consent. Through the resource consents process, discharge activities that may have significant adverse effects on water quality are considered and only allowed subject to compliance with certain conditions (activities that have little or no adverse effects are permitted through rules in the *Regional Fresh Water Plan for Taranaki* – subject to compliance with conditions).

As at 1 April 2009, there were 1,479 discharge consents to surface water in the Taranaki region – 1,046 (or 71%) of which are agricultural discharges. Every discharge activity authorised by resource consent is monitored to ensure that the consent holder is complying with the conditions of that consent. The frequency and extent of that monitoring depends upon the size, scale and nature of discharge activity being monitored as well as the potential environmental impacts of the activity.

Over the last decade, there has been significant investment made by agriculture and industry in waste treatment and disposal systems and the overall level of compliance with consent conditions is high (generally around 95%). As a result, Taranaki rivers and streams show good to excellent water quality against most measures.

Riparian Management Programme

A major focus of the Taranaki Regional Council's land management work over the next ten years will be to continue to promote the retirement and planting of riparian margins along Taranaki rivers, streams, lakes and wetlands through the Riparian Management Programme.

The Riparian Management Programme, targets dairying land use on the ring plain, and includes the provision of a property planning service to land occupiers involving the preparation of riparian management plans and associated supply of low cost, high quality riparian plants.

Riparian management plans set out recommendations for the retirement or re-vegetation of land along the banks of rivers and streams. The retirement or revegetation of riparian margins forms an interface between the stream and land, preventing stock access, and decreases the amount of diffuse contaminants (in the form of animal excreta, sediment and fertiliser run-off) entering the stream and reducing water quality. Not only does this have major benefits for fresh water quality, it also has benefits for coastal waters into which rivers and streams ultimately flow.

As at 30 June 2009, the Taranaki Regional Council had prepared 2,255 riparian management plans, covering 12,212 kilometres of streambank. Some 93% of Taranaki dairy farms now have a riparian plan for their property. The programme has grown exponentially over time particularly since the implementation of the *Dairying and Clean Streams Accord – Regional Action Plan for Taranaki* has begun to be implemented. There continues to be strong demand for the property planning service and most plan recommendations are being implemented progressively. The Council's target as set out in the Regional Action Plan is to have 90% of dairy farms covered by riparian plans by 2010 and to have 90% implemented by 2015.

Appendix III

SEM Physicochemical Programme TRC Intra-lab Quality Control Report 2016-2017

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 and thirteen sites in the 2016-2017 period. Sampling is carried out on the second Wednesday of each month for the entire year at the first eleven sites, and on the next day for last two sites. The programme also meshes with a similar national programme operated by the National Institute of Water and Atmospheric Research (NIWA) since 1989, which included three sites in Taranaki until December 2015 and two sites thereafter.

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 (now two) 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 2016-2017 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 2016 and June 2017.

First QC exercise

These split samples were collected from the Waingongoro River site at SH45 on 10 August 2016 under slightly turbid, recession flow conditions (13.0 m^3/sec), following a moderate fresh, and in fine conditions. Results are presented in Table 1.

Table 1 Results of SEM QC sampling on 10 August 2016

Site: WGG000900					
Date: 10 August 2016				Difference from mean (%)	Comments
Parameter	Units	Routine Sample	QC Sample		
A340F	/cm	0.015	0.015	0	✓
A440F	/cm	0.003	0.003	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	31	33	3	✓
BOD5	g/m^3	1.2	1.1	4	✓
CONDY	mS/m @ 20°C	15.4	15.4	0	✓
DRP	g/m^3-P	0.031	0.032	2	✓
ENT	/100mL	17	12	17	*
ECOL	/100mL	84	92	5	✓
FC	/100mL	84	92	5	✓
NH4	g/m^3-N	0.052	0.052	0	✓
NO2	g/m^3-N	0.053	0.053	0	✓
NO3	g/m^3-N	2.7	2.7	0	✓
pH	pH	7.6	7.6	0	✓
SS	g/m^3	8	8	0	✓
TKN	g/m^3-N	0.28	0.12	40	**
TN	g/m^3-N	3.0	2.9	2	✓
TP	g/m^3-P	0.070	0.066	3	✓
TURBY	NTU	5.0	4.9	1	✓

Comments

The difference between enterococci counts for the paired samples was not significant as the counts were below the lower range limit (20 cfu/100mL) for the test. The difference between paired TKN results was significant (at low concentrations) but neither result was an outlier in terms of the site's historical record.

Overall, results showed relatively good laboratory analytical precision performance, with 17 of 19 pairs of results being within the 10% guideline.

Second QC exercise

These split samples were collected from the Maketawa Stream site at Tarata Road on 9 November 2016 under clear, steady recession flow (2.38 m^3/sec) and fine, cloudless weather conditions. Results are presented in Table 2.

Table 2 Results of SEM QC sampling on 19 November 2016

Site: MRK000420					
Date: 9 November 2016				Difference from mean (%)	Comments
Parameter	Units	Routine Sample	QC Sample		
A340F	/cm	0.032	0.035	4	✓
A440F	/cm	0.007	0.006	8	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	22	22	0	✓
BOD5	g/m^3	<0.5	<0.5	0	✓
CONDY	mS/m @ 20°C	7.0	7.1	1	✓
DRP	g/m^3-P	0.024	0.025	2	✓
ENT	/100mL	900	1200	14	*
ECOL	/100 mL	850	710	9	✓
FC	/100mL	860	720	9	✓
NH4	g/m^3-N	0.010	0.014	17	*
NO2	g/m^3-N	0.002	0.002	0	✓
NO3	g/m^3-N	0.40	0.40	0	✓
pH	pH	7.6	7.6	0	✓
SS	g/m^3	2	<2	33	**
TKN	g/m^3-N	0.12	0.04	100	***
TN	g/m^3-N	0.52	0.44	8	✓
TP	g/m^3-P	0.038	0.038	0	✓
TURBY	NTU	0.8	0.9	6	✓

Comments

The difference between the pair of enterococci counts was within the acceptable tolerance level (20%) for bacteriological samples. The difference in ammonia was relatively insignificant at the low concentration. The differences between the suspended solids and TKN paired results were significant at low concentration. None of the results were outliers in terms of the historical record for this site.

Otherwise, overall laboratory analytical precision performance was good, with 15 of the 19 pairs of results recorded within the 10% guideline.

Third QC exercise

These split samples were collected from the site in the Stony River at Mangatete Road on 8 February 2017 under highly turbid, moderate flow (5.05 m^3/sec) and fine, partially cloudy weather conditions. Results are presented in Table 3.

Table 3 Results of SEM QC sampling on 8 February 2017

Site: STY000300					
Date: 8 February 2017				Difference from mean (%)	Comments
Parameter	Units	Routine Sample	QC Sample		
A340F	/cm	0.027	0.029	4	✓
A440F	/cm	0.013	0.013	0	✓
A770F	/cm	0.004	0.004	0	✓
ALKT	g/m^3 $CaCO_3$	36	36	0	✓
BOD5	g/m^3	<0.5	<0.5	0	✓
CONDY	mS/m @ 20°C	8.8	8.9	1	✓
DRP	g/m^3-P	0.031	0.026	9	✓
ENT	/100mL	3	8	45	**
ECOL	/100mL	11	28	44	**
FC	/100mL	11	28	44	**
NH4	g/m^3-N	<0.003	<0.003	0	✓
NO2	g/m^3-N	0.001	0.002	33	**
NO3	g/m^3-N	0.06	0.06	0	✓
PH	pH	7.9	7.9	0	✓
SS	g/m^3	130	100	13	*
TKN	g/m^3-N	<0.01	<0.01	0	✓
TN	g/m^3-N	0.06	0.06	0	✓
TP	g/m^3-P	0.175	0.174	<1	✓
TURBY	NTU	66	64	2	✓

Comments

The differences between pairs of enterococci and faecal coliform counts were outside acceptable tolerance levels (20%) for bacteriological samples. The difference in nitrite results (0.001 g/m^3) was insignificant at the very low concentration. The difference in suspended solids results was significant at high concentration. None of these results were outliers in terms of the historical record for this site.

Otherwise 15 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 Maketawa Stream at Tarata Road on 10 May 2017 under clear, recession flow conditions (1.68 m^3/sec), and fine, partly cloudy weather. The results are presented in Table 4.

Table 4 Results of SEM QC sampling on 10 May 2017

Site: MKW000300					
Date: 10 May 2017				Difference from mean (%)	Comments
Parameter	Units	Routine Sample	QC Sample		
A340F	/cm	0.014	0.014	0	✓
A440F	/cm	0.003	0.003	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	32	32	0	✓
BOD5	g/m^3	<0.5	<0.5	0	✓
CONDY	mS/m @ 20°C	9.4	9.5	1	✓
DRP	g/m^3-P	0.030	0.031	2	✓
ENT	/100mL	200	180	5	✓
ECOL	/100mL	240	310	13	*
FC	/100mL	250	340	15	*
NH4	g/m^3-N	0.009	<0.003	71	***
NO2	g/m^3-N	0.002	0.002	0	✓
NO3	g/m^3-N	0.45	0.45	0	✓
PH	pH	7.6	7.7	1	✓
SS	g/m^3	<2	<2	0	✓
TKN	g/m^3-N	0.02	<0.01	60	***
TN	g/m^3-N	0.47	0.45	2	✓
TP	g/m^3-P	0.042	0.043	2	✓
TURBY	NTU	0.9	0.9	0	✓

Comments

The differences between the pairs of coliform bacterial counts were within acceptable tolerance levels (20%) for bacteriological samples.

The difference in ammonia results was relatively insignificant at the very low concentrations (<0.01 g/m^3). The difference in TKN was significant at low concentration.

Otherwise 15 of the 19 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 (2016-2017) 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	(97)	-	(7)	-	(0)	-	(0)
A440F	4	(76)	-	(19)	-	(6)	-	(2)
A770F	4	(81)	-	(0)	-	(9)	-	(15)
ALKT	4	(104)	-	(0)	-	(0)	-	(0)
BOD5	4	(90)	-	(12)	-	(1)	-	(1)
CONDY	4	(104)	-	(0)	-	(0)	-	(0)
DO*	-	(100)	-	(0)	-	(0)	-	(0)
DRP	4	(97)	-	(6)	-	(0)	-	(1)
ENT	1	(44)	2	(25)	1	(28)	-	(7)
ECOL	2	(50)	1	(35)	1	(17)	-	(2)
FC	2	(51)	1	(34)	1	(17)	-	(2)
NH4	2	(80)	1	(13)	-	(6)	1	(3)
NO2	3	(98)	-	(4)	1	(2)	-	(0)
NO3	4	(90)	-	(5)	-	(8)	-	(1)
pH	4	(104)	-	(0)	-	(0)	-	(0)
SS	3	(91)	1	(10)	-	(4)	-	(0)
TKN	1	(51)	-	(21)	1	(24)	2	(8)
TN	4	(86)	-	(11)	-	(7)	-	(0)
TP	4	(90)	-	(7)	-	(5)	-	(2)
TURB	4	(102)	-	(1)	-	(1)	-	(0)

[NB: () = % of QC samples for 1995 to 2017 period; * Winkler method to 2012]

This summary for the 2016-2017 period indicated:

- results from pairs of all three bacteriological species' samples varied in precision with one set of results falling outside the acceptable variability (20%). This follows the historical trend for paired bacteriological analyses which have found at least 42% of the period's quality control samples within the 10% difference of the mean (for all three species), and from 66% to 82% of samples within 20% of the mean for paired samples in all species.
- TKN analytical variability greater than 20% was recorded on three 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 49% and 69% to date within 10% and 20% of the mean respectively.
- Ammonia and nitrite analytical variability of % was recorded on two and one occasions, respectively at low to very low concentrations and the differences were considered insignificant at these levels.

- 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 not recorded (at any of the three wavelengths) over the 2016-2017 period.

In general, laboratory analytical performance has been acceptable, with very good precision of results shown for the 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 22-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 intra-laboratory programme.

Appendix IV

SEM Physicochemical Programme
Inter-lab Quality Control Report 2016-2017

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, another in the 2003-2004 period and two more in the 2015-2016 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 included 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 thirteen 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 (now two) sites and then split for sub-samples' analyses by each of the laboratories. A sample was collected from one of the three (now two) sites, on one occasion in the 2016-2017 year for the inter-laboratory comparison exercise.

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 2016-2017 period, on 21 February 2017. Sampling was performed at the Manganui River site at SH3 during a steady recession flow (0.95 m^3/s), four days after a very small fresh in fine, overcast weather. The water appeared clear and uncoloured.

Results

2016-2017 exercise

Comparisons of the individual samples' analytical results for the Manganui River (at SH3) site are presented in Table 1.

Table 1 Results of SEM QC sampling by TRC & NIWA on 21 February 2017

MGN000195					
		Time:1030 (NZST)		Difference from mean (%)	Comments
Parameter	Units	TRC	NIWA		
A340F	/cm	0.013	0.013	0	✓
A440F	/cm	0.002	0.003	20	*
BDISC	m	5.82	5.83	<1	✓
CONDY	mS/m @ 20^{0}C	6.2	6.7	4	✓
DO	g/m^3	10.0	N/A	N/A	-
DRP	g/m^3-P	0.016	0.011	19	*
ECOL	cfu/100 mL	200	121.1	25	**
NH4	g/m^3-N	0.004	0.005	11	*
NO3	g/m^3-N	0.04	0.046	7	✓
pH	pH	7.7	7.74	<1	✓
TEMP	°C	15.0	15.2	0.1	✓
TN	g/m^3-N	0.07	0.106	20	*
TP	g/m^3-P	0.064	0.017	29	**
TURBY	NTU	0.8	1.1	16	*

[Note: N/A = not available as DO meter not working; N/R = not reported]

Comments

A significant difference in paired measurements between the two laboratories was recorded for absorbance at 440 nm, turbidity, dissolved reactive and total phosphorus, ammoniacal nitrogen and *E. coli*, of which total phosphorus showed the most significant difference. Otherwise good analytical agreement was recorded for all other parameters.

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

	Difference from mean of pairs of split samples							
Parameter ID	<10%		10-20%		20-50%		>50%	
A340F	1	(92)	-	(4)	-	(4)	-	(0)
A440F	-	(56)	1	(40)	-	(0)	-	(4)
CONDY	1	(92)	-	(4)	-	(0)	-	(4)
DO	-	(100)	-	(0)	-	(0)	-	(0)
DRP	-	(40)	1	(28)	-	(28)	-	(4)
ECOL	-	(24)	-	(36)	1	(40)	-	(0)
NH4	-	(36)	1	(24)	-	(20)	-	(20)
NO3	1	(92)	-	(4)	-	(4)	-	(0)
pH	1	(100)	-	(0)	-	(0)	-	(0)
TEMP	1	(100)	-	(0)	-	(0)	-	(0)
TN	-	(84)	1	(8)	-	(8)	-	(0)
TP	-	(56)	-	(28)	1	(16)	-	(0)
TURB	-	(32)	1	(48)	-	(20)	-	(0)

[NB: () - % of QC samples over the 1995 to 2017 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 from time to time for DRP and further comparisons will be performed during future SEM programmes. Good field agreement was recorded for water temperature and black disc measurements as normally recorded in the past (dissolved oxygen comparison was not possible).

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

Appendix V

An evaluation of the representativeness of existing SEM physicochemical sites as descriptors of baseline water quality in the Taranaki region

Executive summary

The Taranaki Regional Council maintains a network of surface freshwater physicochemical monitoring sites as a component of the State of Environment Monitoring (SEM) programme for Taranaki. In July 2015, the network was enlarged by the establishment of sites in the Whenuakura and Waitara catchments, to increase representation of the waterways within the eastern hill country. This brought the total number of sites monitored to thirteen in eight selected ring-plain catchments and three eastern hill-country catchments that together comprise 44% of the total area of the region.

These sites are considered representative of the water bodies in the region (shown by both internal review and external audit), while also being chosen as sites located in the parts of the region subject to the greatest pressures on water quality, thus enabling the Council to give effect to Section 35 (1) and (2)(a)-(2)(d) of the Resource Management Act 1991. An analysis of the proportional distribution of the sites against the distribution of all reaches of the region's rivers when both were classed according to the national River Environment Classification, found that the sites' distribution reflects the regional distribution of land cover classes extremely closely. Further, an audit of the Council's physico-chemical SEM network by NIWA in 2010 on behalf of the Auditor-General's Office found the network to be satisfactory for its purpose. However, more recently it was decided by Council officers to further examine the representative nature of the site network, to engender further confidence in the integrity and strength of the monitoring network and the value of its results for informing the regional community on the state of and trends in the quality of Taranaki's freshwater systems, for feedback on policy and intervention effectiveness, and as a basis for informing further policy development.

Therefore, an evaluation of the representativeness of the existing SEM physicochemical sites as descriptors of baseline water quality in the Taranaki region has been carried out during the 2015-2016 monitoring year. Ten "equivalent" sites within the region were selected to match by landscape and hydrological characteristics with existing SEM sites, for comparative assessment of respective water quality. Four, seasonal surveys were conducted at or near base flows within one day of the regular monthly SEM sampling, at about the same time of day for "paired sites".

The equivalent sites were selected on the basis of factors such as commonality of mountain, ring-plain or hill country source, size of and position within the catchment, land cover and use, and types of discharge to the waters. Adjacent catchments were chosen where practicable. Some sites were within catchments already monitored. The additional catchments (Huatoki, Kapoaiaia, Kaupokonui, Kapuni and Waiongana) increased the proportion of the regional area covered to 48%. All sites except one had a hydrometric station within the catchment.

The surveys were carried out in July and October 2015 and January and April 2016. Stream flows generally were above annual median in July, at about median in October and April, and below median in January. Neither flood nor drought occurred at the times of sampling. All samples were analysed for physical parameters, dissolved oxygen, nutrients and faecal indicator bacteria.

This report presents the water quality data in tables. Box plots are included which allow visual assessment of variation within each site, between matched pairs of sites, and across all sites, for each parameter measured.

In summary, for all physicochemical parameters, the range of values across the regular SEM sites encompassed the range found across the "comparative" sites. That is, under base flow conditions monitored seasonally over the full course of a year, the existing SEM sites were found to already represent the full range of baseline water quality in the Taranaki region.

Table of contents

List of tables

List of figures

1 Introduction

1.1 State of environment monitoring for freshwater physicochemistry

The Resource Management Act 1991 (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') has 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).

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, another site in the 2003-2004 period, and two more sites in the 2015-2016 period (Table 1). The latter two were added as a consequence of the *National Policy Statement for Freshwater Management 2014*. This NPS stipulated that all fresh water in each region must be included in a Freshwater Management Unit (FMU), and that councils must establish and undertake monitoring at one or more representative sites in every FMU. While 3 of the 4 FMUs proposed for the Taranaki region (*Regional Land and Water Plan*, in development) were covered by the existing monitoring network, it was considered that an additional site located on one of the coastal plains of the region, and a second site within the hill country alongside an existing site in that FMU, would strengthen the informative value of the surface freshwater monitoring network. Table 1 and Figure 1 give further information on the network as of 2018.

Table 1 Sample sites for TRC network programme and NIWA national 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
Whenuakura River	at Nicholson Road	WHN000450
Waitara River	at Autawa Road	WTR000540
*Waitara River	at Bertrand Road	WTR000800
*Manganui River	at SH3	MGN000195

The Taranaki Regional Council's SEM programme also includes a freshwater biological component encompassing the same thirteen sites plus forty-six additional sites, which is reported separately (see TRC, 2012a).

The physicochemical programme has been designed to provide a general picture of water quality for nine 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 enables 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 44% of the total area of the region (Figure 1). 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.

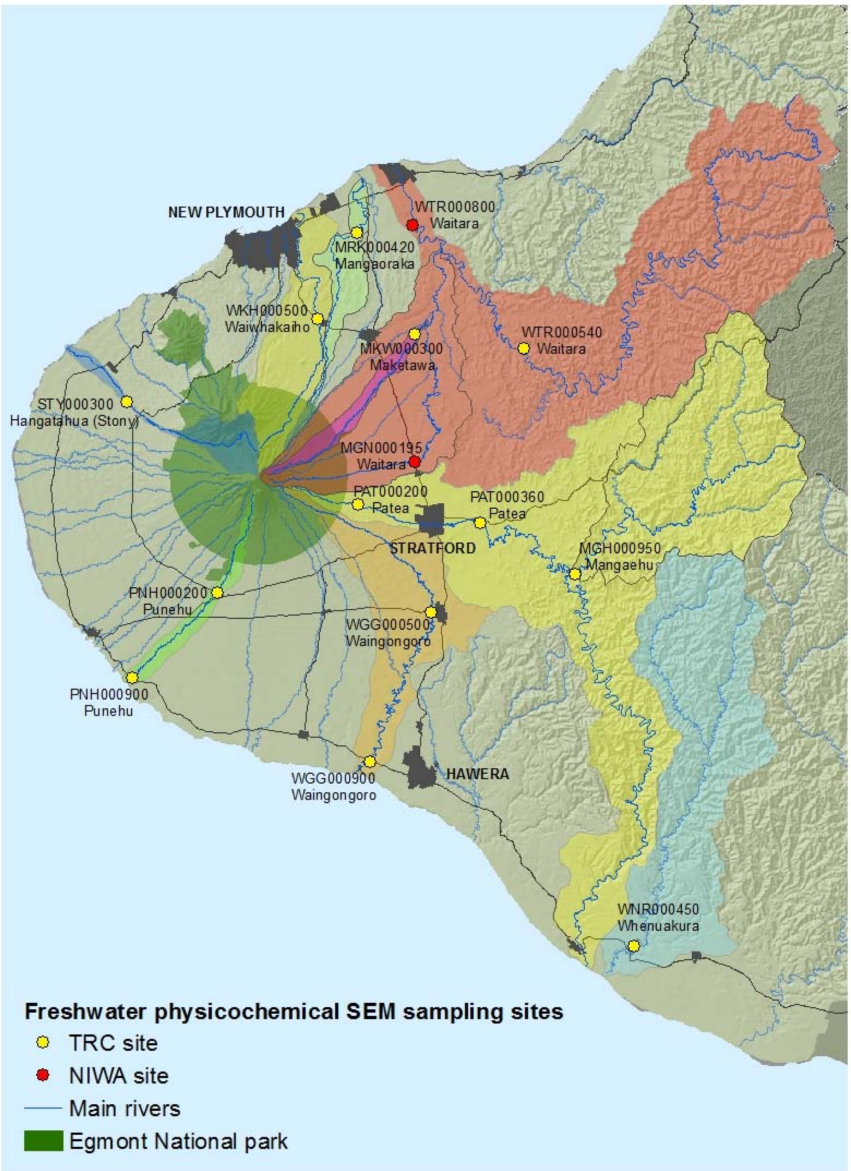


Figure 1 Freshwater physicochemical SEM sampling sites and catchments aerial map

The sites were specifically selected to be representative of major/significant waterways and positioned in the upper, middle, and lower reaches of catchments (Figure 1). Both ring-plain 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. The National Rivers Water Quality Network (NRWQN) was designed to monitor changes in water quality by sampling physical and chemical parameters monthly at 77 river sites around New Zealand. The programme includes two sites in Taranaki (Figure 1): one upper/mid catchment site (Manganui River at State Highway 3, incorporating some farm land area) and one lower catchment site (Waitara River at Bertrand Road, incorporating both ring-plain and hill country). Another lower catchment site (Waingongoro River at State Highway 45), which is also a Council monitoring site, was dropped by NIWA from their NRWQN programme in December 2015, but is still maintained by the Council. The Waiokura Stream site is also a NIWA national best-farming practices catchment monitoring site sampled monthly (more recently by the Council) at Manaia Golf Course.

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.

The existing sites are considered representative of the various types and characteristics of water bodies in the region, while also being chosen as sites located in the parts of the region subject to the greatest pressures on water quality, thus enabling the Council to give effect to Section 35 (1) and (2)(a)-(2)(d) of the Resource Management Act 1991. An analysis of the proportional distribution of the sites against the distribution of all reaches of the region's rivers when both were classed according to the national River Environment Classification, found that the sites match the regional distribution of land cover classes extremely closely. [1]

Council SEM sites vs REC land cover classes for Taranaki rivers

REC Land cover class	**B**	**EF**	**IF**	**P**	**S**	**U**	
Taranaki rivers (km)	68	115	3448	8605	632	129	12,559
% of rivers in class	0.5	0.9	26	66	5	1	
% of SEM sites in class	0	0	27	64	9	0	

Further, an audit of the Council's physico-chemical SEM network by NIWA in 2010 on behalf of the Auditor-General's Office found the network to be adequate for its purpose of having sufficient statistical power and coverage to detect large scale patterns (ie within each REC class) in surface water quality state and trends in the Taranaki region.[2]

Nonetheless, the Council has decided to further test the representative nature of its network of sites, to engender further confidence in the integrity and strength of the monitoring network and the value of its

[1] *Trends in the quality of the surface water of Taranaki,* Taranaki Regional Council February 2006, FRODO 95735

[2] *Freshwater quality monitoring by Environment Southland, Taranaki Regional Council, Horizons Regional Council and Environment Waikato,* NIWA Report CHC2010-141

results for informing the regional community on the state of and trends in the quality of Taranaki's freshwater systems, for feedback on policy and intervention effectiveness, and as a basis for informing further policy development.

2 Objectives of the survey

An evaluation of the representativeness of the existing SEM physicochemical sites as descriptors of baseline water quality in the Taranaki region was carried out during the 2015-2016 monitoring year. The survey was designed:

- To include sites of equivalent characteristics located elsewhere in the region which may be matched with existing SEM sites for comparative assessment
- To undertake sampling within one or two days of the regular monthly SEM sampling survey at approximately the same time of day as sampled at each equivalent SEM site
- To cover seasonal variation by sampling once in all four seasons under base flow conditions
- To be sufficiently robust in site selection and sampling protocols to allow meaningful comparisons of data across sites.

2.1 Sites

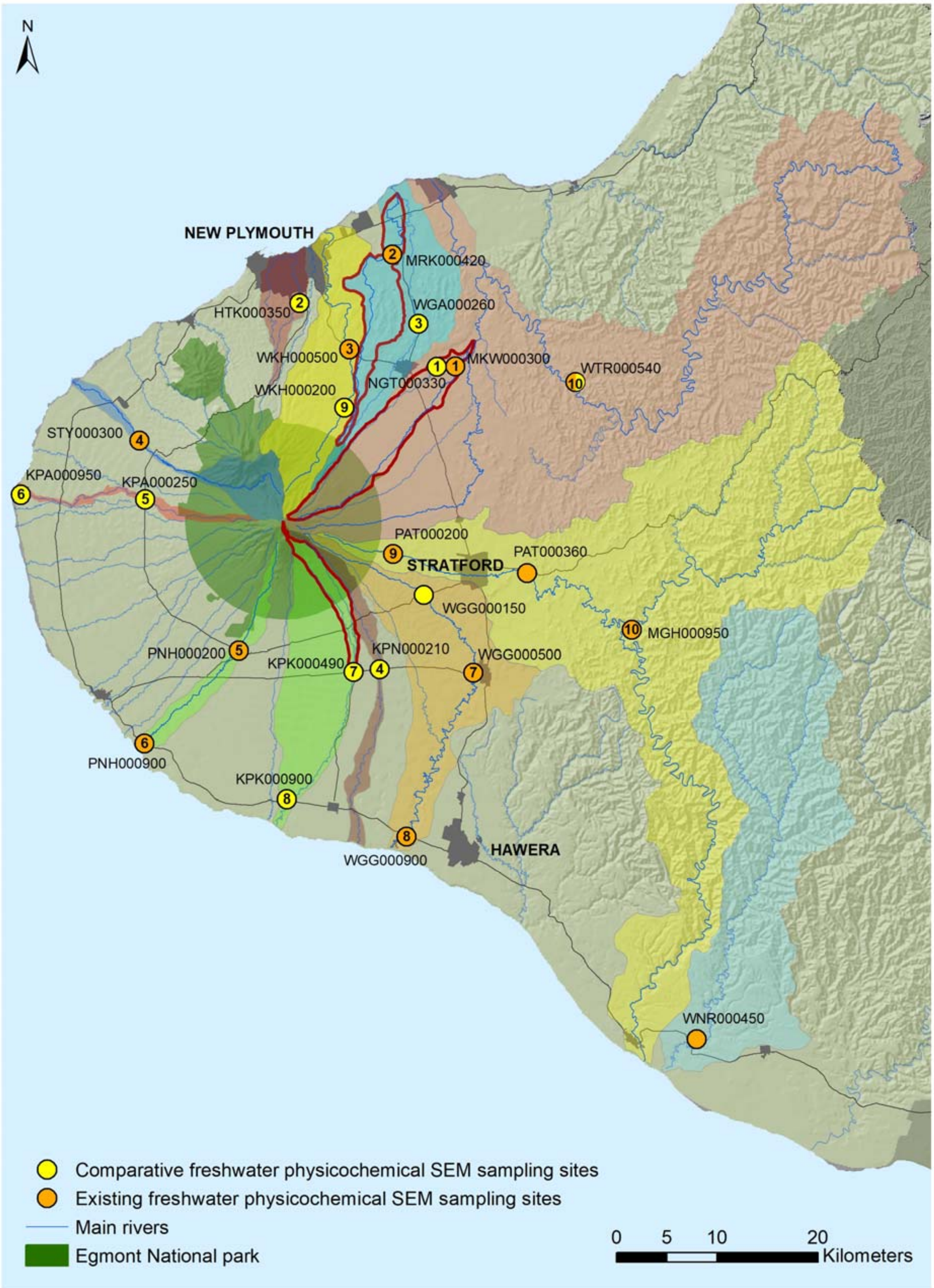
The set of ten sites chosen for comparative sampling in the extended programme is described in Table 2 and depicted in Figure 2. One of the two new long-term SEM sites (Waitara River at Autawa Rd, Tarata) was matched to an existing site (Mangaehu River at Raupuha Road).

Table 2 Additional physicochemical sites for comparison with SEM programme sites

SEM sites			Additional sites			
Stream	**Location**	**Site code**	**Stream**	**Location**	**Site code**	**Timing**
Maketawa S.	Tarata Rd	MKW000300	Ngatoro S.	Tarata Rd	NGT000330	0730-0900
Mangaoraka S.	Corbett Rd	MRK000420	Huatoki S	Hadley Drive	HTK000350	0800-0930
Waiwhakaiho R.	SH3	WKH000500	Waiongana S.	SH3A	WGA000260	0830-1000
Stony R.	Mangatete Rd	STY000300	Kapuni S.	Eltham Rd	KPN000210	0930-1100
Punehu S.	Wiremu Rd	PNH000200	Kapoaiaia S.	Wiremu Rd	KPA000250	1000-1130
Punehu S.	SH45	PNH000900	Kapoaiaia S.	Near coast	KPA000950	1030-1200
Waingongoro R.	Eltham Rd	WGG000500	Kaupokonui S.	Kaponga	KPK000490	1130-1245
Waingongoro R.	SH45	WGG000900	Kaupokonui S.	SH45	KPK000900	1145-1315
Patea R.	Barclay Rd	PAT000200	Waiwhakaiho R.	Peters Rd.	WKH000200	1200-1345
Patea R.	Skinner Rd	PAT000360	-	-	-	1300-1500
Mangaehu R.	Raupuha Rd	MGH000950	*Waitara R.*	*Autawa Rd*	*WTR000540*	1330-1530
Whenuakura R. (new)	Nicholson Rd	WNR000450	-	-	-	0930-1100
Waitara R. (new)	Autawa Rd	WTR000540				1300-1430
Waitara R. (NIWA)	Bertrand Rd	WTR000800	-		-	0900-0930
Manganui R. (NIWA)	SH3	MGN000195	Waingongoro R.	Opunake Rd	WGG000150	1000-1030

The pairs of sites were selected largely from adjacent or near catchments, with similar elevation and land uses.

Figure 2 Freshwater physicochemical SEM sampling sites and catchments aerial map, with additional sites surveyed for comparison



A brief description of the “paired sites” selected for the comparative sampling follows. The existing SEM site is listed first.

Sites Maketawa and Ngatoro Streams at Tarata Road

These sites are in adjacent sub-catchments of the Manganui River, a tributary of the Waitara River. They are representative of the lower reaches of developed farmland, mainly dairy, with valued trout and native fish habitat. The streams join before draining into the Manganui River below the principal abstractions for the Motukawa HEP scheme. The Maketawa Stream is flow gauged on each sampling; there is a hydrometric station on the Ngatoro Stream about 4.3 km upstream, below the abstraction for Inglewood water supply and above its confluences with the Ngatoro-nui and Ngatoro-iti Streams.

Sites Mangaoraka Stream at Corbett Road and Huatoki Stream at Handley Road

These sites are representative of the lower reaches of northern Taranaki ring-plain streams arising outside of the National Park, draining intensive agricultural catchments. Both streams are regionally significant for angling. The Mangaoraka site is a hydrometric station.

Sites Waiwhakaiho River at SH3 and Waiongana Stream at SH3A

These sites in adjacent catchments are representative of the mid-reaches of streams draining developed farmland that arise within the National Park on the northern side. The Waiwhakaiho catchment has a larger proportion within the Park than the Waiongana catchment; both sites are existing hydrometric stations.

Sites Hangatahua (Stony) River at Mangatete Road and Kapuni Stream at Eltham Road

These sites are representative of the mid-reaches of narrow catchments that have a relatively large proportion within the National Park. The Stony River is protected in its natural state by a Local Conservation Order. It has been affected by significant natural erosion events in its headwaters from time to time. The Kapuni Stream site is representative of agricultural impacts in the upper catchment. The Stony River is flow-gauged on each sampling; there is a hydrometric station on the Kapuni Stream, 15.2 km downstream of the monitoring site.

Sites Punehu and Kapoaiaia Streams at Wiremu Road (1) and SH45 (2)

These sites are representative of south-western and western Taranaki catchments, respectively, which are subjected primarily to intensive agricultural land use. Both catchments are narrow, the Kapoaiaia unusually so, and have sources high within the National Park. The upstream sites, both about 5 km from the Park boundary, are representative of relatively un-impacted stream water quality, though the reaches sampled are in open farmland. The lower sites are both within 1.5 km of the coast. The Punehu Stream is flow gauged at both sites on each sampling; there is a hydrometric station on the Kapoaiaia Stream near the lower site.

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

These sites are representative of relatively broad catchments on the southern Taranaki ring-plain. Sites 1 in the mid reaches are representative of agricultural impacts in the upper catchment. Sites 2 in the lower reaches are representative both of agricultural point source discharges and diffuse run-off, and of industrial/municipal discharges which occur around Eltham (Waingongoro) and Kaponga (Kaupokonui). Both streams are important trout fisheries. The Waingongoro River sites are existing hydrometric stations; there is a hydrometric station near the lower sampling site on the Kaupokonui Stream.

Sites Patea River at Barclay Road and Waiwhakaiho River at Peters Road

These sites are representative of upper catchments adjacent to the National Park that are largely above agricultural impacts. The Patea River is flow gauged on each sampling occasion; there is a hydrometric station on the Waiwhakaiho River about 8.0 km downstream.

Sites Mangaehu River at Raupuha Road and Waitara River at Autawa Road

These sites in adjacent catchments are representative of rivers draining Taranaki eastern hill country in the central (Mangaehu) and northern (Waitara) parts of the region. At about 100 metres altitude, both sites are above confluences with the mountain-sourced Patea and Manganui Rivers, respectively. They are representative of a combination of upland agriculture and native forest, the Waitara having the greater proportion of forest. The Mangaehu site is an established hydrometric station; the Waitara site is 6.1 km above the hydrometric station at Tarata, with the discharge from Motukawa power station in between.

Two existing SEM sites were not "paired", and another site was monitored for possible comparison with a NIWA site:

Site Whenuakura River at Nicholson Road

This site is representative of the lower reaches of an eastern hill country catchment in the southern part of the region that has largely been developed for agriculture, with some exotic and native forest. Together with the Waitara River at Autawa Road site, it was established in July 2015 to increase representation of the eastern hill country, and may be compared to the Waitara and Mangaehu River sites (above). It is an established hydrometric station, on the marine terrace 10.7 km from the coast in the upper section of tidal river, above the saline influence.

Site Patea River at Skinner Road

This site is representative of developed farmland drainage and is downstream of Stratford (urban run-off, closed landfill, municipal oxidation pond and thermal power station discharges). It is an established hydrometric station and dissolved oxygen monitoring site. No directly comparable site was surveyed, though the site in the adjacent Waingongoro catchment at Eltham would be similar in terms of farmland drainage from a relatively wide ring-plain catchment.

Site Waingongoro River at Opunake Road

This site was surveyed for comparison with the NIWA site on the Manganui River at SH3, which is representative of the upper/mid reaches of a high quality river on the eastern ring-plain receiving limited agricultural run-off. Direct comparison between these sites was not carried out, as the respective sampling dates were too far apart (5 days) for the weather/flow conditions encountered. However, comparison may be drawn with two nearby sites that are representative of south-eastern ring plain streams, at similar distance from the National Park though at lower altitude: Kapuni and Kaupokonui Streams at Eltham Road. There is a hydrometric station 23 km downstream.

2.2 Sampling procedure and analytical parameters

The additional sites were all sampled on the same day [the day following the normal SEM run] on four occasions:

9 July 2015

15 October 2015

14 January 2016

14 April 2016

The two new permanent SEM sites, Whenuakura River at Nicholson Road and Waitara River at Autawa Road, where monthly monitoring commenced in July 2015, were sampled on the same days as the additional sites.

No flow measurements were undertaken with the additional sampling, but indicative data were obtained from hydrometric stations in the same catchment except the Huatoki.

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

Table 3 SEM physicochemical parameters and site of measurement

Parameter	Unit	Location
Time	NZST	On site
Flow	m^3/s	On site recorder or rated SG or gauging
Temperature	˚C	On site
Dissolved oxygen	g/m^3	On site
BOD_5 (total)	g/m^3	Laboratory
Suspended solids	g/m^3	Laboratory
Turbidity	NTU	Laboratory
Conductivity @ 20°C	mS/m	Laboratory
pH	pH	Laboratory
Alkalinity	g/m^3CaCO_3	Laboratory
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
Faecal coliform and *E. coli* bacteria (mTEC)	cfu/100 mL	Laboratory

3 Results

Water quality data from the four, seasonal two-day surveys of the ten pairs of sites and three unpaired sites are presented in Appendix I of this report. Some dissolved oxygen data are missing, for seven of the "comparative" sites, due to a field instrument fault on 14 January 2016.

Flow data are included for the sites that are hydrometric stations, or where manual gauging was done. As well as volumetric rate, percentage of median flow is given to allow direct comparison between sites. For those comparative (eight) sites where there was no flow measurement, percentage of median flow at a hydrometric site in the same catchment is reported for the time of sampling, except for the Huatoki which was without flow monitoring.

"Box and whisker" plots are presented in Appendix II, which allow visual assessment of variation within each site, between matched pairs of sites, and across all sites, for each parameter measured. (The plots, which normally require a minimum of five data, have been modified by replicating the datasets, so the whiskers represent the data range, and the box ends and inner line are the averages of adjacent quartile values).

On each of the four surveys, there was little or no rainfall between the two sampling days throughout the Taranaki region, except some showers in and near the National Park on 8/9 July 2015. On three of the surveys, in winter and spring 2015 and autumn 2016, some rainfall did occur shortly before the first day of sampling, the most on 12/13 April 2016 - this resulted in fresh flows that had reduced to about median levels on the second day of sampling. The rainfall had (relatively) greater impact at the regular SEM sites, which were sampled on the first day of the surveys, than at the "matched" sites, which were sampled on the second day.

Maketawa and Ngatoro Streams at Tarata Road

These sites were well matched for landscape and hydrological characteristics, being in adjacent catchments similar in size, shape and elevation, and both were on streams receiving several discharges from farm dairy effluent treatment systems. Overall, similar results were produced. The Maketawa had slightly higher conductivity, and higher BOD.

Mangaoraka Stream at Corbett Road and Huatoki Stream at Handley Road

While both sites are at 60 m elevation on the northern ring plain, the Mangaoraka catchment upstream is larger, and proportionally wider in the lower reaches, with a higher intensity of dairy farming. The results reflect this. Temperature, electro-conductivity (EC), pH and alkalinity were higher in the Mangaoraka, while turbidity and suspended solids were similar. BOD, and faecal coliform and ammonia concentrations, which may be related to farm dairy discharges, were higher in the Mangaoraka, while other nutrients (nitrate and phosphorus species) were similar to the Huatoki values.

Waiwhakaiho River at SH3 and Waiongana Stream at SH3A

These sites in adjacent catchments differ in distance from the Park boundary, 10.6 km for the Waiwhakaiho, (175 m altitude) versus 16.1 km for the Waiongana, (140 m), almost entirely through pastoral land. The median flow in the Waiwhakaiho, at 3.92 m^3/s, is more than double that in the Waiongana, at 1.46 m^3/s. Rainfall preceding the October 2015 survey affected the Waiwhakaiho results the more. Overall, temperature and pH/alkalinity values were similar, with higher conductivity in the Waiongana, BOD and ammonia values were similar, whereas oxidised nitrogen and total nitrogen were higher in the Waiongana. Phosphorus species were similar. These results are consistent with two catchments both receiving some farm dairy discharges, one over a longer distance (ie a greater cumulative increase) than the other.

Hangatahua (Stony) River at Mangatete Road and Kapuni Stream at Eltham Road

Despite the Stony River site being at higher altitude (260 m versus 168 m) and closer to the Park boundary (7.2 km versus 10.6 km), the temperatures were similar or lower in the Kapuni Stream, perhaps as a result of the narrower channel and more riparian shading of the Kapuni. EC was similar, and pH slightly higher in the Stony. The natural erosion events that occur occasionally in the Stony were manifest in the winter and autumn surveys, with comparatively very high suspended solids, turbidity and total phosphorus values. BOD was very low and dissolved oxygen consistently near saturation level at both sites. Nitrogen species and faecal bacteria were present at comparatively higher levels in the Kapuni Stream, consistent with farming activities in the upper catchment, which are absent in the Stony catchment under the Conservation Order.

Punehu and Kapoaiaia Streams at Wiremu Road (1) and SH45 (2)

Overall, the results for the two upper catchment sites on the western ring plain were very similar and showed good water quality. The upper Kapoaiaia had higher pH/alkalinity. The upper Punehu had higher suspended solids and turbidity. Total ammonia concentrations were higher in the upper Punehu. DRP concentrations were higher in the upper Kapoaiaia, probably from natural sources in the Park, while total phosphorus concentrations were similar. BOD and faecal bacteria level were low at both sites.

Differences in water quality between the catchments developed with distance downstream (16.6 km between the SEM Punehu sites and 19.6 km between the matching Kapoaiaia sites). This is consistent with the higher proportion of pastoral activities in the broader, but still narrow, Punehu catchment, and the extreme narrowness of the Kapoaiaia catchment. Temperature range was wider in the lower Punehu. EC was significantly higher in the lower Punehu, a function of a larger proportion of the catchment being near to the saline influence of the coast. The pH of the lower Kapoaiaia was significantly higher, though alkalinity was similar, the result of algal photosynthesis. Turbidity and suspended solids were noticeably higher in the lower Punehu, and BOD, faecal bacteria and all nutrient species were also higher.

Waingongoro River and Kaupokonui Stream at Eltham Road (1) and SH45 (2)

While the upstream sites both represent the mid reaches of southern ring plain waters flowing through intensive pastoral farming lands, the mid Waingongoro site is considerably further (22.8 km) from the Park boundary compared to the mid Kaupokonui site (9.1 km), although it is also much further from the sea (44.0 km versus 22.3 km). This is reflected in the monitoring results. The temperature at the mid-Waingongoro site was higher, consistent with its lower altitude (200 m versus 270 m). EC was much higher in the mid-Waingongoro, and the pH, alkalinity, suspended solids and turbidity were all higher than in the mid-Kaupokonui. BOD was higher, and faecal bacteria and all nutrient species were much higher in the mid-Waingongoro as a result of accumulation along a longer, broader catchment.

The comparative results for the two lower catchment sites, which represent the largest (Waingongoro) and second-largest (Kaupokonui) catchments on the southern ring plain, are similar to those for the mid-catchment sites, with increased effects from agriculture as a greater proportion of the catchments above the lower sites is in agriculture. At the two lower sites, both at 20 m altitude, temperatures were similar, and EC slightly higher in the Waingongoro. The pH was higher in the Kaupokonui, and alkalinity was similar, suggesting more algal influence. Turbidity and suspended solids were similar. BOD was notably higher in the Waingongoro and faecal bacteria levels were similar. Nutrient levels were all higher in the Waingongoro.

Patea River at Barclay Road and Waiwhakaiho River at Peters Road

While these sites are both near the National Park on the eastern side, they are at different altitudes (500 m for the SEM upper Patea site, and 330 m for the matched upper Waiwhakaiho site), and drain catchments of differing lithology. This was reflected in the lower temperatures at the upper Patea site, and the higher conductivity, pH and alkalinity at the upper Waiwhakaiho site. Turbidity and suspended solids levels, BOD, faecal bacteria and nutrients were all low at both sites, as might be expected near to the Park, with the exception of dissolved phosphorus at the upper Waiwhakaiho site, which is known to leach naturally from the rock in that catchment.

Mangaehu River at Raupuha Road and Waitara River at Autawa Road

These sites, representing large eastern hill country catchments, produced similar results for temperature and conductivity, Suspended solids and turbidity, both high as a result of land erosion, were also similar. The range of pH and dissolved oxygen was wider at the Mangaehu site, suggesting a greater influence of algal photosynthesis. Dissolved oxygen was slightly below saturation on some occasions, more at the Waitara site. BOD was significantly higher at the Mangaehu site. Faecal bacterial levels were similar, the Mangaehu tending to be higher. Nitrogen species levels were similar, with a large proportion in organic form and a wider range of total nitrogen at the Mangaehu site. Total phosphorus concentration range was very wide at the Mangaehu site, with much higher levels than at the Waitara site. Conversely, dissolved phosphorus levels, while low, were the lower at the Mangaehu site.

4 Discussion

The original selection of the existing surface freshwater physicochemical SEM sites in Taranaki was undertaken with great care specifically to cover a wide range of situations, based upon knowledge gained from the extensive Taranaki Ring Plain Water Resources Survey of 1980-1982, various water quality surveys for major development projects, and resource consent compliance monitoring throughout the region over more than a decade. Flow measurement is required at every sampling, to enable accurate assessment of temporal trends in water quality, which has taken considerable effort, particularly for those sites which must be gauged manually each month.

Two sites were added in July 2015 to represent better the eastern hill country, one of which is situated in a marine terrace landform not included previously.

The 13 physicochemical monitoring sites serve as base sites for the freshwater biological (benthic macroinvertebrate) SEM programme, which covers a much greater number of locations (59) in the region.

The ten sites chosen in 2015-2016 for comparative assessment comprise two in upper reaches (Waiwhakaiho and Kapoaiaia), five in mid-reaches (Ngatoro, Waiongana, Huatoki, Kaupokonui and Kapuni), and three in lower reaches (Kapoaiaia, Kaupokonui and Waitara), giving a spread of location within catchments. The matches between "paired" sites were the best practicable, on the basis of ease of access and availability of flow data. Some matching of features was particularly good, for example, the Maketawa and Ngatoro sites in adjacent catchments; others less so, for example, the mid Waingongoro and mid-Kaupokonui sites with different catchment areas.

Flow conditions at sampling were reasonably steady, considering the seasonal and spatial variables involved in a region with frequent rainfall. Some rainfall did occur on the day before three of the four surveys commenced, but no or negligible amount between the two days of sampling. This potentially affected the regular SEM sites more than the comparative sites, as only SEM sites were sampled on the first day of each survey. No very high or low (extreme) flow conditions were encountered.

The water quality monitoring results for the regular SEM sites were all within the normal ranges for the near-base flow conditions surveyed. The results for the "matched" additional sites were collectively all within the respective ranges of values found for the regular SEM sites. No result was returned that could not be explained in terms of site location, generic land use, geological and hydrological characterisation, and season.

This one-off investigation added another 5 catchments to the 11 already included in the regular monitoring network. When results for each parameter were reviewed across all types of catchment, it was found that no additional site gave results that lay outside the usual range of results from within the existing network. That is, amongst the additional catchments staff found no waterways that would give results that lie outside the range of results reported to the Council and public each year. Conversely, the survey showed that the existing sites can be properly considered representative and informative of the range of catchment types found in the region.

Now it has been demonstrated that the existing surface physicochemical SEM sites comprehensively represent freshwater quality in the Taranaki region, it is suggested that further information about the nature of the region's waterways can be usefully gained through some additional monitoring and data review, to assess whether subtle changes are occurring in the water chemistry. This relates to examining the ionic composition of the water, and parameters such as silica, which currently are not monitored, but should be periodically, for example, over twelve months every five years at each site.

5 Recommendations

It is recommended that the Council:

1. notes that the existing freshwater physicochemical SEM sites have been further demonstrated to be representative as descriptors of baseline water quality in the Taranaki region and as a network to satisfy the Freshwater Management Unit monitoring requirements of the National Policy Statement on Freshwater Management 2014
2. notes that additional monitoring and analysis in the form of ionic balances be carried out periodically to enable assessment of more subtle changes in water quality

Bibliography and references

Taranaki Catchment Commission, 1984: Taranaki Ring Plain Water Resources Survey – Water Quality, April 1984

Taranaki Regional Council, 2006: Trends in the quality of the surface waters of Taranaki. TRC publication 44pp. February 2006.

Appendix I

Seasonal data tables of 2015-2016 Water Quality Parameters for SEM and comparative sites

SEM site: MKW000300 (Maketawa Stream at Tarata Road)

Date	Time NZST	ALKT g/m³ $CaCO_3$	BOD_5 g/m³	Cond @ 20 °C mS/m	DO g/m³	DO Sat %	DRP g/m³P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m³/s	Flow* % median
08-Jul-2015	0805	24	<0.5	8.0	10.5	100	0.027	200	200	2.470	
14-Oct-2015	0700	28	0.6	8.3	10.9	100	0.029	3400	3400	2.157	
13-Jan-2016	0705	29	0.8	8.1	9.9	100	0.043	320	330	1.411	
13-Apr-2016	0815	20	1.1	6.9	10.0	100	0.055	1100	1200	2.788	

Date	Time NZST	NH_4 g/m³N	NO_2 g/m³N	NO_3 g/m³N	pH pH	SS g/m³	Temp °C	TKN g/m³N	TN g/m³N	TP g/m³P	Turb NTU
08-Jul-2015	0805	0.017	0.002	0.408	7.5	3	7.9	0.09	0.50	0.036	1.6
14-Oct-2015	0700	0.013	0.003	0.217	7.7	<2	10.9	0.12	0.34	0.042	1.3
13-Jan-2016	0705	0.007	<0.001	0.139	7.7	<2	15.2	0.03	0.17	0.048	0.5
13-Apr-2016	0815	0.061	0.012	0.478	7.6	4	13.8	0.25	0.74	0.1	2.4

Matched site: NGT000330 (Ngatoro Stream at Tarata Road)

Date	Time NZST	ALKT g/m³ $CaCO_3$	BOD_5 g/m³	Cond @ 20 °C mS/m	DO g/m³	DO Sat %	DRP g/m³P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m³/s	Flow* % median
09-Jul-2015	0830	27	<0.5	9.1	12.3	101	0.028	120	120		141
15-Oct-2015	0800	32	0.6	9.3	11.0	99	0.031	500	510		88
14-Jan-2016	0745	33	<0.5	9.0			0.047	360	360		74
14-Apr-2016	0835	30	0.5	9.0	10.6	100	0.066	300	300		93

Date	Time NZST	NH_4 g/m³N	NO_2 g/m³N	NO_3 g/m³N	pH pH	SS g/m³	Temp °C	TKN g/m³N	TN g/m³N	TP g/m³P	Turb NTU
09-Jul-2015	0830	<0.003	0.003	0.52	7.5	<2	6.2	0.09	0.61	0.028	0.9
15-Oct-2015	0800	0.014	0.006	0.33	7.3	<2	10.5	0.08	0.42	0.048	1.1
14-Jan-2016	0745	<0.003	0.001	0.18	7.9	<2	16.1	0.00	0.18	0.054	0.6
14-Apr-2016	0835	0.010	0.005	0.46	7.5	2	11.6	0.21	0.68	0.077	1.1

*Flow at SH3, 4.3 km upstream: median, 0.580 m³/s; MALF, 0.273 m³/s.

SEM site: MRK000420 (Mangaoraka Stream at Corbett Road)

Date	Time NZST	ALKT g/m³ $CaCO_3$	BOD_5 g/m³	Cond @ 20 °C mS/m	DO g/m³	DO Sat %	DRP g/m³P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m³/s	Flow % median
08-Jul-2015	0845	35	<0.5	13.7	11.1	99	0.010	500	500	1.931	157
14-Oct-2015	0735	53	1.6	17.1	10.5	99	0.010	9200	9200	0.969	79
13-Jan-2016	0740	62	0.7	17.7	9.6	101	0.018	670	670	0.287	23
13-Apr-2016	0845	47	1.2	15.6	9.7	100	0.026	5300	5300	1.082	88
Date	**Time NZST**	**NH_4 g/m³N**	**NO_2 g/m³N**	**NO_3 g/m³N**	**pH pH**	**SS g/m³**	**Temp °C**	**TKN g/m³N**	**TN g/m³N**	**TP g/m³P**	**Turb NTU**
08-Jul-2015	0845	0.026	0.004	1.12	7.5	5	9.6	0.34	1.46	0.028	2.7
14-Oct-2015	0735	0.049	0.008	0.84	7.8	<2	12.9	0.25	1.10	0.024	2.8
13-Jan-2016	0740	0.017	0.003	0.44	7.9	<2	17.3	0.02	0.46	0.031	0.8
13-Apr-2016	0845	0.019	0.009	0.87	7.8	5	15.6	0.28	1.16	0.060	4.5

Median flow 1.228 m³/s; MALF 0.246 m³/s.

Matched site: HTK000350 (Huatoki Stream at Handley Road)

Date	Time NZST	ALKT g/m³ $CaCO_3$	BOD_5 g/m³	Cond @ 20 °C mS/m	DO g/m³	DO Sat %	DRP g/m³P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m³/s	Flow % median
09-Jul-2015	0745	23	<0.5	10.0	11.7	100	0.011	150	290		
15-Oct-2015	0710	28	0.5	10.8	10.7	97	0.007	410	410		
14-Jan-2016	0710	35	0.6	11.1			0.007	420	420		
14-Apr-2016	0800	29	<0.5	10.8	10.6	99	0.011	460	460		
Date	**Time NZST**	**NH_4 g/m³N**	**NO_2 g/m³N**	**NO_3 g/m³N**	**pH pH**	**SS g/m³**	**Temp °C**	**TKN g/m³N**	**TN g/m³N**	**TP g/m³P**	**Turb NTU**
09-Jul-2015	0745	<0.003	0.001	0.83	7.3	3	8.1	0.15	0.98	0.015	1.9
15-Oct-2015	0710	0.009	<0.001	0.54	7.6	<2	11.1	0.03	0.58	0.019	1.7
14-Jan-2016	0710	0.008	<0.001	0.27	7.7	2	16.1	0.03	0.30	0.019	2.0
14-Apr-2016	0800	0.006	0.002	0.62	7.4	8	11.7	0.22	0.84	0.019	1.8

SEM site: WKH000500 (Waiwhakaiho River at SH3)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^3P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow % median
08-Jul-2015	0915	32	<0.5	9.2	11.8	101	0.020	96	96	6.178	158
14-Oct-2015	0805	28	0.8	7.7	11.4	103	0.019	2500	2500	5.630	144
13-Jan-2016	0810	59	<0.5	13.5	10.5	105	0.036	1200	1200	2.599	66
13-Apr-2016	0920	39	0.7	10.4	10.4	104	0.042	1900	2000	5.454	139
Date	**Time NZST**	**NH_4 g/m^3N**	**NO_2 g/m^3N**	**NO_3 g/m^3N**	**pH pH**	**SS g/m^3**	**Temp °C**	**TKN g/m^3N**	**TN g/m^3N**	**TP g/m^3P**	**Turb NTU**
08-Jul-2015	0915	0.009	0.001	0.17	7.6	4	7.7	0.03	0.20	0.027	0.5
14-Oct-2015	0805	0.013	0.002	0.06	7.8	3	10.0	0.19	0.25	0.037	1.7
13-Jan-2016	0810	<0.003	<0.001	0.07	8.2	<2	14.5	0.01	0.08	0.040	0.4
13-Apr-2016	0920	0.030	0.010	0.19	7.6	<2	13.6	0.07	0.27	0.058	1.0

Median flow 3.922 m³/s; MALF 2.036 m³/s.

Matched site: WGA000260 (Waiongana River at SH3A)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^3P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow % median
09-Jul-2015	0900	32	<0.5	11.3	11.9	100	0.019	780	800	2.103	144
15-Oct-2015	0820	47	1.0	14.7	11.0	99	0.022	2000	2100	0.819	56
14-Jan-2016	0810	57	<0.5	16.4			0.038	370	370	0.590	40
14-Apr-2016	0900	45	0.6	14.1	10.5	100	0.039	1400	1400	1.213	83
Date	**Time NZST**	**NH_4 g/m^3N**	**NO_2 g/m^3N**	**NO_3 g/m^3N**	**pH pH**	**SS g/m^3**	**Temp °C**	**TKN g/m^3N**	**TN g/m^3N**	**TP g/m^3P**	**Turb NTU**
09-Jul-2015	0900	0.018	0.004	0.54	7.5	2	7.2	0.30	0.84	0.034	3.5
15-Oct-2015	0820	0.020	0.013	0.68	7.9	<2	10.4	0.10	0.79	0.046	1.4
14-Jan-2016	0810	<0.003	0.002	0.28	8.1	<2	15.9	0.00	0.28	0.047	0.7
14-Apr-2016	0900	0.012	0.009	0.61	7.7	<2	11.9	0.22	0.84	0.055	1.2

Median flow 1.463 m³/s; MALF 0.407 m³/s.

SEM site: STY000300 (Stony River at Mangatete Road)

Date	Time NZST	ALKT g/m³ $CaCO_3$	BOD_5 g/m³	Cond @ 20 °C mS/m	DO g/m³	DO Sat %	DRP g/m³P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m³/s	Flow % median
08-Jul-2015	1015	28	<0.5	7.9	11.9	101	0.018	12	12	5.740	
14-Oct-2015	0905	26	<0.5	7.0	11.4	102	0.014	9	9	6.569	
13-Jan-2016	0915	49	<0.5	10.8	10.5	106	0.024	4	4	2.939	
13-Apr-2016	1020	32	<0.5	8.3	10.3	101	0.028	12	12	4.181	
Date	**Time NZST**	**NH_4 g/m³N**	**NO_2 g/m³N**	**NO_3 g/m³N**	**pH pH**	**SS g/m³**	**Temp °C**	**TKN g/m³N**	**TN g/m³N**	**TP g/m³P**	**Turb NTU**
08-Jul-2015	1015	0.004	<0.001	0.05	7.6	24	7.3	0.	0.05	0.029	11
14-Oct-2015	0905	0.003	<0.001	0.01	7.7	2	9.7	0.06	0.07	0.018	2.0
13-Jan-2016	0915	<0.003	<0.001	0.03	8.0	<2	14.4	0.02	0.05	0.024	0.4
13-Apr-2016	1020	<0.003	0.001	0.02	7.8	250	12.8	0.04	0.06	0.277	76

Matched site: KPN000210 (Kapuni Stream at Eltham Road)

Date	Time NZST	ALKT g/m³ $CaCO_3$	BOD_5 g/m³	Cond @ 20 °C mS/m	DO g/m³	DO Sat %	DRP g/m³P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m³/s	*Flow % median
09-Jul-2015	1045	24	<0.5	8.9	12.3	101	0.017	160	160		150
15-Oct-2015	0940	27	<0.5	8.8	11.1	102	0.010	92	100		95
14-Jan-2016	0935	28	<0.5	8.0	9.9	101	0.018	170	180		31
14-Apr-2016	1110	28	0.5	9.0	11.1	101	0.030	300	310		44
Date	**Time NZST**	**NH_4 g/m³N**	**NO_2 g/m³N**	**NO_3 g/m³N**	**pH pH**	**SS g/m³**	**Temp °C**	**TKN g/m³N**	**TN g/m³N**	**TP g/m³P**	**Turb NTU**
09-Jul-2015	1045	0.017	0.002	1.00	7.3	<2	6.1	0.15	1.15	0.021	1.5
15-Oct-2015	0940	0.015	0.003	0.85	7.7	<2	10.5	0.01	0.86	0.016	0.9
14-Jan-2016	0935	0.006	0.003	0.47	7.8	<2	15.3	0.	0.38	0.021	0.6
14-Apr-2016	1110	0.055	0.006	0.71	7.5	5	10.1	0.24	0.96	0.045	0.6

*Flow at Normanby Road, 15.2 km downstream. Median 1.304 m³/s; MALF 0.348 m³/s

SEM site: PNU000200 (Punehu Stream at Wiremu Road)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^3P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow* % median
08-Jul-2015	1050	15	<0.5	8.7	11.8	101	0.014	90	90	0.940	(276)
14-Oct-2015	0950	16	<0.5	7.3	11.0	102	0.018	88	88	0.540	(158)
13-Jan-2016	0955	26	<0.5	8.4	9.6	102	0.032	70	76	0.228	(45)
13-Apr-2016	1055	10	<0.5	9.7	9.9	100	0.014	130	130	1.042	(225)

Date	Time NZST	NH_4 g/m^3N	NO_2 g/m^3N	NO_3 g/m^3N	pH pH	SS g/m^3	Temp °C	TKN g/m^3N	TN g/m^3N	TP g/m^3P	Turb NTU
08-Jul-2015	1050	0.034	0.002	0.11	7.3	4	7.2	0.17	0.28	0.032	4.3
14-Oct-2015	0950	0.004	<0.001	0.01	7.6	<2	10.7	0.11	0.12	0.021	1.9
13-Jan-2016	0955	0.006	<0.001	0.01	7.8	<2	16.8	0.06	0.07	0.045	1.2
13-Apr-2016	1055	0.028	0.004	0.28	7.3	2	13.7	0.09	0.37	0.035	2.4

*Percentage of median flow is based on record for Pihama hydrometric station, 15.6 km downstream

Matched site: KPA000250 (Kapoaiaia Stream at Wiremu Road)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^3P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow* % median
09-Jul-2015	1020	25	<0.5	9.2	12.3	102	0.026	48	51		196
15-Oct-2015	0930	31	<0.5	9.2	10.8	100	0.027	100	100		101
14-Jan-2016	0920	37	<0.5	9.7			0.036	100	110		50
14-Apr-2016	1020	26	<0.5	8.9	10.6	101	0.025	220	220		120

Date	Time NZST	NH_4 g/m^3N	NO_2 g/m^3N	NO_3 g/m^3N	pH pH	SS g/m^3	Temp °C	TKN g/m^3N	TN g/m^3N	TP g/m^3P	Turb NTU
09-Jul-2015	1020	<0.003	0.001	0.37	7.4	<2	6.1	0.03	0.40	0.028	1.0
15-Oct-2015	0930	0.012	<0.001	0.10	7.8	<2	11.2	0.09	0.19	0.035	1.3
14-Jan-2016	0920	0.006	<0.001	0.02	7.9	<2	15.6	0.05	0.07	0.041	0.7
14-Apr-2016	1020	0.005	0.002	0.33	7.4	<2	11.5	0.09	0.42	0.031	1.3

*Flow relates to site near coast, 19.7 km downstream. Median 0.674 m^3/s; MALF 0.270 m^3/s

SEM site: PNH000900 (Punehu Stream at SH45)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^3P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow* % median
08-Jul-2015	1115	28	1.1	20.0	11.5	100	0.028	340	340	2.573	(276)
14-Oct-2015	1015	29	2.0	14.8	10.9	102	0.039	610	610	1.245	(158)
13-Jan-2016	1025	39	0.9	14.8	9.4	99	0.065	700	720	0.342	(45)
13-Apr-2016	1135	14	0.8	11.3	9.9	100	0.026	760	760	1.550	(225)
Date	**Time NZST**	**NH_4 g/m^3N**	**NO_2 g/m^3N**	**NO_3 g/m^3N**	**pH pH**	**SS g/m^3**	**Temp °C**	**TKN g/m^3N**	**TN g/m^3N**	**TP g/m^3P**	**Turb NTU**
08-Jul-2015	1115	0.078	0.016	3.00	7.4	10	9.0	0.13	3.13	0.054	4.8
14-Oct-2015	1015	0.102	0.044	1.28	7.6	3	12.4	0.47	1.79	0.072	4.7
13-Jan-2016	1025	0.032	0.011	0.62	7.8	2	17.8	0.03	0.66	0.088	1.4
13-Apr-2016	1135	0.032	0.005	0.46	7.3	5	14.7	0.22	0.68	0.059	3.8

*Flow at Pihama, 1.0 km upstream, above Mangatawa confl.. Median 0.689 m³/s, MALF 0.270 m³/s

Matched site: KPA000950 (Kapoaiaia Stream 900m from coast)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^3P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow % median
09-Jul-2015	1100	25	<0.5	12.1	12.4	103	0.024	140	140	1.323	196
15-Oct-2015	1020	29	0.7	10.4	10.7	103	0.017	84	84	0.684	101
14-Jan-2016	0955	40	0.7	11.6			0.029	250	250	0.339	50
14-Apr-2016	1045	24	<0.5	10.2	10.7	102	0.030	610	610	0.806	120
Date	**Time NZST**	**NH_4 g/m^3N**	**NO_2 g/m^3N**	**NO_3 g/m^3N**	**pH pH**	**SS g/m^3**	**Temp °C**	**TKN g/m^3N**	**TN g/m^3N**	**TP g/m^3P**	**Turb NTU**
09-Jul-2015	1100	0.007	0.002	0.75	7.5	<2	7.3	0.23	0.98	0.024	1.2
15-Oct-2015	1020	0.008	0.002	0.24	7.9	<2	13.9	0.15	0.39	0.029	1.0
14-Jan-2016	0955	0.003	0.001	0.04	8.4	3	19.7	0.12	0.16	0.046	1.6
14-Apr-2016	1045	0.007	0.004	0.66	7.4	<2	12.9	0.3	0.96	0.043	1.1

Flow median 0.674 m³/s; MALF 0.270 m³/s

SEM site: WGG000500 (Waingongoro River at Eltham Road)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^{3}P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow % median
08-Jul-2015	1240	29	0.5	11.4	11.5	102	0.019	140	140	2.277	130
14-Oct-2015	1135	33	0.6	11.7	11.5	111	0.020	68	68	1.309	75
13-Jan-2016	1150	37	0.7	10.5	10.2	108	0.037	230	230	0.431	25
13-Apr-2016	1250	29	1.1	10.2	10.1	102	0.064	930	1000	1.119	64

Date	Time NZST	NH_4 g/m^{3}N	NO_2 g/m^{3}N	NO_3 g/m^{3}N	pH pH	SS g/m^3	Temp °C	TKN g/m^{3}N	TN g/m^{3}N	TP g/m^{3}P	Turb NTU
08-Jul-2015	1240	0.011	0.005	1.68	7.6	3	8.9	0.30	1.98	0.040	2.1
14-Oct-2015	1135	0.016	0.012	1.38	8.3	<2	12.7	0.13	1.45	0.035	1.4
13-Jan-2016	1150	0.012	0.003	0.38	8.1	<2	18.7	0.03	0.41	0.051	1.2
13-Apr-2016	1250	0.103	0.022	0.83	7.7	<2	14.0	0.37	1.22	0.105	2.0

Flow median 1.751 m^3/s; MALF 0.443 m^3/s; 5-year low 0.346 m^3/s.

Matched site: KPK000490 (Kaupokonui Stream at Eltham Road)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^{3}P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow* % median
09-Jul-2015	1200	26	<0.5	7.8	12.4	102	0.013	14	14		180
15-Oct-2015	1120	29	<0.5	8.1	10.7	101	0.008	64	64		83
14-Jan-2016	1045	34	0.6	8.2			0.013	40	40		35
14-Apr-2016	1140	26	0.7	7.5	10.8	102	0.016	72	80		81

Date	Time NZST	NH_4 g/m^{3}N	NO_2 g/m^{3}N	NO_3 g/m^{3}N	pH pH	SS g/m^3	Temp °C	TKN g/m^{3}N	TN g/m^{3}N	TP g/m^{3}P	Turb NTU
09-Jul-2015	1200	<0.003	0.001	0.40	7.6	<2	5.8	0.00	0.40	0.013	0.7
15-Oct-2015	1120	0.014	0.002	0.26	8.0	<2	11.9	0.03	0.29	0.011	0.8
14-Jan-2016	1045	0.008	<0.001	0.08	8.1	<2	17.4	0.05	0.13	0.022	1.2
14-Apr-2016	1140	0.012	0.002	0.23	7.5	<2	11.1	0.06	0.29	0.019	0.7

*Flow at Glenn Road, 18.0 km downstream, above Mangawhero confluence. Median 2.023 m^3/s; MALF 0.746 m^3/s

SEM site: WGG000900 (Waingongoro River at SH45)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^{3}P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow % median
08-Jul-2015	1200	36	2.1	18.2	11.2	100	0.050	280	280	9.470	188
14-Oct-2015	1100	44	0.9	18.9	10.9	105	0.029	220	220	5.128	102
13-Jan-2016	1110	50	1.0	17.7	9.8	108	0.057	120	130	1.201	22
13-Apr-2016	1220	38	1.6	15.2	9.7	100	0.083	1200	1200	4.279	79
Date	**Time NZST**	**NH_4 g/m^{3}N**	**NO_2 g/m^{3}N**	**NO_3 g/m^{3}N**	**pH pH**	**SS g/m^3**	**Temp °C**	**TKN g/m^{3}N**	**TN g/m^{3}N**	**TP g/m^{3}P**	**Turb NTU**
08-Jul-2015	1200	0.104	0.054	2.58	7.6	8	10.1	0.99	3.62	0.086	4.5
14-Oct-2015	1100	0.034	0.014	2.44	7.9	3	13.7	0.21	2.66	0.056	3.1
13-Jan-2016	1110	0.028	0.010	1.11	8.0	<2	19.6	0.22	1.34	0.084	1.3
13-Apr-2016	1220	0.022	0.015	1.22	7.8	7	15.8	0.67	1.90	0.15	5.4

Flow median 5.042 m³/s; MALF 1.344 m³/s; 5-year LF 1.083 m³/s

Matched site: KPK000900 (Kaupokonui Stream at SH45)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^{3}P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow % median
09-Jul-2015	1230	35	0.6	17.1	12.2	103	0.022	68	68		180
15-Oct-2015	1200	43	0.7	17.7	10.6	102	0.019	220	240		83
14-Jan-2016	1140	55	0.9	16.6			0.024	130	130		35
14-Apr-2016	1215	31	0.7	11.5	10.5	101	0.048	480	510		81
Date	**Time NZST**	**NH_4 g/m^{3}N**	**NO_2 g/m^{3}N**	**NO_3 g/m^{3}N**	**pH pH**	**SS g/m^3**	**Temp °C**	**TKN g/m^{3}N**	**TN g/m^{3}N**	**TP g/m^{3}P**	**Turb NTU**
09-Jul-2015	1230	0.003	0.005	1.94	7.6	5	7.7	0.63	2.58	0.041	2.8
15-Oct-2015	1200	0.016	0.010	1.74	8.2	2	13.8	0.25	2.00	0.040	2.3
14-Jan-2016	1140	0.009	0.006	0.70	8.4	<2	20.0	0.0	0.68	0.041	1.6
14-Apr-2016	1215	0.027	0.008	0.86	7.7	2	13.1	0.21	1.08	0.062	1.6

*Flow at Glenn Road, 0.7 km upstream, above Mangawhero confluence. Median 2.023 m³/s; MALF 0.746 m³/s

SEM site: PAT000200 (Patea River at Barclay Road)

Date	Time NZST	ALKT g/m³ $CaCO_3$	BOD_5 g/m³	Cond @ 20 °C mS/m	DO g/m³	DO Sat %	DRP g/m³P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m³/s	Flow % median
08-Jul-2015	1315	18	<0.5	5.9	11.7	101	0.018	11	11	0.267	(117)
14-Oct-2015	1230	25	<0.5	6.9	11.1	102	0.024	120	120	0.154	(61)
13-Jan-2016	1220	28	<0.5	6.8	10.2	99	0.027	25	25	0.178	(39)
13-Apr-2016	1320	18	<0.5	5.5	10.2	100	0.023	54	54	0.208	(89)
Date	**Time NZST**	**NH_4 g/m³N**	**NO_2 g/m³N**	**NO_3 g/m³N**	**pH pH**	**SS g/m³**	**Temp °C**	**TKN g/m³N**	**TN g/m³N**	**TP g/m³P**	**Turb NTU**
08-Jul-2015	1315	<0.003	<0.001	0.04	7.4	<2	6.0	0.01	0.05	0.027	0.5
14-Oct-2015	1230	0.005	<0.001	0.01	7.6	<2	9.4	0.11	0.12	0.027	1.0
13-Jan-2016	1220	0.006	<0.001	0.01	7.6	<2	11.8	0.04	0.05	0.029	0.5
13-Apr-2016	1320	<0.003	0.001	0.01	7.1	<2	11	0.04	0.05	0.027	0.4

*Flow at Skinner Road, 17.5 km downstream. Median 3.169 m³/s; MALF 0.765 m³/s

Matched site: WKH000200 (Waiwhakaiho River at Peters Road)

Date	Time NZST	ALKT g/m³ $CaCO_3$	BOD_5 g/m³	Cond @ 20 °C mS/m	DO g/m³	DO Sat %	DRP g/m³P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m³/s	Flow* % median
09-Jul-2015	1205	34	<0.5	9.0	12.1	102	0.046	11	11		158
15-Oct-2015	1105	41	<0.5	9.5	10.9	102	0.053	20	20		144
14-Jan-2016	1110	44	<0.5	9.9	10.0	102	0.003	78	78		66
14-Apr-2016	1220	38	<0.5	9.6	10.5	102	0.043	220	220		139
Date	**Time NZST**	**NH_4 g/m³N**	**NO_2 g/m³N**	**NO_3 g/m³N**	**pH pH**	**SS g/m³**	**Temp °C**	**TKN g/m³N**	**TN g/m³N**	**TP g/m³P**	**Turb NTU**
09-Jul-2015	1205	0.016	0.001	0.11	7.6	<2	6.5	0.04	0.15	0.046	0.8
15-Oct-2015	1105	0.007	<0.001	0.02	8.0	<2	11.0	0.03	0.05	0.055	0.8
14-Jan-2016	1110	<0.003	<0.001	0.02	8.0	<2	14.4	0.03	0.05	0.061	0.7
14-Apr-2016	1220	0.011	0.001	0.12	7.7	<2	12.7	0.12	0.24	0.043	0.9

*Flow at SH3, Egmont Village, 8.0 km downstream: Median 3.922 m³/s; MALF 2.036 m³/s

SEM site: MGH000950 (Mangaehu River at Raupuha Road)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^3P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow % median
08-Jul-2015	1445	23	1.4	7.6	10.8	97	0.008	1700	1700	21.704	312
14-Oct-2015	1330	46	<0.5	11.3	10.4	103	0.005	240	240	8.202	118
13-Jan-2016	1355	47	0.5	11.0	9.3	105	0.005	84	84	3.335	48
13-Apr-2016	1440	39	1.9	10.4	9.1	94	0.007	5400	5400	16.400	236
Date	**Time NZST**	**NH_4 g/m^3N**	**NO_2 g/m^3N**	**NO_3 g/m^3N**	**pH pH**	**SS g/m^3**	**Temp °C**	**TKN g/m^3N**	**TN g/m^3N**	**TP g/m^3P**	**Turb NTU**
08-Jul-2015	1445	0.021	0.004	0.16	7.3	460	9.7	1.27	1.43	0.441	390
14-Oct-2015	1330	0.017	0.002	0.11	7.9	10	14.5	0.14	0.25	0.023	13
13-Jan-2016	1355	0.010	0.002	0.03	8.0	5	20.8	0.14	0.17	0.018	4.3
13-Apr-2016	1440	0.019	0.004	0.07	7.4	210	15.6	0.83	0.90	0.373	160

Flow median 6.952 m³/s, MALF 2.342 m³/s

Matched (new SEM) site: WTR000540 (Waitara River at Autawa Road)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^3P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow* m^3/s	Flow* % median
09-Jul-2015	1335	15	0.7	7.0	11.0	96	0.01	930	930	38.519	210
15-Oct-2015	1250	30	0.6	9.0	10.1	100	0.007	63	63	20.901	114
14-Jan-2016	1230	31	0.5	8.9	8.6	96	0.008	120	120	9.985	55
14-Apr-2016	1330	32	<0.5	10.2	9.4	94	0.008	540	560	21.389	117
Date	**Time NZST**	**NH_4 g/m^3N**	**NO_2 g/m^3N**	**NO_3 g/m^3N**	**pH pH**	**SS g/m^3**	**Temp °C**	**TKN g/m^3N**	**TN g/m^3N**	**TP g/m^3P**	**Turb NTU**
09-Jul-2015	1335	0.027	0.003	0.21	7.3	320	8.6	0.43	0.64	0.021	300
15-Oct-2015	1250	0.008	0.002	0.13	7.6	6	14.8	0.15	0.28	0.021	8.6
14-Jan-2016	1230	0.018	0.002	0.10	7.5	7	20.7	0.16	0.26	0.029	8.3
14-Apr-2016	1330	0.017	0.003	0.11	7.4	19	15.6	0.44	0.55	0.043	18

*Flow at Tarata, 6.1 km downstream, below Motukawa HEP station outflow. Median 18.312 m³/s; MALF 3.187 m³/s

SEM site (new): WNR000450 (Whenuakura River at Nicholson Road)

Date	Time NZST	ALKT g/m³ $CaCO_3$	BOD_5 g/m³	Cond @ 20 °C mS/m	DO g/m³	DO Sat %	DRP g/m³P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow* m³/s	Flow* % median
09-Jul-2015	1015	36	1.3	14.5	11.2	94	0.019	830	830	14.157	267
15-Oct-2015	0855	68	0.8	19.7	10.1	96	0.012	280	280	6.819	129
14-Jan-2016	0855	64	1.2	19.4	8.4	90	0.019	490	520	2.742	52
14-Apr-2016	0915	32	1.9	11.8	9.3	88	0.018	2200	2300	6.299	119
Date	**Time NZST**	**NH_4 g/m³N**	**NO_2 g/m³N**	**NO_3 g/m³N**	**pH pH**	**SS g/m³**	**Temp °C**	**TKN g/m³N**	**TN g/m³N**	**TP g/m³P**	**Turb NTU**
09-Jul-2015	1015	0.021	0.007	0.34	7.3	980	7.9	1.27	1.62	0.709	760
15-Oct-2015	0855	0.016	0.004	0.34	7.7	26	13.5	0.21	0.55	0.065	24
14-Jan-2016	0855	0.035	0.005	0.42	7.6	32	18.6	0.2	0.63	0.100	40
14-Apr-2016	0915	0.052	0.006	0.27	7.2	400	13.8	0.92	1.20	0.042	340

*Flow median 5.293 m³/s; MALF 1.939 m³/s

SEM site (unmatched): PAT000360 (Patea River at Skinner Road)

Date	Time NZST	ALKT g/m³ $CaCO_3$	BOD_5 g/m³	Cond @ 20 °C mS/m	DO g/m³	DO Sat %	DRP g/m³P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow* m³/s	Flow* % median
08-Jul-2015	1405	26	0.5	9.6	11.6	103	0.026	100	100	3.696	117
14-Oct-2015	1300	30	0.9	9.9	11.8	116	0.036	92	92	1.948	61
13-Jan-2016	1315	32	1.0	10.1	9.9	106	0.073	370	370	1.235	39
13-Apr-2016	1410	28	1.3	9.9	10.1	104	0.057	600	600	2.834	89
Date	**Time NZST**	**NH_4 g/m³N**	**NO_2 g/m³N**	**NO_3 g/m³N**	**pH pH**	**SS g/m³**	**Temp °C**	**TKN g/m³N**	**TN g/m³N**	**TP g/m³P**	**Turb NTU**
08-Jul-2015	1405	0.072	0.011	0.93	7.6	<2	8.7	0.50	1.44	0.043	1.7
14-Oct-2015	1300	0.028	0.016	0.89	8.6	<2	13.6	0.10	1.01	0.054	1.7
13-Jan-2016	1315	0.047	0.018	0.63	8.0	<2	17.1	0.02	0.67	0.096	1.3
13-Apr-2016	1410	0.044	0.021	0.86	7.6	3	14.9	0.39	1.27	0.096	2.5

*Flow median 3.169 m³/s, MALF 0.765 m³/s.

Additional site: WGG000150 (Waingongoro River at Opunake Road)

Date	Time NZST	ALKT g/m^3 $CaCO_3$	BOD_5 g/m^3	Cond @ 20 °C mS/m	DO g/m^3	DO Sat %	DRP g/m^3P	E.coli cfu/ 100mL	FC cfu/ 100mL	Flow m^3/s	Flow % median
09-Jul-2015	1000	22	<0.5	7.0	12.4	101	0.020	23	23		130
15-Oct-2015	0900	27	<0.5	7.7	11.2	102	0.017	28	28		75
14-Jan-2016	0900	27	<0.5	7.2	9.9	100	0.023	100	100		25
14-Apr-2016	1040	24	<0.5	6.9	10.8	100	0.020	40	40		64

Date	Time NZST	NH_4 g/m^3N	NO_2 g/m^3N	NO_3 g/m^3N	pH pH	SS g/m^3	Temp °C	TKN g/m^3N	TN g/m^3N	TP g/m^3P	Turb NTU
09-Jul-2015	1000	<0.003	<0.001	0.48	7.3	<2	5.1	0.07	0.55	0.020	0.6
15-Oct-2015	0900	0.005	<0.001	0.41	7.7	<2	9.7	0.02	0.43	0.018	0.4
14-Jan-2016	0900	<0.003	<0.001	0.16	7.8	<2	14.4	0.0	0.16	0.026	0.5
14-Apr-2016	1040	0.007	<0.001	0.36	7.4	<2	10.2	0.1	0.46	0.022	0.2

Flow at Eltham Road, 23 km downstream: median 1.751 m^3/s; MALF 0.443 m^3/s; 5-year low 0.346 m^3/s.

Appendix II

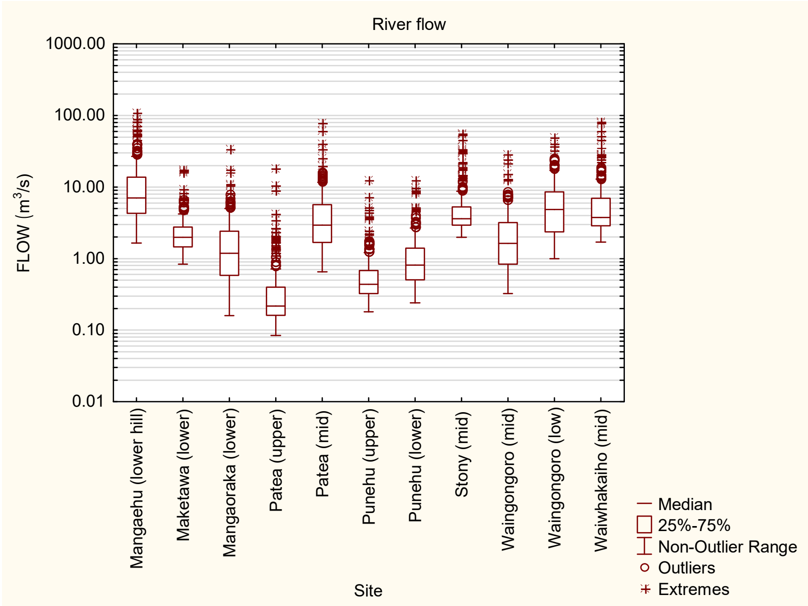
Seasonal ‘Box & Whisker’ Plots of 2015-2016 Water Quality Parameters for SEM and comparative sites

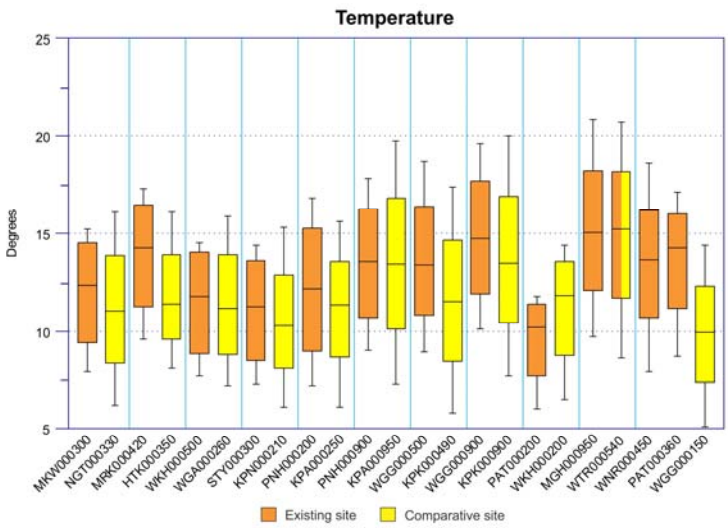
Site locations

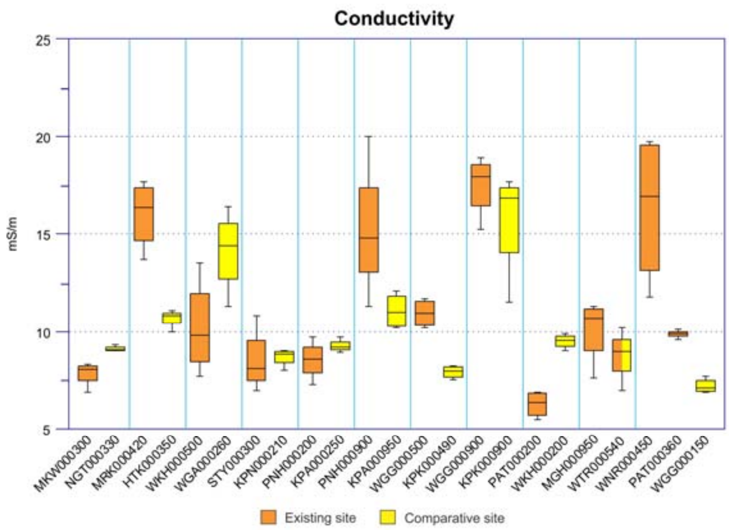
Stream*	Location	Site code
Maketawa Stream	at Tarata Road	MKW000300
Ngatoro Stream	at Tarata Road	NGT000330
Mangaoraka Stream	at Corbett Road	MRK000420
Huatoki Stream	at Handley Road	HTK000350
Waiwhakaiho River	at SH3	WKH000500
Waiongana Stream	at SH3A	WGA000260
Stony River	at Mangatete Road	STY000300
Kapuni Stream	at Eltham Road	KPN000210
Punehu Stream	at Wiremu Road	PNH000200
Kapoaiaia Stream	at Wiremu Road	KPA000250
Punehu Stream	at SH45	PNH000900
Kapoaiaia Stream	at SH45	KPA000950
Waingongoro River	at Eltham Road	WGG000500
Kaupokonui Stream	at Eltham Road	KPK000490
Waingongoro River	at SH45	WGG000900
Kaupokonui River	at SH45	KPK000900
Patea River	at Barclay Road	PAT000200
Waiwhakaiho River	at Peters Road	WKH000200
Mangaehu River	at Raupuha Road	MGH000950
Waitara River	at Tarata	WTR000540
Whenuakura River	at Nicholson Road	WNR000450
Patea River	at Skinner Road	PAT000360
Waingongoro River	at Opunake Road	WGG000150

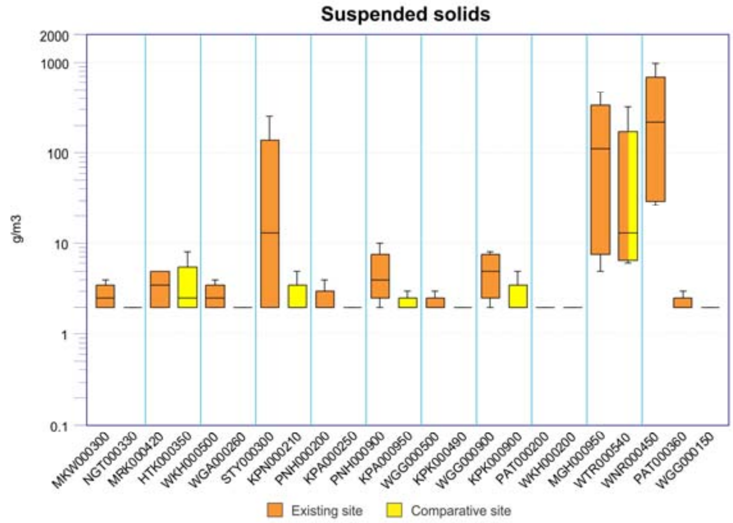
- The long-term SEM site, followed by the paired site monitored in this comparative survey. The Whenuakura River site may be compared with the Mangaehu and Waitara Rivers sites, all representing eastern hill country catchments. The Patea River at Skinner Road and Waingongoro River at Opunake Road are unmatched with another site on the graphs.

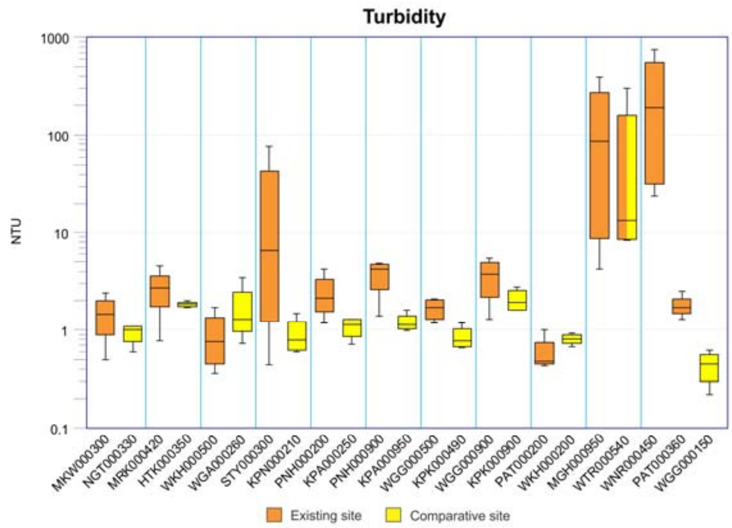
Physical Quality

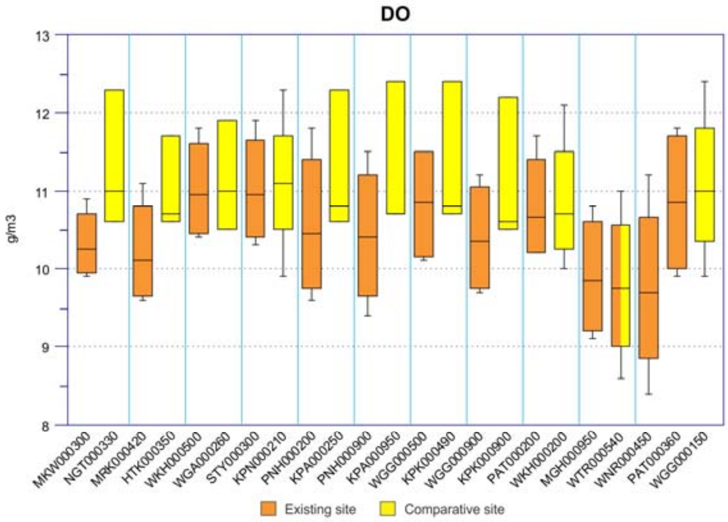


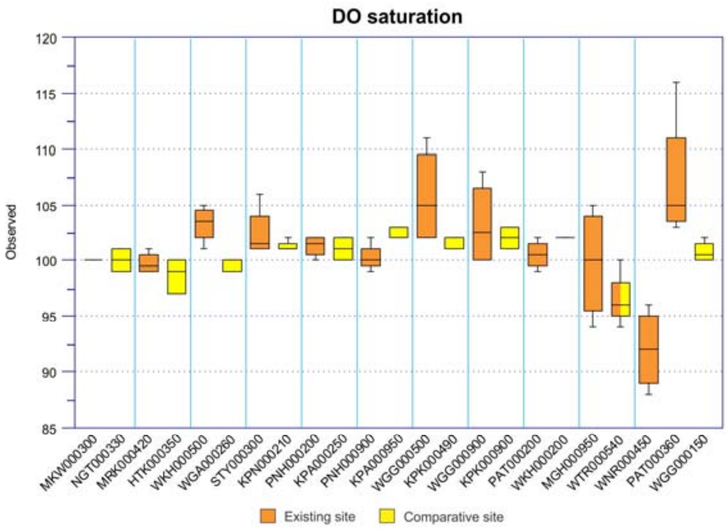


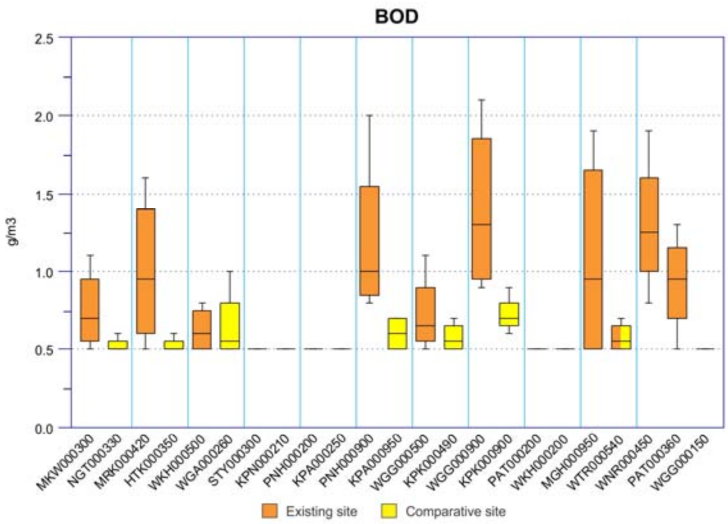


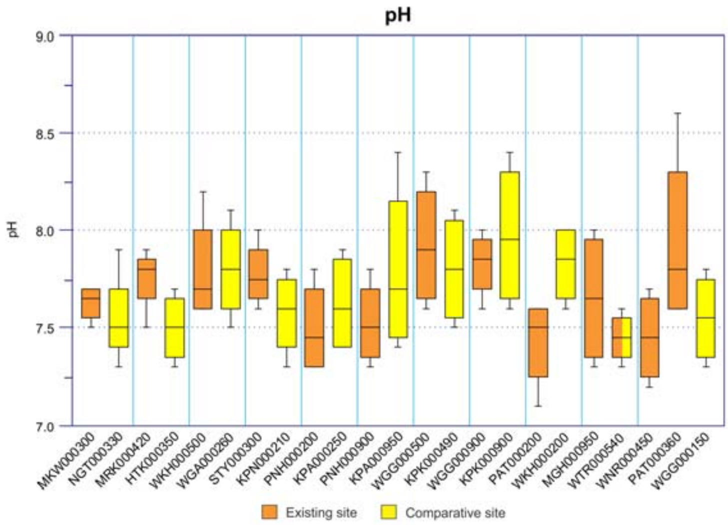

Suspended solids
g/m3
2000
1000
100
10
1
0.1
MKW000300
NGT000330
MRK000420
HTK000350
WKH000500
WGA000260
STY000300
KPN000210
PNH000200
KPA000250
PNH000900
KPA000950
WGG000500
KPK000490
WGG000900
KPK000900
PAT000200
WKH000200
MGH000950
WTR000540
WNR000450
PAT000360
WGG000150
Existing site
Comparative site

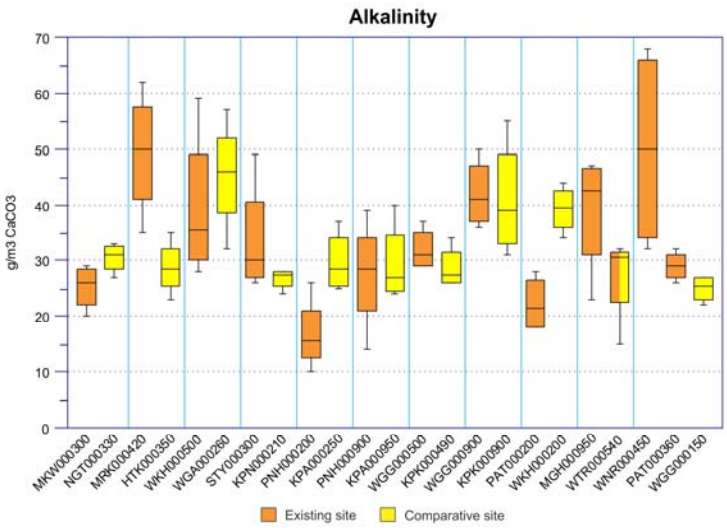

Turbidity
NTU
1000
100
10
1
0.1
MKW000300
NGT000330
MRK000420
HTK000350
WKH000500
WGA000260
STY000300
KPN000210
PNH000200
KPA000250
PNH000900
KPA000950
WGG000500
KPK000490
WGG000900
KPK000900
PAT000200
WKH000200
MGH000950
WTR000540
WNR000450
PAT000360
WGG000150
Existing site
Comparative site


DO
g/m3
MKW000300
NGT000330
MRK000420
HTK000350
WKH000500
WGA000260
STY000300
KPN000210
PNH000200
KPA000250
PNH000900
KPA000950
WGG000500
KPK000490
WGG000900
KPK000900
PAT000200
WKH000200
MGH000950
WTR000540
WNR000450
PAT000360
WGG000150
Existing site
Comparative site

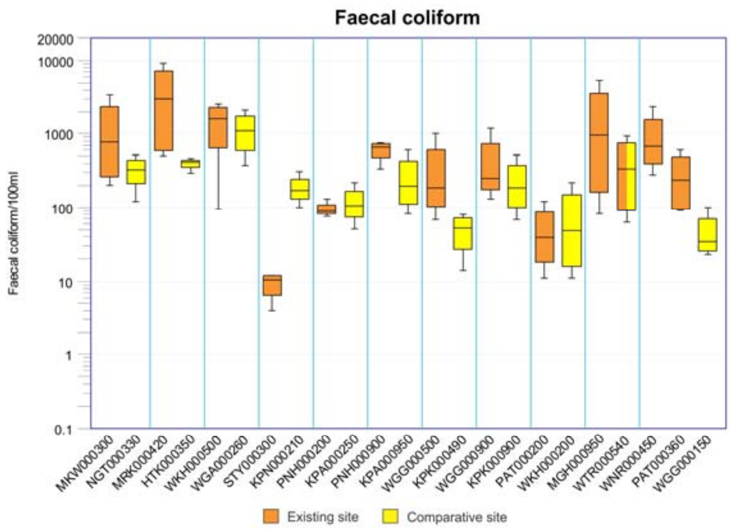

DO saturation
Observed
MKW000300
NGT000330
MRK000420
HTK000350
WKH000500
WGA000260
STY000300
KPN000210
PNH000200
KPA000250
PNH000900
KPA000950
WGG000500
KPK000490
WGG000900
KPK000900
PAT000200
WKH000200
MGH000950
WTR000540
WNR000450
PAT000360
WGG000150
Existing site
Comparative site


BOD
g/m3
MKW000300
NGT000330
MRK000420
HTK000350
WKH000500
WGA000260
STY000300
KPN000210
PNH000200
KPA000250
PNH000900
KPA000950
WGG000500
KPK000490
WGG000900
KPK000900
PAT000200
WKH000200
MGH000950
WTR000540
WNR000450
PAT000360
WGG000150
Existing site
Comparative site

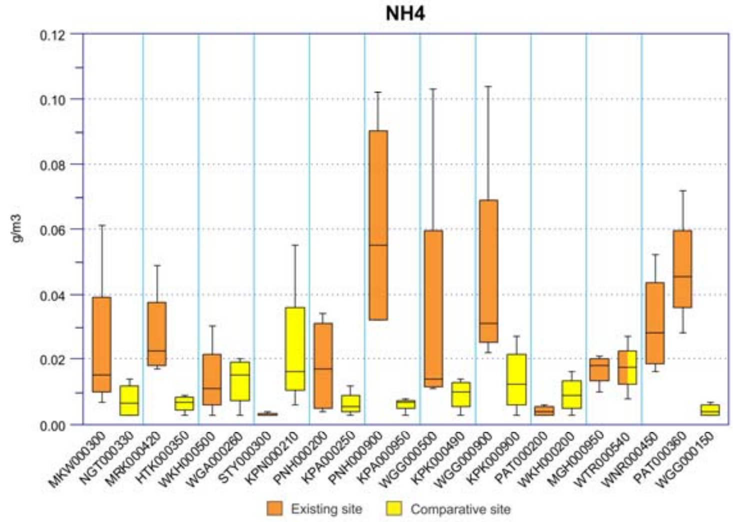

pH
pH
MKW000300
NGT000330
MRK000420
HTK000350
WKH000500
WGA000260
STY000300
KPN000210
PNH000200
KPA000250
PNH000900
KPA000950
WGG000500
KPK000490
WGG000900
KPK000900
PAT000200
WKH000200
MGH000950
WTR000540
WNR000450
PAT000360
WGG000150
Existing site
Comparative site

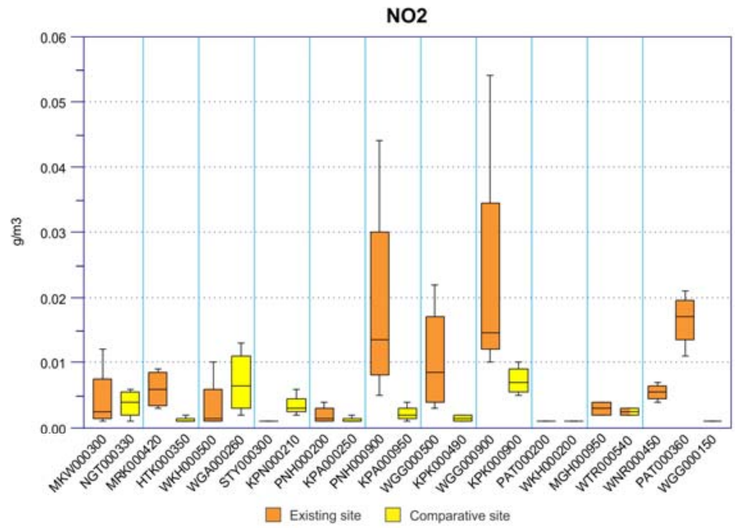

Alkalinity
g/m3 CaCO3
MKW000300
NGT000330
MRK000420
HTK000350
WKH000500
WGA000260
STY000300
KPN000210
PNH000200
KPA000250
PNH000900
KPA000950
WGG000500
KPK000490
WGG000900
KPK000900
PAT000200
WKH000200
MGH000950
WTR000540
WNR000450
PAT000360
WGG000150
Existing site
Comparative site

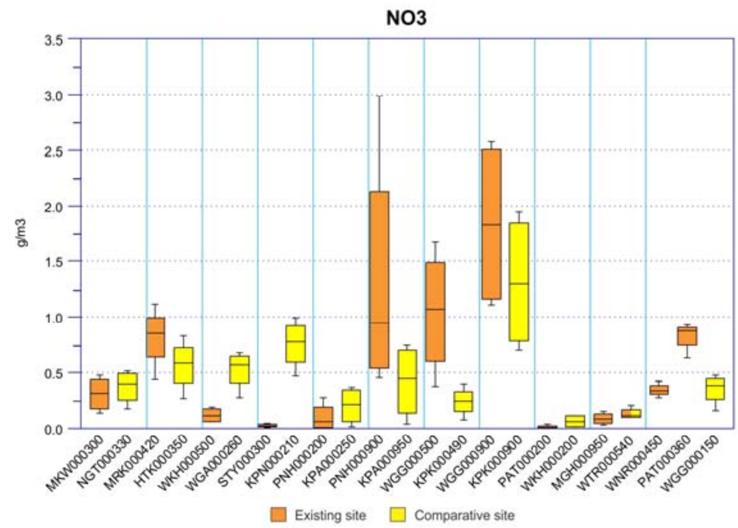
Bacteria

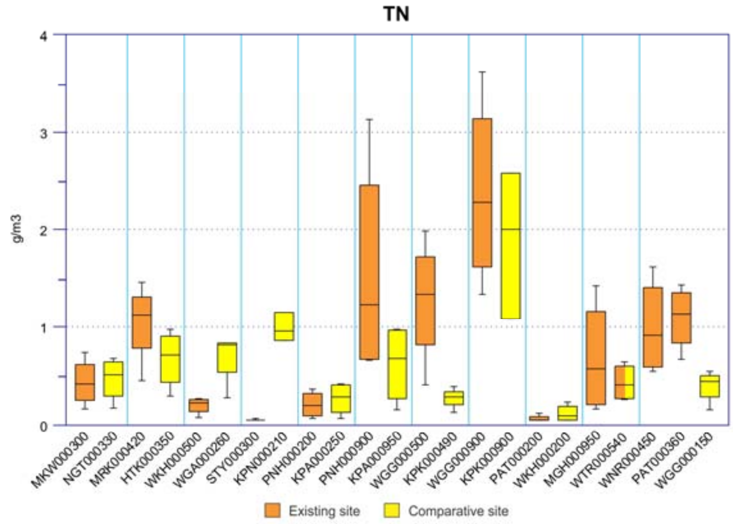

Faecal coliform
Faecal coliform/100ml
MKW000300
NGT000330
MRK000420
HTK000350
WKH000500
WGA000260
STY000300
KPN000210
PNH000200
KPA000250
PNH000900
KPA000950
WGG000500
KPK000490
WGG000900
KPK000900
PAT000200
WKH000200
MGH000950
WTR000540
WNR000450
PAT000360
WGG000150
Existing site
Comparative site

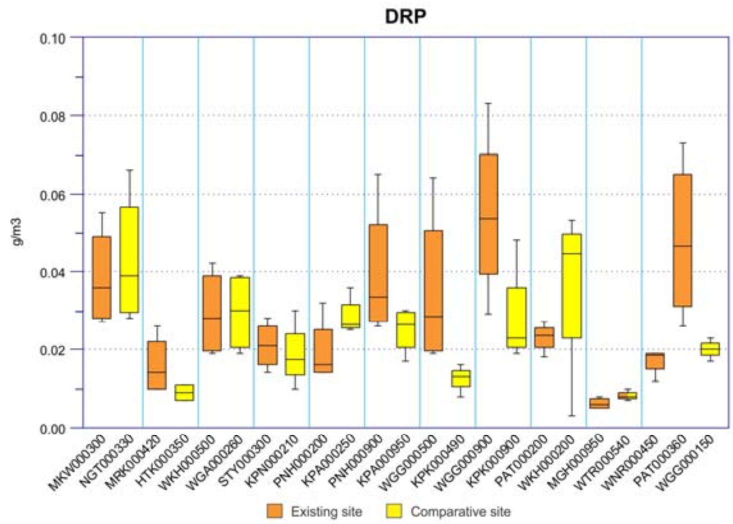
Nutrients

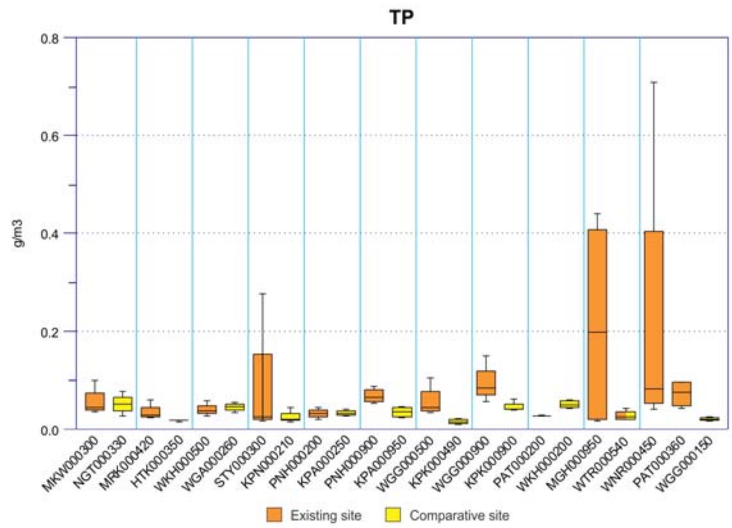

NH4
0.12
0.10
0.08
0.06
0.04
0.02
0.00
g/m3
MKW000300
NGT000330
MRK000420
HTK000350
WKH000500
WGA000260
STY000300
KPN000210
PNH000200
KPA000250
PNH000900
KPA000950
WGG000500
KPK000490
WGG000900
KPK000900
PAT000200
WKH000200
MGH000950
WTR000540
WNR000450
PAT000360
WGG000150
Existing site
Comparative site


NO2
0.06
0.05
0.04
0.03
0.02
0.01
0.00
g/m3
MKW000300
NGT000330
MRK000420
HTK000350
WKH000500
WGA000260
STY000300
KPN000210
PNH000200
KPA000250
PNH000900
KPA000950
WGG000500
KPK000490
WGG000900
KPK000900
PAT000200
WKH000200
MGH000950
WTR000540
WNR000450
PAT000360
WGG000150
Existing site
Comparative site


NO3
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
g/m3
MKW000300
NGT000330
MRK000420
HTK000350
WKH000500
WGA000260
STY000300
KPN000210
PNH000200
KPA000250
PNH000900
KPA000950
WGG000500
KPK000490
WGG000900
KPK000900
PAT000200
WKH000200
MGH000950
WTR000540
WNR000450
PAT000360
WGG000150
Existing site
Comparative site


TN
g/m3
Existing site
Comparative site


DRP
g/m3
Existing site
Comparative site


TP
g/m3
Existing site
Comparative site